SPECIALTY MUSHROOMS: CONSUMPTION, PRODUCTION AND CULTIVATION

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ABSTRACT

Diversification of the mushroom industry, in terms of number and quantity of mushroom species cultivated, has accelerated world-wide during the 1980's and 1990's. Twenty years ago, 70 percent of the world's mushroom supply was *Agaricus bisporus*. By the mid 1990's *Agaricus bisporus* accounted for only 37 percent of the world supply. *Lentinula edodes* (shiitake) and *Pleurotus* spp. (oyster mushroom) accounted for 16.8 and 16.3 percent, respectively, of the world's production in 1994. The People's Republic of China is the major producer (2,640,900 t – or 54 percent of the total) of cultivated mushrooms. Production and consumption of specialty mushrooms in the USA and other western countries is expected to increase at an accelerated rate in the years to come. The development of improved technology to cultivate each species more efficiently, will allow consumer prices to decline. As economies improve in Latin America, production of specialty mushrooms could increase at an even faster rate than in the United States. The culinary advantages offered by specialty mushrooms bode well for the continued growth and development of the specialty mushroom industry worldwide.

Key words: mushrooms, consumption, production, cultivation.

RESUMEN

HONGOS GOURMET: CONSUMO, PRODUCCIÓN Y CULTIVO. Rev. Mex. Mic. 13: 1-11 (1997). La diversificación de la industria de los hongos presentó una rápida expansión a nivel mundial a partir de la década de 1980, fundamentalmente en términos del número y volumen de especies cultivadas. Hace veinte años, *Agaricus bisporus* representaba el 70% de la producción mundial de hongos. Hacia mediados de la década de 1990 *Agaricus bisporus* representaba únicamente el 37% de la producción mundial. Para el año de 1994 *Lentinula edodes* (shiitake) y *Pleurotus* spp. (hongo ostra) constituían el 16.8 y 16.3%, respectivamente, de la producción internacional. A nivel mundial la República Popular de China es el productor de hongos más importante (2,640,900 t, 54% de la producción mundial). En los años por venir es de esperarse que la producción de hongos comestibles en EE.UU., y el resto de occidente, se incremente rápidamente. El desarrollo e implementación de nuevas tecnologías, que permitan el cultivo más eficiente de las distintas especies, permitirá el descenso en el precio final al consumidor. A medida que se desarrolle la economía en Latinoamérica, la producción de hongos comestibles seguramente presentará un rápido incremento, inclusive mayor al de los EE.UU.. Las ventajas que presenta el cultivo de hongos comestibles como un alimento alternativo, nos permite augurarle un brillante futuro a esta industria.

Palabras clave: hongos, consumo, producción, cultivo.

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Introduction

Total commercial mushroom production world-wide has increased more than 14-fold in the last 30 years from about 350,000 t (one metric t = 2,205 lb) in 1965 to about 4,909,000 t in 1994. The bulk of this increase has occurred during the last 15 years. A considerable shift has occurred in the composite of genera that constitute the mushroom supply. During the 1979 production year, the button mushroom, *Agaricus bisporus* (=*A. brunnescens* Peck) accounted for over 70 percent of the world's supply. By 1994, only 38% of world production was *A. bisporus* (Table 1). The People's Republic of China is the major producer (2,640,900 t – or about 54 percent of the total) of edible mushrooms. In 1995 to 1996, it is estimated that the United States produced 357,078 t (or about seven percent of the total world supply) of mushrooms. *Agaricus bisporus* accounted for over 90 percent of total mushroom productio value while *Lentinula, Flammulina, Pleurotus, Hypsizygus, Morchella,* and *Grifola* were the main specialty genera cultivated. The value of the 1995 to 96 specialty mushroom crop in the USA amounted to $30 million – a three percent increase over the previous season (USDA 1996, Phelps 1996). Annual increases for specialty mushroom production in the United States has averaged over 15 percent since 1987 (USDA 1996). Based on recent and historical trends, it is expected that diversification of the

	Fresh wt (x 1,000 t)				Increase
Species	1986		1994		(%)
Agaricus bisporus	1,215	(55.8%)	1,846	(37.6%)	51.9
Lentinula edodes	320	(14.7%)	826	(16.8%)	158.1
Pleurotus spp.	169	(7.8%)	797	(16.3%)	371.6
Auricularia spp.	119	(5.5%)	420	(8.5%)	301.0
Volvariella volvacea	178	(8.2%)	299	(6.1%)	68.0
Flammulina velutipes	100	(4.6%)	230	(4.7%)	130.0
Tremella fuciformis	40	(1.8%)	156	(3.2%)	290.0
Hypsizygus marmoreus	--	--	55	(1.1%)	--
Pholiota nameko	25	(1.1%)	27	(0.6%)	8.0
Grifola frondosa	--	--	14	(0.3%)	--
Others	10	(0.5%)	239	(4.8%)	2,290.0
Total	2,176	(100.0%)	4,909	(100.0%)	125.6

