Part I Shiitake

Chapter 1

What is Shiitake

WHAT IS SHIITAKE?

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Introduction to Shiitake

What are shiitake? Shiitake (*Lentinula edodes*) are the mushrooms that the Chinese affectionately named "Xiang-gu"(or "Shiang-gu"), "the fragrant mushrooms". They are a treasured and traditional delicacy at dinner tables in China, Japan, and Korea. These favorite mushrooms from the Orient are not only delicious and nutritious food with great flavor and an enticing aroma, but they also contain a material well-known for its medicinal benefits. Lentinan (β-1,3 glucan with β-1,6 and β-1,3 glucopyranoside branchings), a water-soluble polysaccharide produced and extracted from shiitake, is an approved anti-cancer drug in Japan.

Native to the Far East, shiitake have been found in the wild only in such places as China, Japan and Korea until recently. Two recent findings of shiitake in natural habitats in the United States could have originated from disposed fibrous stems of fresh shiitake. Mushrooms that grow primarily in temperate climates, shiitake grow singly or in clusters in declining or dead hardwoods, in particular, Shii (*Pasania* spp.), oaks (*Quercus* spp.), and other Asian oaks and beeches (Stamets, 2000). In nature, shiitake are saprophytic[1] white-rot fungi that degrade woody substrates containing recalcitrant, hard to decompose, lignin components. It is due to this capacity that wood logs and sawdust are now used as substrates to cultivate shiitake.

Figure 1. Shiitake culture
(Photo courtesy of Dr. Noel Arnold)

Fleshy gilled mushrooms, shiitake produce white spores and white mycelia (Fig. 1). How the four basidiospores[2] in shiitake are formed on a basidium[3] was described vividly through electron-scanning microscopy by Wu (2000). Shiitake usually have central stalks attached to circular-shaped mushroom caps that are light tan to dark brown and 5-25cm across. Some strains produce light-colored mushrooms, while others produce dark ones. Some shiitake have a nice flecking with velvety white hairy material on the caps. Growers are aware what kind of shiitake consumers want in their targeted markets. Consumers in upstate New York in the U.S. are familiar with the tasty light-colored shiitake produced by one of the leading specialty mushroom farms; Phillips Mushroom farms in Pennsylvania (www.phillipsmushroomfarms.com), while consumers in China, Japan, and Korea cherish flower shiitake (Figs. 2). There may be a reasonable question arises as to whether consumer preferences are actually dictated by the growers according to product availability.

Taxonomy

In different parts of the world, shiitake is known by different names. The name shiitake (shii-mushroom) is derived from Japanese words: "shii" meaning the hardwood of *Pasania* spp. and "take" meaning mushroom. The name shiitake is now the most popular name for this mushroom that is the most popular specialty mushroom worldwide. In the U.S. it is also known

[1] saprophytic: growing on dead or decaying organic matter
[2] basidiospore: a sexually produced spore borne on a basidium
[3] basidium: a small, specialized club-shaped structure bearing basidiospores

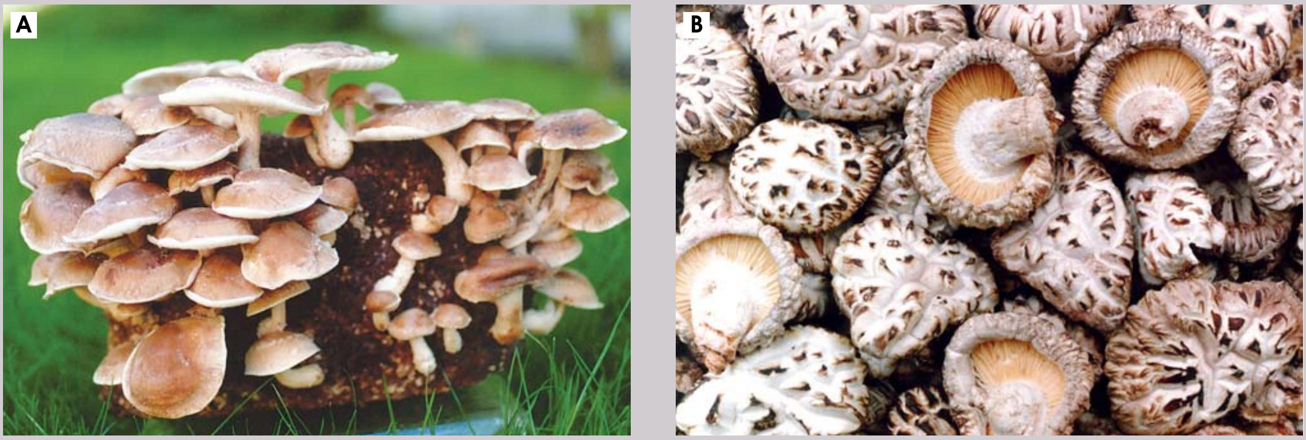

Figure 2. Consumer preference **A**: Light-colored shiitake **B**: Dried flower shiitake with white cracks on the cap (Jang-heung, Korea)