Chang (1996)

Table 1. World production of cultivated edible mushrooms in 1986 and 1994.

mushroom industry will continue in the United States and many other western countries. The development of improved technology to cultivate each species more efficiently, will allow consumer prices to decline.

Production technology

Flammulina velutipes (Enokitake)

Worldwide production of *F. velutipes* has increased from about 100,000 metric tons in 1986 to about 230,000 t in 1994 (Fig. 1). Mainland China and Japan are the main producers of enokitake (Table 2). In 1994, China produced 47 percent (109,000 t) of the world's total production of enokitake while Japan produced 44 percent (101,800 t). Taiwan accounted for seven percent (16,800 t) of the world's production while S. Korea produced about one percent (1,700 t). Production of most enokitake in Japan and the US is based on synthetic substrate contained in polypropylene bottles (Fig 2). Substrates (primarily sawdust and bran) are mechanically mixed and filled into heat resistant bottles with a capacity of 800 to 1,000 ml (Oei 1996). In Japan, sawdust consisting primarily of *Cryptomeria japonica*, *Chamaecyparis obtusa* or aged (9 to 12 months) *Pinus* spp. appears to produce the best yields. In the United States, ground corn cobs supplemented with bran serves as the primary medium (Royse 1997). After filling into

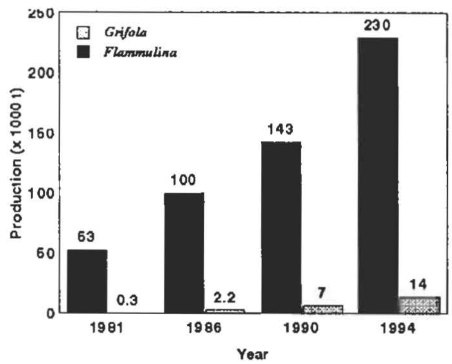

Figure 1. World-wide production of enokitake (*Flammulina velutipes*) and maitake (*Grifola frondosa*) from 1981-1994 (Chang 1996, Royse 1997). One metric ton = 2,205 lbs.

bottles, the substrate is sterilized in a two-step process (4 h at 95°C and 1 h at 120°C), mechanically inoculated and incubated at 18 to 20°C for 20 to 25 days. When the substrate is fully colonized, the original inoculum is removed mechanically from the surface of the substrate and the bottles may be placed upside down for a few days. At the time of original inoculum removal, the air temperature is lowered to 10 to 12°C for 10 to 14 days.

Country	Fresh wt	%
China	109,000	47.4
Japan	101,800	44.3
Taiwan	16,800	7.3
S. Korea	1,700	0.8
Others	500	0.2
Total	229,800	100.0

[a]One metric ton = 2,204.6 lbs

Chang (1996)

Table 2. Estimated production (t)[a] of *Flammulina velutipes* under commercial production in some countries in 1994.

To improve quality during fruiting, temperatures are lowered to 3 to 8°C until harvest. As the mushrooms begin to elongate above the lip of the bottle, a plastic collar (Fig 2, b) is placed around the neck and secured with a Velcro® strip. This collar serves to hold the mushrooms in place so that they are long and straight. When the mushrooms are 13 to 14 cm long, the collars are removed and the mushrooms are pulled as a bunch from the substrate. The mushrooms then are vacuum packed (Fig 2, c) and placed into boxes for shipment to market. Only one flush of mushrooms usually is harvested prior to mechanical removal of the "spent" substrate from the bottles. In some cases, a second flush may be harvested but the quality of the mushrooms is inferior to that of the first flush.

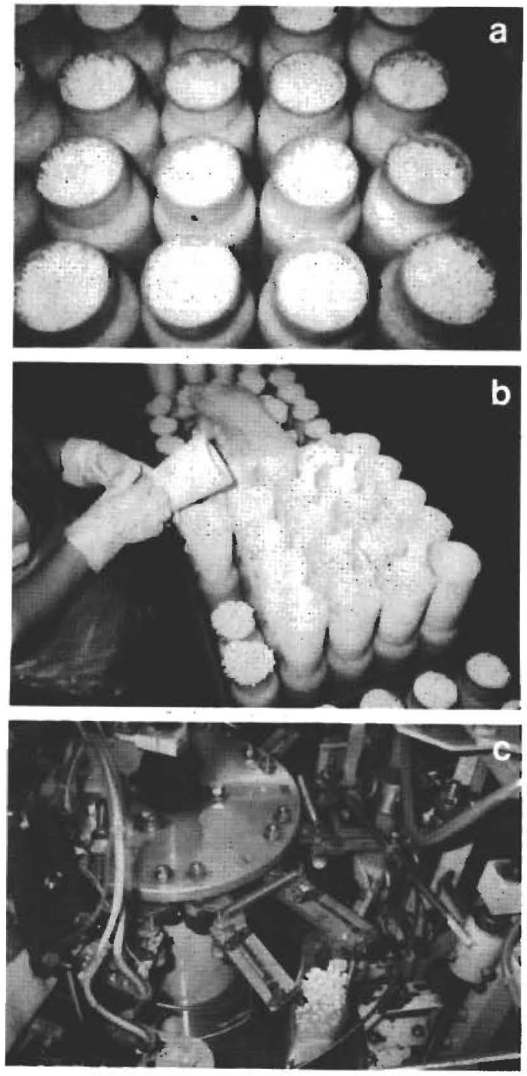

Figure 2. Production of enokitake (*Flammulina velutipes*) on synthetic substrate contained in polypropylene bottles; (a) young mushrooms emerging from substrate (b) applying collars to maintain straight mushroom stipes, and (c) vacuum packaging of mushroom clusters.

Ganoderma lucidum (Reishi)

Known as reishi or mannentake to the Japanese and Ling Zhi to the Chinese, *G. lucidum* is renown for its medicinal properties (for an extensive review see Willard, 1990). Reishi often is associated with health and recuperation, longevity, wisdom and happiness (Stamets 1990, 1993). It is believed that certain triterpenes and polysaccharides may account for the multiple activities of Reshi. Thus, considerable time and effort has gone into the isolation and characterization of these compounds. About 100 triterpenes have been isolated from either the fruitbodies or mycelium but only a few have been tested for bio-activity (Mizuno et al. 1995).

Most cultivation of *G. lucidum* is on supplemented sawdust contained in heat-resistant polypropylene bottles or bags (Fig. 3). Sawdust of hardwoods is supplemented with rice bran (10 percent) and $CaC0_3$ (3 percent), moistened with water and filled (700 g) into plastic bags. A plastic collar then is fitted onto each bag and stoppered with a cotton plug. After heat treatment (95 to 100°C for 5 h)the substrate is allowed to cool overnight and then inoculated with grain or sawdust spawn. The inoculated substrate then incubated for 3 to 4 weeks or until the spawn has fully colonized the substrate. Mushroom production is initiated by maintaining air temperature at about 28°C with relative humidity in the range of 85 to 90 percent. Basidiocarps begin to appear in about 1 to 2 weeks after initiation. Approximately 2 to 3 months after the appearance of primordia, mushrooms are ready to harvest. A mushroom is considered mature when the whitish margin around the edge of the basidiocarp has turned red. The substrate may yield another harvest of mushrooms after removal of the first flush.

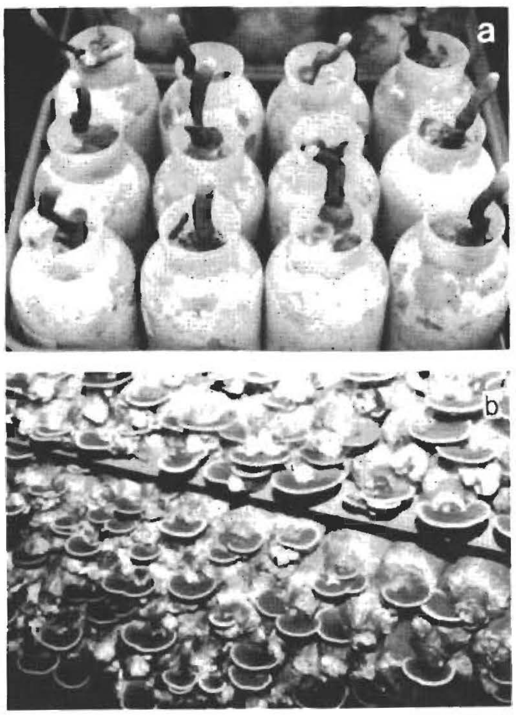

Figure 3. Production of reishi (*Ganoderma lucidum*) in: (a) bottles and (b) in plastic bags (photo courtesy of Dr. Chow-Chin Tong, Univ. of Pertanian, Malaysia).