as the black forest mushroom. In France, it is known as lectin. In China, different forms of shiitake are known by various names such as xiang-gu, the fragrant mushroom, dong-gu, the winter mushroom, and hua-gu, the flower mushroom or variegated mushroom (Chen, 2001). This abundance of different local common names for the same species illustrates the importance of having a universal name that everyone understands. The scientific name for shiitake is *Lentinula edodes* (Berkeley) Pegler. Based on macro- and micro- morphological characteristics as well as other features including DNA analysis, *L. edodes* is classified in the genus of *Lentinula*, the family of *Tricholomataceae*, the order of *Agaricales*, and the subphylum of *Basidioimycotina*.

For a long time shiitake was known as *Lentinus edodes* (Berk.) Singer, especially among mushroom growers. In 1975, Pegler proposed this species be transferred to *Lentinula*. The rationale of the transfer was based on microscopic studies. The genus *Lentinula* is monomitic (one kind of mycelium), so the species in this genus do not contain dimitic (two kinds of) hyphae in the mushroom flesh seen in the genus of *Lentinus*. The cells are arranged in the mushroom gill trama in a parallel and descending fashion instead of having highly irregular or interwoven cells in the gill trama as in the genus of *Lentinus*. Recent DNA studies also support placement in the *Lentinula* genus. Mushroom growers, however, continued to use the old name *Lentinus edodes* until the 1980's and beyond. The name *Letinus edodes* was still used in 1989 and 1992 in two important books. It is helpful to keep in mind this historical name, *Lentinus edodes* (Berk.) Singer, when conducting literature searches or other explorations.

Life cycle

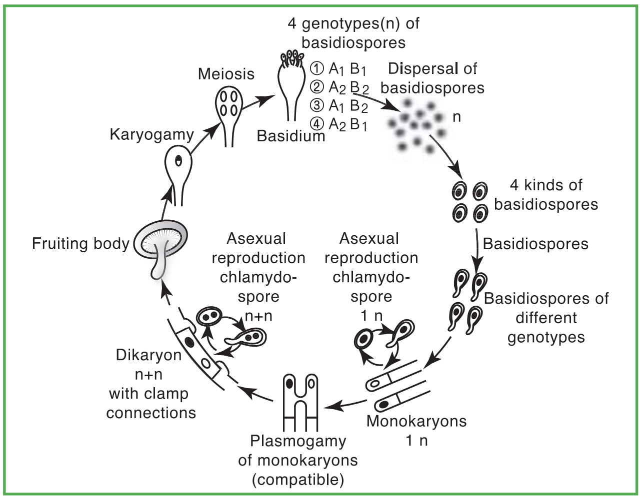

Figure 3. Shiitake life cycle

The accompanying illustration of the shiitake life cycle clearly indicates how shiitake grows from dispersed basidiospores produced in the fertile gills in the underside of the mushroom cap (Fig. 3). In a favorable environment, these basidiospores, produced by sexual reproduction through meiosis, germinate into monokaryotic hyphae[4]. Genetically compatible mononucleate hyphae fuse through plasmogamy (hyphal fusion) to produce dikaryotic hyphae[5]. With genetic material from both nuclei, it is the dikaryotic hypha (hyphae: plural in number) which is capable of giving rise to the spore-bearing fruiting body known as the mushroom, the target in shiitake cultivation. The production of basidiospores by the matured mushroom completes the life cycle.

It is wise to understand the life cycle of a mushroom before attempting to grow it. A good example of effective strain development is the development in Japan by cross-breeding of the

[4] monokaryotic hyphae: with one nucleus in each hyphal compartment
[5] dikaryotic hyphae: with two genetically different nuclei in each hyphal compartment

Figure 4. Hokken 600, a related strain

highly desirable shiitake strain, Hogan 101 in 1990 (Fig. 4). This fast-growing strain of shiitake has a firmer flesh and produces a higher yield than other available shiitake strains.