Grifola frondosa (Maitake)

Japan is the major producer and consumer of *G. frondosa*. Commercial production of maitake in Japan (325 t) began in 1981 (Takama et al. 1981). By 1990, production was 7,000 t and, by 1994, production reached 14,000 t (a 200 percent increase; Chang 1996). Maitake is produced primarily in the Japanese provinces of Niigata, Nagano, Gunnma, and Shizuoka.

Most maitake is marketed as food. However, maitake has been shown to have both anti-tumor and anti-viral properties (Breene 1990, Jong and Birmingham 1990, Jong et al. 1991, Mizuno and Zhuang 1995). Powdered fruitbodies are used in the production of many health foods such as maitake tea, whole powder, granules, drinks and tablets. Maitake also is believed to lower blood pressure, reduce cholesterol and reduce the symptoms of chronic fatigue syndrome (Jong and Birmingham 1990, Mizuno and Zhuang 1995).

Commercial production of most *G. frondosa* is on synthetic substrate contained in polypropylene bottles or bags (Fig. 4). A common substrate used for production is sawdust supplemented with rice bran or wheat bran in a 5:1 ratio, respectively (Takama et al. 1981, Lee 1996). Some growers may add soil to the mix to stimulate fruit body formation (Fig 3, b). For bottle production, the containers are filled with moistened substrate and sterilized or pasteurized prior to inoculation. Most growers use automated inoculation equipment thereby saving on labor costs. For production in bags, the moistened substrate (2.5 kg) is filled into microfiltered polypropylene bags and sterilized to kill unwanted competitive microorganisms. After cooling (16 to 20 h), the substrate is inoculated and the bags are heat sealed and shaken to uniformly distribute the spawn throughout the substrate. Spawn run lasts about 30 to 45 days depending on strain and substrate formulation (Lee 1996, Royse and Guardino 1997). Some growers use a cold shock (4°C) for 1 to 4 days

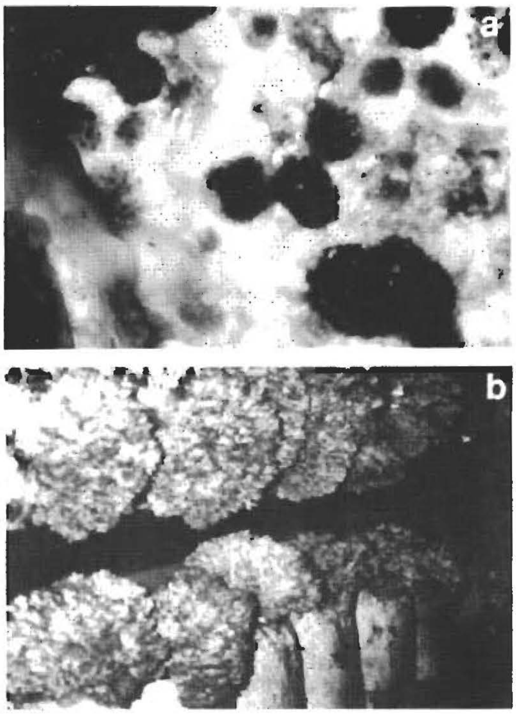

Figure 4. Maitake (*Grifola frondosa*) fruiting on substrate contained in plastic bags; (a) young primordia forming on substrate surface, and (b) mature fruit bodies ready for harvest.

to insure fruiting induction. For growers not using a hard cold shock, temperatures may be lowered more gently from about 22°C during spawn run to 14°C to induce fruiting and fruitbody maturation.

During production, humidity management is important to maintain optimum quality fruitbody development. Primordia may die if the humidity is too low. Alternatively, if the humidity is too high, moisture may condense on the fruitbody and, in turn, cause death of the immature mushroom. Expected yields are in the range of 0.75 to 1.5 lb per 2.5 kg bag. Yields are lower for the 800 to 1,000 ml bottles. Production of a second break is possible but results are highly variable. Most growers discard their substrate after harvesting the first break although some bury the substrate in soil outdoors to produce a second flush of mushrooms (Lee, 1996).