Three major milestones in shiitake cultivation

First discovered in China, shiitake have a fascinating history. Professors S. T. Chang and Philip G. Miles (2004), two pioneers in specialty mushrooms, described the first milestone in the history of shiitake as the first cultivator. Many centuries ago, a legendary figure known as Wu San Kang hunted and collected mushrooms for food in the wild forest of the mountainous Lung-Skyr village, in Longquan County in southwest Zhejiang Province bordering Fujian. He was an ingenious observer who figured out how to grow wild shiitake in 1100 A.D. during the Sung Dynasty (Luo, 2004). Wu San Kang noticed that shiitake were found on fallen logs in the woods. When he cut the logs, the mushrooms grown on the logs were larger and better. However, at times to his disappointment, there were not any mushrooms despite his cuttings. One day, in a rage he beat the logs furiously. To his surprise, mushrooms sprang up profusely like flowers all over the logs after several days. This is said to be the origin of the "shocking method," the cutting and beating practice in shiitake log cultivation. Today, 95% of the farmers in the three-county region where Wu was born (Longquan, Qingyuan and Jingning) continue the tradition of growing mainly shiitake, although today 80% use sawdust bags, while only 20% still use wood logs.

This historical place is in a region with 98% mountainous terrain. The three counties are located between 118°43′ and 120°15′ East longitude, and 27°00′ and 28°21′ North latitude. The climate is warm and humid with four distinct seasons. The average rainfall is 1,200mm and the average temperature is 17℃ with an average of 300 frost-free days per year. Such information may be useful to those who are encouraging the growing of shiitake in the uncharted frontiers of poverty-stricken

Figure 5. Various methods of shiitake cultivation **A**: Log cultivation **B**: Cylindrical synthetic log **C**: Sawdust substrate block **D**: Sawdust slate

regions world-wide in order to alleviate hunger.

The second milestone in the history of shiitake cultivation was the application of pure-culture spawn[6] in growing shiitake logs by K. Kitajima in Japan in 1936 (Chang and Miles, 2004). Kitajima was an important grower who took advantage of the discovery of the pure culture technique[7] by using it in shiitake log production. He demonstrated how spawn can be made from a pure culture without the contamination of other microbes, and how this could be used to inoculate logs deliberately at the growers' will. The discovery of the pure culture technique was credited to Shozaburo Mimura, a Japanese mycologist, who had published earlier his findings in 1904 and 1915 (Stamets, 2000). The pure culture approach put the control of shiitake production in the hands of the growers.

The third historical milestone in shiitake cultivation was the invention of sawdust substrate cultivation. The "Mushroom Cylinder Method" was evolved and improved by Z. W. Peng in Gutien, Fujian, China in 1983 (Ting, 1994) (Fig. 5B). This most well-known Gutien method widely used on a large scale in China was described in detail by Ting (1994) and Chang and Miles (2004). Development of shiitake sawdust cultivation can be traced back to the early 1970's, and Shanghai was a center for such innovation in 1974. Today, the latest development in the U.S. is the use of much larger sawdust-substrate blocks in sealed polypropylene bags with micro-porous filters as breathing windows (Fig. 5C). This methodology lends itself to faster and greater productivity by mixing the spawn thoroughly with the substrate which produces more flushes of mushrooms in much shorter growing cycles. Shiitake produces 3-5 flushes of mushrooms per year on natural logs. With synthetic substrates, each flush of shiitake requires only 16-20 days. Sawdust cultivation may produce 3-4 times as many mushrooms as natural logs in only one tenth of the time (Royse, 2002). It is also very easy to use this growing process to manage the spawn run. In Europe, more substrate in larger bags is used. Each bag contains 15 kg of substrate shaped in a flat slate (Fig. 5D). The growing cycle in Europe is usually shorter than in South East Asia, but longer than in the U.S. (Oei, 2003).

The benefits of modern sawdust cultivation include a consistent market supply through year-round production to meet consumer demand. Moreover, sawdust cultivation is a means to utilize agricultural wastes (Lopez, Valencia and Chang, 2004) and spent mushroom substrates (Babcock, 2004) to generate food.

The three major milestones in the history of shiitake cultivation are summarized in Table 1.

Table 1. Three major milestones in shiitake cultivation

Discovery	Discoverer	Country	Time
1. Spontaneous log cultivation in nature	Wu San Kang	China	1100
2. Pure culture spawn in log cultivation	K. Kitajima	Japan	1936
Pure culture technique	S. Mimora	Japan	1904 1915
3. Sawdust cultivation in cylindrical synthetic logs in plastic bags	Z. W. Peng	China	1983
- Sawdust cultivation	Shanghai	China	1974
- Sawdust blocks, 5-6kg(w/w) in sealed polypropylene bags	_	The U.S.	1989
- Sawdust substrate slate, 15kg in large plastic bag	_	Europe	Recent

Nutritional Requirements and Environmental Factors for Shiitake Cultivation

Nutritional requirements (carbon source, nitrogen source, C/N ratio, minerals and trace elements, and vitamins) and environmental factors (temperature, moisture, oxygen-air, light and pH value of the substrate) are important considerations in shiitake cultivation (Ting, H.K., 1994 and others).

Nutritional requirements

As a saprophytic white-rot fungus, shiitake produces mycelia during its most vigorous vegetative growing phase. Mycelia can absorb small molecules of nutrients directly, but it is necessary to break down the complex food molecules in the environment first by secreting enzymes from the mycelia to decompose these complex lignocellulosic substances that serve as the shiitake's major carbon source. Shiitake use protoplasm in growing tree bark and xylem as a nitrogen source, and absorb a small amount of soluble substances as well as minerals from xylem and phloem in wood.

Carbon source

Carbon is a the most important required nutrient for shiitake. Carbon is the building block for protein, nucleic acids, and

[6] pure culture spawn: spawn made from one species of mushroom
[7] pure culture technique: using one species under sterile conditions

sugars in the living cells. Carbon is also the major component for the energy source used for oxidation in the metabolism. Carbon usually comes from organic compounds such as sugars, organic acids, alcohols, starch, cellulose, hemicellulose, and lignin.

Nitrogen source

Nitrogen is indispensable for building protoplasm[8] and cell structural elements in shiitake. The major sources of nitrogen are organic and inorganic nitrogen compounds including urea and proteins. Nitrogen sources are distributed unevenly in wood logs. Nitrogen content is highest in the cambium[9], and lowest in the heartwood[10]. Tree bark contains 3.8-5% nitrogen, while xylem[11] contains only 0.4-0.5 % nitrogen.

C/N ratio

Materials with a carbon to nitrogen ratio of 25:1 are the best for vegetative mycelial growth, while materials with a C/N of 40:1 are the best for the mushroom production phase. Too much nitrogen may allow the shiitake mycelium to grow luxuriously in the spawn run, but these colonized blocks will not produce good mushrooms. The most suitable nitrogen concentration during the vegetative phase is 0.016-0.064%, while 0.02% is the best for reproductive phase. Primordia formation and the subsequent formation of fruiting bodies are both sensitive to nitrogen concentrations, and ideally the nitrogen concentration during these phases should not be over 0.02%.

Minerals and trace elements

Table 2. Carbon to nitrogen ratio (C/N) and nitrogen concentration in shiitake production

	Best for mycelial growth	Best for fruiting
C/N	25:1	40:1
N-concentration	0.016-0.064%	0.02%

The major mineral elements, such as phosphorus, sulfur, calcium, magnesium and potassium are used for building cell components and enhancing metabolism. Some minerals maintain balanced cellular osmotic pressure in cells. Phosphorus and potassium, in particular, are not only beneficial to mycelial growth, but also to the formation of fruiting bodies. The trace elements, Fe, Cu, Zn, Mn, B, and Mo are components or catalysts for enzymes. The required amounts of these trace elements are minute. Inorganic compounds, such as KH_2PO_4, K_2HPO_4, gypsum, magnesium phosphate, at concentrations of 100-500mg, are usually used in making substrates. It is not necessary to add trace elements as they are usually contained in water or substrate ingredients.

Vitamin B_1 (thiamin)

Vitamin B_1 is required for shiitake mycelial growth and fruiting. Fresh coarse (not refined) rice or wheat bran in the substrate contains such vitamins. Vitamin B_1 is sensitive to heat. It decomposes above 120℃, so overheating during substrate sterilization should be avoided.

Environmental factors[12]

Temperature

Shiitake are fungi of temperate climates. They require low temperatures and temperature fluctuations in order to form fruiting bodies. In the shiitake metabolic processes, all of the physical and chemical reactions are controlled by temperature, and the numerous enzymes all have their own optimal activity temperatures. When temperatures are too high, protein molecules in the enzyme may be denatured and lose their viability. When temperatures are too low, it is difficult for the nutrients to be absorbed, enzymatic activity becomes lower, and the rate of respiration slows down. These lower rates result in a decrease in mycelial growth. The optimal temperature for shiitake mycelial growth is 24-27℃. The species can be adapted to grow in a wide range of temperatures from 5 to 32℃. Shiitake tolerate cold temperatures. In winter-like temperatures of 8-10 ℃, shiitake mycelia are still viable even after 30-40 days. However, shiitake are vulnerable to the high temperatures of summer. Shiitake mycelia stop growing above 34℃ and turn yellow. Serious mycelial damage occurs at 36℃. Mycelia turn reddish and die above 40℃[13].