Hypsizygus marmoreus (Shimeji)

Japanese are the main producers and consumers of *H. marmoreus*. Shimeji production has increased steadily over the last few years although not as fast as some other types of mushrooms (Royse 1995). In 1986, production of shimeji was 11,439t in Japan (Royse 1997); by 1994 production reached 54,400t– an increase of 375 percent.

Shimeji usually is produced in polypropylene bottles contained in plastic trays. After the completion of vegetative mycelial growth, bottle lids are removed and the colonized substrate subjected to environmental conditions known to stimulate fruiting. When the mushrooms are mature, the entire cluster of fruiting bodies are removed from the bottles. The mushrooms are packaged by placing an entire cluster (or multiple clusters) into each overwrapped package. Only one flush of mushrooms is harvested prior to mechanical removal of the "spent" substrate from the bottles. The bottles then are refilled with fresh substrate and the process is repeated.

The antitumor polysaccharide, ß-(1-3)-D-glucan, isolated from *H. marmoreus* showed very high activity (Ikekawa 1995). The water solubility of the polysaccharide was much higher than the same polysaccharide isolated from other fungi. Dried mushroom powder from this mushroom is believed to stimulate the radical-trapping activity of blood (Ikekawa 1995). Excessive free radicals in the blood stream are believed to hasten the aging process.

Lentinula edodes (Shiitake)

The cultivation of *L. edodes* first began in China about AD 1100 (Nakamura, 1983; Royse et al. 1985; Chang and Miles 1987; 1989). It is believed that shiitake cultivation techniques developed in China were introduced to the Japanese by Chinese growers (Ito 1978).

Cultivation on natural logs

Various species of trees have been used for the cultivation of shiitake (San Antonio 1981). One of the primary species used in one area of Japan in past years was the shii tree-thus the derivation of the name shii-take (Singer 1961). Most production today, however, is on various species of oak (Harris 1986; Stamets and Chilton 1982).

Natural logs usually are cut in the fall (after leaf drop) and may be inoculated within 15 to 30 days of felling. Trees that are cut in the fall also may be left intact through winter and, just before inoculation, cut into lengths of about one meter. Trees that are cut in the summer tend to have bark that is more loosely bound and sugar contents usually are lowest during this time. If trees are cut during the summer, the bark may strip off more easily, increasing the chances of contamination of the wood by competitive organisms. The most efficient log diameter appears to be in the 7 to 15-cm range (Ito 1978). Logs greater than 25 cm in diameter often are cut in half prior to inoculation (Royse et al. 1985).

Growers who inoculate the logs with wood-piece spawn drill holes in the logs with high speed drills to correspond to the diameter and length of the wood-piece spawn. Enough holes are drilled in the log to provide spacing of about one hole per 500 cm^2. The wood spawn then is driven into the holes with a hammer and then usually covered with hot wax to prevent excessive drying of the spawn. Sawdust spawn sometimes is used instead of wood-piece spawn.

Spawn run may last from 6 to 9 months, depending on the tree species, log size, spawn cultivar, moisture, temperature, and other variables (Leatham 1982). After the spawn run period the logs often are transferred to a "raising" yard. Raising yards usually are cooler and more moist than the spawn run area. The change in conditions provides an optimum environment for the growth and development of mushrooms. In the raising yard, the logs are arranged to provide for convenient harvesting of the mushrooms. Most production occurs in the spring and fall when conditions are most favorable. However, prices received by the growers usually are lowest during these periods.

Growers may use greenhouses for winter production of mushrooms (Przybylowicz and Donoghue 1988). More overall production is possible, and prices for fresh mushrooms are considerably higher, in winter than during the rest of the year. In the greenhouse method, logs usually are soaked in water (usually less than 48 h) and vibrated mechanically for various periods prior to placement in the greenhouse. After the mushrooms are harvested, the logs are incubated further (up to three months) and the process is repeated (up to five times).

Synthetic log production

Hardwood sawdust is the most popular basal ingredient used in synthetic formulations of substrate used to produce shiitake (Miller and Jong 1987). Other basal ingredients that may be used include straw and corn cobs or mixtures thereof. Regardless of the main ingredient used, starch-based supplements such as wheat bran, rice bran, millet, rye, corn, etc are added to the mix in a 10 to 40% ratio (dry wt) to the main ingredient. These supplements serve as nutrients to provide an optimum growing medium (Royse et al. 1990).