[8] protoplasm: living material outside the nucleus of a cell
[9] cambium: thin layer of generative tissue lying between the bark and the wood of a stem, most active in woody plants
[10] heartwood: *see* page 58
[11] xylem: a tissue that forms the stem of woody plant. It conducts sap upward from the roots to the leaves, stores food in the form of complex carbohydrates, and provides support.
[12] For detailed information on environmental conditions for shiitake cultivation, *see* SHIITAKE BAG CULTIVATION in Chapter 4.
[13] For detailed information on shiitake strains, with variation in their temperature requirements for fruiting, *see* SHIITAKE BAG CULTIVATION in Chapter 4.

Table 3. Shiitake temperature requirements at different stages

Stage	Temperature range (℃)	Optimal temperature range (℃)
Spore germination	15-28	22-26
Mycelial growth	5-32	24-27
Fruiting	5-25	15 ± 1-2 (strain dependent)

Moisture

Water is vital for shiitake growth and production. Nutrients need to be dissolved in water in order to be absorbed by mycelia. Likewise, metabolic wastes need to be dissolved in water in order to be disposed from the mycelia. The proper amount of moisture is required for metabolism. It is important to provide and maintain the optimal moisture content in the substrate for growing shiitake. It is also important to maintain optimal relative humidity (R.H.) of the air according to the different growth stages.

Table 4. Moisture and humidity requirement for shiitake (under Chinese system)

Stage	Substrate moisture content	R. H.	Adverse growing conditions
Mycelial growth	55%	< 75%	Moisture < 50%, growth slow Moisture > 65%, growth weak Moisture > 75%, contamination
Fruiting	50-55%	85-95%	Moisture < 30%, difficult to produce mushrooms Moisture > 95%, producing rotten mushrooms

Air

Shiitake are aerobic fungi. During the process of their metabolism, depending upon the availability of oxygen, organic compounds are oxidized through respiration. Energy thus released is stored in ATP to be used for mycelial growth and fruiting. Different stages of shiitake production require different amounts of oxygen. More oxygen is required during the reproductive phase than during the vegetative mycelial growth stage. A well-ventilated room with fresh air is necessary for the vigorous mycelial growth that produces carbon dioxide. During fruiting body formation, the requirements for oxygen are higher, and the concentrations of carbon dioxide released are also higher. It has been reported that each shiitake can produce 0.06g CO_2 per hour.

Well-circulated fresh air and more frequent ventilation during the reproductive phase are important. Fresh air contains 0.03% CO_2, and a concentration of CO_2 greater than 1% inhibits the development of fruiting bodies and causes the mushroom caps to open early. At high CO_2 concentrations malformation of shiitake mushrooms occurs. When the CO_2 levels reach 5% the failure of fruiting body formation is observed.

Light

Light is the direct or indirect source of energy for shiitake. Light is required for basidiospore formation and dispersal. Mycelia can grow in darkness without light. Under weak diffused light, mycelia grow better than under direct strong light which inhibits mycelial growth. In darkness, mycelia grow 3-4 times faster than under 500 lux. Light is required for shiitake fruiting body formation. The optimal light level is 50-100 lux of diffused light during fruiting.

pH of the substrate

Extra-cellular enzymes function at a specific pH range in degrading the substrate, and substrate pH is thus of great importance. Shiitake prefer an acidic environment. They can grow at a wide range of pH 3-7 with the optimal pH range being 4.5-5.5. The best range for primordia formation and fruiting body formation is pH 3.5-4.5. Initial substrate pH is usually pH 5-6. As mycelia grow, organic acids are produced, which decrease the pH of the substrate. K_2HPO_4 and KH_2PO_4 are usually added to the substrate to buffer and stabilize the pH. The wood, straw and water used for shiitake cultivation usually have an appropriate pH and do not need to be adjusted. Attention should be paid when the available water is alkaline in nature.

The keys for successful cultivation of shiitake include; 1) A well-supplemented substrate with balanced nutrition and optimal C/N and pH is invaluable, 2) At each different growing and fruiting stage, a different set of environmental conditions are required. Knowing how to create optimal conditions as shiitake grow will enable the grower to produce high yields of the best quality mushrooms.

World Shiitake Production and Consumption

World production of mushrooms is being dominated increasingly by species which are both edible and have medicinal benefits. Shiitake now ranks number one in specialty mushroom production. Current trends in mushroom production and consumption (Table 5) steer towards fresh shiitake consumption, particularly in the main markets in the U.S. and Europe. There is wide-spread interest worldwide both in mushroom production and consumption. Asia, where mushroom cultivation originated, remains strong in mushroom industry. China is leading in mushroom production with 8,650,000 tons produced in 2002 (Zhang, 2004).

Table 5. World production of cultivated mushrooms in 1986 and 1997 (fresh weight/1,000 tons)

Species	1986	1997	Growth rate (%)
Agaricus bisporus	1,227 (56.2%)	1,956 (31.8%)	59.4
Lentinula edodes	314 (14.4%)	1,564 (25.4%)	398.1
Pleurotus spp.	169 (7.7%)	876 (14.2%)	418.3
Auricularia spp.	119 (5.5%)	485 (7.9%)	307.6
Volvariella volvacea	178 (8.2%)	181 (2.9%)	1.7
Flammulina velutipes	100 (4.6%)	285 (4.6%)	130.0
Tremella spp.	40 (1.8%)	130 (2.1%)	225.0
Hypsizygus spp.	N/A	74 (1.2%)	-
Pholiota spp.	25 (1.1%)	56 (0.9%)	124.0
Grifola frondosa	N/A	33 (0.5%)	-
Others	10 (0.5%)	518 (8.4%)	5,080.0
Total	2,182 (100.0%)	6,158 (100.0%)	182.2

Source: Chang, 1999 and Royse, 2004

Table 6. Trends of mushroom production and consumption

1. Dramatic increase in mushroom production
2. Species diversity towards specialty mushrooms
3. High interest in mushrooms both edible and with medicinal benefits
4. Fresh-mushroom consumption in shiitake in the U.S. and Europe
5. Wide-spread of interest worldwide both in mushroom production and consumption
6. Mushrooms as an international business
7. Mushroom production as an environmental-sound practice in converting wastes into a valuable food

The dynamics of global shiitake production

Shiitake production became an industry in Japan after World War II. Over 20 years ago in 1983, 171,200 tons fresh equivalent weight of shiitake with a value of USD689 million were produced by almost 167,000 growers in Japan. In 1983 alone, Japan accounted for more than 82.0% of the total world production of shiitake. During the same period, China produced only 9.4% (Table 7). Only 4 years later, China overtook Japan for the first time in 1987 as the leading shiitake producer with a production volume of 178,800 tons. Since its peak production of 240,771 tons equivalent fresh weight in 1984, the volume of shiitake production has declined in Japan. China has maintained its position as the shiitake production leader since 1987.

Today in China, the cultivation of shiitake is an important agricultural industry. An estimated of 18 million farmers are engaged in shiitake production and a steady increase in annual output has occurred in recent years. In 2002, the total production of shiitake was estimated to be 2 million tons in fresh weight, of which 45,000 tons of shiitake were exported to other countries and regions (Luo, 2004). The shiitake production figures from the U.S. are posted annually by United States Department of Agriculture (USDA) and the Mushroom Growers' Newsletter. The value of commercially grown specialty mushrooms in the 2002-2003 season totaled USD37.7 million. Included in this survey was the sale of USD25.3 million from the volume of 8.25 million pounds of shiitake produced by 217 shiitake growers (USDA, 2004). There is evidence of a new trend towards consuming and growing shiitake worldwide.

Table 7. World production of shiitake in different years (fresh weight/1,000 tons)

Country	1983		1985		1991		1994		1997	
	Volume	Share (%)	Volume	Share (%)	Volume	Share (%)	Volume	Share (%)	Volume	Share (%)
China	19.5	9.4	50.0	13.9	380.0	60.5	626.0	73.6	1,125.0	85.1
Japan	171.2	82.8	227.3	63.3	179.7	28.8	157.4	18.5	132.6	10.0
Taiwan	7.5	3.6	49.0	13.7	36.8	5.9	28.0	3.3	27.0	2.1
Korea	4.9	2.4	23.4	6.5	17.2	2.7	22.0	2.6	17.0	1.3
Others	3.6	1.7	9.4	2.6	14.5	2.3	17.0	2.0	20.0	1.5
Total	208.7	99.9	359.1	100	638.2	100	850.4	100	1,321.6	100

Source: Chang and Miles, 2004

Shiitake production in different parts of the world

Oei (2003b) analyzed trends in the shiitake sector in Europe. The recent studies of Lahman and Rinker (2004) showed mushroom production in South America, Central America, and Mexico in North America (Table 8). Latin America has continued to increase in mushroom production. South America produced about 94% of the shiitake in Latin America, with Brazil ranking highest.