Once the proper ratio of ingredients are selected, they are combined in a mixer and water is added to raise the moisture content of the mix to around 60%. On large farms, the mix then is augured to a machine that fills and weighs the substrate so that a uniform amount is filled into each bag (Fig. 5). The filled bags are stacked on racks, loaded into a industrial-sized autoclave, sterilized for 2 h at 121°C, cooled and inoculated with shiitake spawn. After a 20- to 25-day spawn run (Fig. 5c) the bags are removed and the substrate blocks are exposed to an environment conducive for browning of the exterior log surfaces. As the browning process nears completion (4 weeks), primordia begin to form about 2 mm under the surface of the log indicating that the log is ready to produce mushrooms.

Primordium maturation is stimulated by soaking the substrate in water (12°C) for 3 to 4 hours. Soaking allows water rapidly to displace carbon dioxide contained in air spaces, providing enough moisture for one flush of mushrooms. Approximately 9 to 11 days after soaking, mushrooms are ready to harvest (Fig. 6).

The main advantages of using synthetic medium over natural logs is time and efficiency. The cycle for synthetic medium cultivation lasts approximately 4 months from time of inoculation to cleanout. Biological efficiencies for this method may average from 75 to 125 percent. In contrast, the natural log cultivation cycle usually lasts about 6 years with maximum efficiencies around 33 percent. The time required on synthetic substrate, therefore, only is about 1/15th that of the natural system with about 3 times the yield efficiency. As a result of these developments, shiitake production in the United States has increased dramatically in the last nine years.

Shiitake is one of the best known and best charac terized mushrooms used for medicinal purposes.

Several medicinal properties have been attributed to shiitake in recent years. These properties include antitumor polysaccharides activity (Breene, 1990; Mizuno, 1995) and glycoproteins, antiviral nucleic acids, platelet agglutination inhibitive substances, and anti-cholesterol active substances (Tokuda et al. 1974, Fujii et al. 1978, Suzuki et al. 1979, Tokuda and Kaneda 1978, Mizuno 1995).

	Production		
Country	1,000 mt	1,000 lbs	%
China	632.0	1,390,400	76.5
Japan	141.3	310,860	17.1
S. Korea	20.1	44,220	2.4
U.S.A.	2.5	5,500	0.3
Taiwan	28.1	61,820	3.4
Thailand	0.3	66	--
Others	1.9	4,180	0.3
Total	826.2	1,817,046	100

Chang (1996)

Table 3. Estimated production (fresh wt) of shiitake (*Lentinula edodes*) in some countries in 1994.

Morchella **spp. (Morel)**

Morels (Fig. 7) are some of the most highly prized mushrooms found in the wild. Researchers have long sought to consistently cultivate the morel; until recently this was not possible. In 1982, a report describing the successful production of ascocarps of *Morchella esculenta* under laboratory conditions appeared in the literature (Ower 1982). Since that first report, several patents (Ower et al. 1986, 1988) have issued describing a process for the commercial cultivation of these fungi. While patents have revealed some of the processes involved in predictable production of sporocarps. Attempts to practice the invention have met only with limited success.

At present, one company in the United States is producing morels on a commercial scale. Commercial cultivation involves the production of sclerotia, an early overwintering stage of the mushroom. "Nutrient primed" sclerotia (Fig. 7a) are produced in soil placed on a layer of sterilized wheat or rye grain. The production of nutrient primed sclerotia requires about 18 to 21 days under optimum conditions. The sclerotia are harvested, soaked in clean water for 24 h and distributed into a thin layer of pasteurized bark/soil mix. The sclerotia germinate via the production of mycelium. After the mycelium has spread throughout the soil mix, a continuous (12 to 36 h) fine mist of clean water is provided to stimulate the formation of ascocarps.

Several problems have yet to be solved in the commercial production of morels. Consistent fruiting, control of competitive weed molds, poor yields and small mushroom size are just a few of the problems facing successful cultivation. A better understanding of the many factors contributing to increased yields and quality should lower the cost of commercially produced morels to consumers.

Pleurotus **spp. (Oyster)**

Oyster mushroom production has increased at rapid rate world-wide during the last few years (Table 1). From 1986 to 1994, oyster mushroom production increased from 169,000 t to 797,000 t (372 percent increase). China was responsible for most of the production increase. In the United States, production of oyster mushrooms was 812t in 1994, the same as the previous year (USDA 1996). *Pleurotus* spp. (*P. ostreatus* and *P. cornucopiae*) production in Japan peaked in 1989 at about 36,000 t. Production was 20,800t in 1994, a decrease of 42 percent in five years.

In the United States, the primary ingredients used for *Pleurotus* spp. production is chopped wheat straw or cottonseed hulls or mixtures thereof. For production on wheat straw, the material is milled to a length of about 2- to 6-cm. The pH of the material is adjusted with limestone to about 7.5 or higher to provide selectivity against Trichoderma green mold (Stolzer and Grabbe 1991).

After completion of pasteurization (60°C for 1 to 2 h) the substrate is cooled an spawned with the desired strain. At time of spawning, a delayed release supplement (rates of 3 to 10% of dry substrate wt) may be added to increase yield and size of the mushroom (Royse and Schisler 1987, Royse et al. 1991, Royse and Zaki 1991). Use of supplements, however, may cause overheating of the substrate if growers are not able to anticipate and control air temperatures to maintain a steady substrate temperature.

Production of *Pleurotus* spp. on cotton seed hulls has some advantages over straw-based production systems in that chopping of the hulls is not required (Royse 1995). The pasteurized, supplemented hulls

Figure 5. Preparation of synthetic logs for shiitake culture: (a) filling polypropylene bags with nutrient supplemented sawdust, (b) autoclave used for sterilizing synthetic medium, (c) spawn run in plastic bags, and (d) browning process prior to induction of basidiomes.

are spawned and filled (12 to 15 kg) into clear or black perforated polyethylene bags and then incubated at 23 to 25°C for 12 to 14 days.

In Japan, bottle production of oyster mushrooms is most common. Substrate is filled into bottles, sterilized and inoculated with *Pleurotus* spawn.Upon completion of spawn run, bottle lids are removed and mushroom emerge from the surface of the

Pholiota nameko (Nameko)

Japan produced 22,600t of *P. nameko* in 1994–an increase of only 2,562t (13 percent increase) from 1986 levels (Table 1). World-wide production increases averaged 8 percent over the same time period. In 1994, Japan produced about 84 percent of the total world production of nameko compared to 80% of total production in 1986.

Nameko means "viscid mushroom" in Japanese. This mushroom is prized for its gelatinous viscosity and for its flavor and is generally used in miso soup,

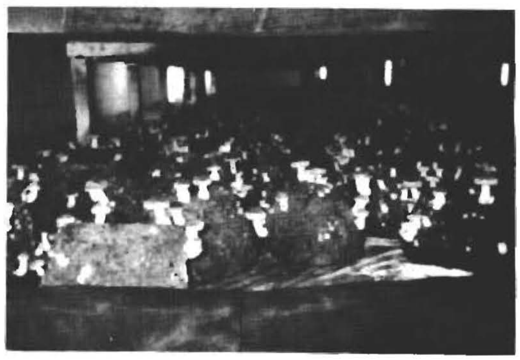

Figure 6. Shiitake fruiting from synthetic logs in production room.

cooked fresh with grated radish, and steamed in pipkin. Preparation of the medium for nameko production is similar to that for enokitake except that

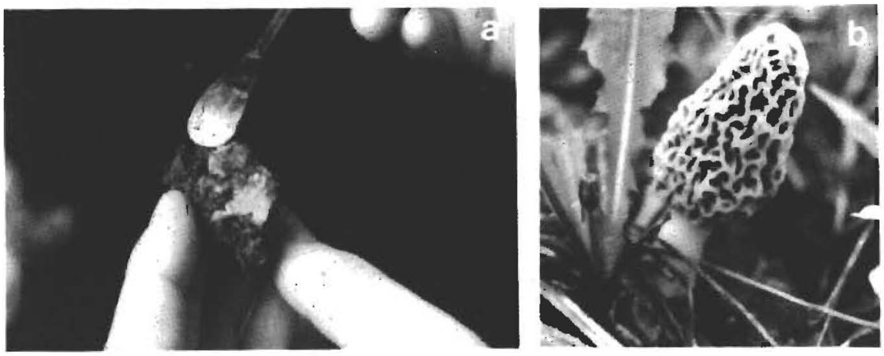

Figure 7. Morels: (a) sclerotium used to produce ascocarps under controlled conditions, (b) *Morchella esculenta* (morel) fruiting in the wild.

a higher moisture content of the substrate is desirable. A substrate of broad leaf tree sawdust is preferred but research has shown that sawdusts from conifers such *Pinus* spp. and *Cryptomeria japonica* are suitable for growth. Rice bran usually is added as a supplement in the ratio of 15 percent for conifer sawdust and 10 percent for broad-leaf sawdust.After the mushrooms are harvested they are weighed and packaged for shipment to market.