Table 8. Estimated annual production of white button mushroom (Agaricus) and shiitake in Latin America in 2002

Country		White button mushroom (ton)	Shiitake (ton)
South America			
	Argentina	1,500	8
	Bolivia	10	2
	Brazil	6,885	800
	Chile	4,872	0
	Colombia	6,312	3.6
	Ecuador	625	0
	Peru	750	0
	Venezuela	1,320	0
	Sub total	22,274	813.6
Central America			
	Costa Rica	90	3
	Guatemala	80	30
	Sub total	170	33

North America			
	Mexico	37,230	30
Total		**59,674**	**876.6**

Source: Composite from Lahman and Rinker (2004)

Shiitake consumption patterns

Shiitake were originally highly treasured Asian mushrooms with great flavor, taste, and an enticing aroma. They are also well-known for their medicinal benefits in strengthening the immune system. Asian populations worldwide continue to favor shiitake, whether fresh or dried. In the cosmopolitan cities in different corners of the world, gourmet restaurants feature shiitake dishes on their menu. Limited marketing studies show females, the traditional main grocery shoppers, may consume more mushrooms including shiitake than males. Bing and Li (2004) analyzed consumer buying behavior for fresh shiitake in Japan, while Brownlee and Seymour (2004) targeted Australians for consumer research on mushroom consumption. Factors that may effect shiitake consumption include consumers' ethnic and cultural backgrounds, tastes for food, ages, sex, perception and knowledge of mushroom products, mushroom image and consumers' income.

Projection of a positive and appealing mushroom image is vital. Shiitake appeals to health-conscious populations as well as vegetarians for its attributes of high nutrition, quality protein, essential amino acids, low calorie content, and health benefits. In regions where edible mushrooms are not a traditional food, demand for mushrooms such as shiitake depends on the continuous effort of the mushroom producers and industry in educating the consumers. Mushroom growers in Nepal were reluctant to grow shiitake because it is not a familiar native species.

Shiitake prices

Mushroom Growers' Newsletter (www.MushroomCompany.com), a monthly publication, posts U.S. weekly mushroom wholesale market prices in Chicago, Dallas, Miami, New York and San Francisco. It also lists mushroom world spot prices per pound in USD. For the week of November 22, 2004, the wholesale market price per pound for shiitake in New York was USD 5.00-5.33 for jumbo size, USD3.67-4.33 for large and USD2.67-3.17 for #2 small. The retail shiitake prices at regional super markets in upstate New York in the U.S. are usually USD7.99/lb. Shiitake prices at international markets were Tokyo, Japanese shiitake, USD2.90-9.20/100g; Chinese shiitake USD0.37-41.11 for 5kg box (Nov. 22, 2004), Paris, USD4.09-4.36/lb. (Nov. 4, 2004), Toronto, Canada, USD4.19-5.60 per 3lbs (Nov. 17, 2004), Montreal, Canada, USD6.77-7.82 per 3lbs (Nov. 17, 2004).

In Colombia, the retail price of 1kg of selected and packed shiitake was COP[14]16,000 (USD6.87), while the production costs including salary was COP10,000 (USD4.30) in 2002 (Lopez *et al.*, 2004).

Table 9. Shiitake price in the world

Market	Size / Quality	Unit	Price in USD	Date
New York (wholesale market)	Jumbo	Pound	5.00-5.33	November 22, 2004
	Large	Pound	3.67-4.33	
	#2	Pound	2.67-3.17	
New York (retail market)	Average	Pound	7.99	
Tokyo	Japanese shiitake	100g	2.90-9.20	
	Chinese shiitake	5kg	0.37-41.11	
Paris		Pound	4.09-4.36	November 4, 2004
Toronto		3 pound	4.19-5.6	November 17, 2004
Montreal		3 pound	6.77-7.82	November 17, 2004
Colombia (retail market)		1kg	6.87	2002

[14] COP (Colombian Peso, USD1 ˙.COP2,325.58 in March, 2005)