Mushrooms are harvested from the substrate by cutting the stems near the base with scissors. The harvested mushrooms are washed and packed for shipment to market.

Volvariella spp. (Paddy Straw)

The straw mushroom derives its name from the substrate on which it originally was grown (San Antonio and Fordyce 1972). Cultivation of *Volvariella* was believed to have begun in China as early as 1822 (Chang 1977). In the 1930's, straw mushroom cultivation began in the Philippines, Malaysia, and other Southeast Asian countries (Chang 1982, Quimio et al. 1990, Chang and Quimio 1982). Production of the straw mushroom increased from 178,000 t in 1986 to about 299,000 t in 1994–a 68 percent increase. *Volvariella* accounts for approximately 6 percent of the total world-wide production of edible mushrooms (Table 1).

Many agricultural by-products and waste materials have been used to produce the straw mushroom. These include paddy straw, water hyacinth, oil palm bunch, oil palm pericarp waste, banana leaves and sawdust, cotton waste and sugarcane waste (Chang 1982, Ho 1985). *Volvariella* is well suited for cultivation in the tropics because of its requirement for higher production temperatures. In addition, the mushroom can be grown on nonpasterized substrate-more desirable for low input agricultural practices.

In recent years, cotton wastes (discarded after sorting in textile mills) have become popular as substrates for straw mushroom production (Chang 1982). Cotton waste give higher and more stable biological efficiencies (30 to 45 percent), earlier fructification (four days after spawning) and harvesting (first nine days after spawning) than that obtained using straw as a substratum. Semi-industrialization of paddy straw cultivation on cotton-wastes has occurred in Hong Kong, Taiwan and Indonesia as a result of the introduction of this method (Chang 1979).

Marketing

Marketing of specialty mushrooms in the United States is a relatively new enterprise. Since 1984, some farms have seen their production rise as prices have fallen. For example, Donovan (1991) indicates that production of shiitake on their farm has increased from slightly less than 1t per week in 1984 to over 7t per week in 1990. At the same time, the price has decreased from US $12.50/kg ($5.50 per pound) to about US $ 8.80/kg ($4.00 per pound). In the 1995 to 96 growing season, the price growers received for shiitake was about $7.68/kg ($3.49 per pound; USDA 1996). Over the past nine years (1987 to 1996) the price of shiitake has declined an average of $0.19/kg ($0.09 per pound) per year (USDA 1996).

In recent years, the trend for specialty mushroom sales has been toward the retail market (Gunn 1992; Sorenson 1992). This trend is driven partly by an increased interest in specialty mushrooms and by the convenience packaged products offer to the consumer. In some retail markets, only 10 percent of the customers buy 90 percent of the specialty types (Gunn 1992).

Some merchandisers have projected a steady growth in consumption of specialty mushrooms. As consumers become more aware of specialty mushrooms, demand is expected to increase. Aggressive marketing will help to find new markets for these relatively new products. Therefore, specialty mushroom producers seeking new outlets for their mushrooms may want to check sources listing reputable produce industry firms (Anonymous 1995a, 1995b).

Specialty mushrooms are sold fresh, dried or processed in Japan and China. Most fresh shiitake is collected and shipped to central wholesale markets where brokers and other participants buy the mushrooms through a bidding process in Japan (Hara, 1988). Mushrooms then are distributed to retailers for consumer purchase. Other mushrooms, such as *Pleurotus*, may be packaged at the farm and shipped directly to brokers or to retailers.

Dried shiitake is distributed through traders specializing in this mushroom (Hara 1988). These traders (about 400 in Japan in 1988; data not available for China) buy shiitake at special bidding markets and then distribute the product to retailers for in country consumption or to trading firms for overseas export. In recent years, however, exports of shiitake from Japan have declined as the number of shiitake producers have declined and shiitake production has decreased (Anonymous 1992, Royse 1995). On the other hand, Chinese production of shiitake and exportation of the product to Japan have increased dramatically in the last five years.

Future outlook

Production and consumption of specialty mushroom in the USA and other western countries is expected to increase at an accelerated rate in the years to come (Farr 1983, Molin 1995, Royse 1997). As production technology is improved through interdisciplinary efforts, the retail price for specialty mushrooms should decrease. As economies improve in Latin America, production of specialty mushrooms could increase at an even faster rate than in the United States. The culinary advantages offered by specialty mushrooms bode well for the continued growth and development of the specialty mushroom industry worldwide.

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