Shiitake Cultivation for Poverty Alleviation

The example of Qingyuan, China

In the light of the mission of MushWorld of alleviating hunger in poverty-stricken regions in the world by encouraging the cultivation of mushrooms, the study of shiitake production in Qingyuan county could be interesting. Qingyuan in China, declared by Chinese government as "Shiang-Gu city of China," was the birth place of spontaneous shiitake log cultivation in 1100 A.D.. The county of Qingyuan is located in a warm monsoon climate. Such a climate is considered ideal for shiitake production at high elevations. Sixty percent of the population of less than 200,000 in Qingyuan county engage directly in growing shiitake. Today the majority of the farmers (80%) use sawdust for growing shiitake. The production of shiitake has increased from 2,765 tons in 1986 to 106,500 tons in 1997. The total value of mushroom production in 1997 reached USD46.3 million. Qingyuan is now one of the richest counties among some 3,000 counties in China. The flourishing of the economy in Qingyuan is solely due to the cultivation and marketing of shiitake. The assistance of the local government in creating a trading floor has played an important role in the growth of the shiitake industry (Chang and Miles, 2004).

Figure 6. Market for dried shiitake in Qingyuan, China

Su Decheng, a mushroom scientist, who lived in poverty himself during his first 16 years in life in the mountainous region of Fujian Province in southeast China, vowed to help his countrymen get out of poverty by studying mushroom science. In 1989, he took part in a project to help people in poverty-stricken areas of China learn how to grow mushrooms for self–sufficiency. Using his knowledge of mushroom cultivation and his experience of successfully running the Youxi Shanglin Mushroom Farm, he went to Nanpin County with 20 mushroom science students to train the local people how to grow shiitake on sawdust. They established a mushroom farm to demonstrate to the locals how mushrooms could be cultivated.

In another location in Shouling County in Fujian, there were 70,000 people in 14,000 rural families living well below the poverty level with a yearly income of less then CNY[15]300 (USD36.01). The land here was barren, producing only scrub wood and little grain. In 1989, Su and his students trained them how to grow mushrooms. Almost all the families participated in this shiitake cultivation project. Since then, growing mushrooms has become increasingly economically important in this county. The average annual income per *capita* reached CNY1,800 (USD216.09) in 1993, six times higher than in 1989 when the project was first initiated. Three quarters of their income came from producing mushrooms. This vivid report demonstrates the incredible impact mushroom farming had on Shouling County in Fujian, China. More than a dozen such successful examples of shiitake cultivation in Fujian, Zhejiang, Henan and Hebei Province are quoted in Wu (2000).

Mission of Zero Emission Research Initiative (ZERI)

Table 10. Wastes from industry for mushroom cultivation

Industry	Usable biomass	Waste
The flax industry	2%	98%
The brewing industry	8% of the grain's nutrients	92%
The palm oil industry	< 9%	> 81%
The cellulose industry	< 30%	> 70%
The coffee industry	9.5% of the weight of the fresh material	90.5% residue waste

On our planet earth, an estimated 155 billion tons of organic matter are produced annually through photosynthesis (Rajarathnam *et al*., 1991). However, only a small portion of this organic matter is directly edible by humans and animals. The bulk of such organic matter can not be used as food, but becomes a source of environmental pollution. Examples of wastes from industry which can be used in mushroom cultivation are shown in Table 10. Growing mushrooms is one of the ways the ZERI methodology makes value-added products from the waste of several industries. Lopez *et al*. (2004) showed how valuable shiitake mushrooms can be grown on coffee waste in Colombia to increase farmers' income[16]. As decomposers, mush-

[15] CNY (Chinese Yuan, USD1 ˙.CNY8.33 in March, 2005)
[16] For detailed information, *see* MUSHROOM GROWING PROJECT IN COLOMBIA in Chapter 9

rooms secrete enzymes which break down the complex molecules of plant wastes. In the process of such degradation, mineral elements including carbon are released for "recycling", thus creating an enormous ecological impact. Shiitake can be cultivated at altitudes of 1,300-1,700m above sea level in coffee growing regions. Maintaining 10-23℃ during shiitake fruiting was achieved by spraying the floors and the walls with cold water containing 5% sodium hypochlorite to prevent mold contamination.

Table 11. Impacts and benefits of mushrom cultivation

1. Use of wastes in sustainable forestry
2. Use of wastes in the integrated waste management
3. Use of wastes in farming system
4. Use of wastes in the beer industry
5. Producing a valuable food source
6. Producing nutraceuticals and nutriceuticals for health benefits
7. Innovation: such as using mushroom spent substrates in growing earthworms for fishing or soil conditioning

Conclusion

For the study of technology in shiitake production, China and the U.S. are good models. Latin America is an example of emerging shiitake markets where shiitake was not a traditional food. Much of the world's undernourished population are in subtropical and tropical regions. Studies on shiitake production under such climates, such as in Latin America, will be helpful in encouraging mushroom growing in other parts of the world to alleviate poverty.

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