

Growing *Lentinula edodes* and other mushrooms in China a low input technology alternative

Qing Shen¹
Qi Tan²
Daniel J. Royse³

¹Kennett Square Specialties, Kennett Square, PA 19348, ²Edible Fungi Institute, Shanghai Academy of Agricultural Sciences, Shanghai, P.R. China, ³Department of Plant Pathology, The Pennsylvania State University, University Park, PA 16802.

Cultivo de *Lentinula edodes* y otros hongos en China una tecnología alternativa de bajo costo

Resumen. La producción mundial de hongos cultivados se ha incrementado más de 18 veces de 1965 a 1997 (últimos datos estadísticos disponibles). China es el principal contribuyente de este incremento con aproximadamente el 65% del total de la producción mundial en 1997. La producción de *Lentinula edodes* (shiitake) ocupa el primer lugar en China. En 1997 China produjo el 89.3 % del total de la producción mundial de *L. edodes*. La proeza de la industria de los hongos en China se debe principalmente al mejoramiento de tecnologías de cultivo de baja inversión, i.e., cultivo en ambientes naturales y a baja escala, granjas con producción familiar. Los cultivadores han desarrollado muchas técnicas de cultivo para explotar las condiciones ecológicas prevaescentes y de esta forma reducir los costos de cultivo. La inversión baja, incluyendo bajo costo de insumos, mano de obra, administración y energía, es un factor clave en el éxito de los cultivadores chinos en mercados tanto a nivel nacional como internacional. China, por ejemplo, es capaz de producir 1 kg de shiitake por una décima parte del costo de producción que este tendría en una granja de tamaño promedio en los Estados Unidos. El ahorro en los costos de producción en China es especialmente marcado en la mano de obra, pero también es importante en cada fase del ciclo de producción.

Palabras clave: China, costos de producción, *Lentinula edodes*, shiitake.

Abstract. World production of cultivation mushrooms increased more than 18-fold from 1965 to 1997 (last date for available statistics). China is a major contributor to this increase, accounting for about 65 percent of total world mushroom production in 1997. The production of *Lentinula edodes* (shiitake) ranks first in China. In 1997, China produced 89.3% of the total world production of *Lentinula edodes*. The achievement of the Chinese mushroom industry mainly is due to improved and low input cultivation technologies, i.e., natural cultivation environments and small-scale, family-oriented production farming. Farmers developed many cultivation techniques to exploit the prevailing ecological conditions thereby reducing cultivation costs. Low input, including low cost raw materials, labor, management, utilities and energy, is a key factor in the success of Chinese farmers in both domestic and international markets. For example, China is able to produce one kilogram of shiitake for about 1/10 the cost of producing one kilogram of shiitake on a medium sized farm in the United States. Production cost savings in China is especially pronounced in the area of labor but also is prevalent in every phase of the production cycle.

Key words: China, production costs, *Lentinula edodes*, shiitake.

Recibido 26 de noviembre 2003; aceptado 15 enero 2004.

Received 26 November 2003; accepted 15 January 2004.

Autor para correspondencia: Daniel J. Royse
djr4@psu.edu

Introduction

World production of cultivation mushrooms was about 350,000 metric tons in 1965. Production reached 2,182,000 metric tons in 1986 (Figure 1). The latest data shows 6,160,800 metric tons of production in 1997 or a 18-fold increase in 32 years. During the period 1986 to 1997, mushroom production in China increased 584%. In 1986,

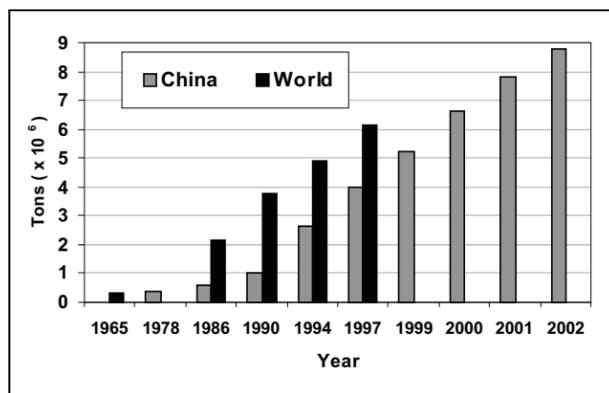


Figure 1. Mushroom production worldwide (Tons x 10⁶) and in China from 1965 to 2002 [3], and personal communication

585,000 metric tons of mushrooms were produced, accounting for approximately 26.8% of the total world production of edible mushrooms. By 1997, production in China reached 4,000,000 metric tons, or about 64% of the total world supply of cultivated edible mushrooms. Mushroom production in China has continued to grow in recent years. The latest data shows 8,764,873 metric tons in 2002, which is a 22-fold increase and a 52% annual growth from 1978.

China has been a major producer of mushrooms for centuries, but especially in the last two decades. As the major producer of edible mushrooms, China commercially produces a wide diversity of mushroom species. Among the 10 to 15 commercially produced edible mushrooms (*Agaricus bisporus*, *Lentinula edodes*, *Pleurotus* spp., *Auricularia* spp., *Volvariella volvacea*, *Flammulina*

velutipes, *Tremella fuciformis*, *Hericiium erinaceus*, *Hypsizyugus* spp., *Pholiota* spp., *Grifola frondosa*) worldwide, China is the largest producer of six of these. In 1997, China produced 99.6%, 89.3%, 86.8%, 9.9%, 6.6% and 5.3% of the world production of *Tremella fuciformis*, *Lentinula edodes*, *Pleurotus* spp., *Auricularia* spp., *Volvariella volvacea*, *Flammulina velutipes*, respectively. In the same year, China produced 16.9% of the world production of *Agaricus bisporus*, ranking third after the EU and North America, respectively. China also ranked second after Japan for production of *Pholiota* spp. and *Grifola frondosa*. Other species commercially grown in China include *Hericiium erinaceus*, *Agaricus blazei*, *Lepista nuda*, *Pleurotus eryngii*, *Agrocybe aegerita*, *Tricholoma giganteum*, *Tremella cinnabarina*, *Coprinus comatus*, etc.; however, no world production data is available. Among all the cultivated species, *Lentinula edodes* (shiitake) has the greatest economic importance in China. In 1997, China produced 1,397,000 tons *Lentinula edodes*, which is equal to 35% of the total national mushroom production.

The mushroom industry in China has developed mainly based on natural cultivation environments and small-scale, family-oriented production farming. The low environmental input combined with the improved cultivation technologies provided the reliability and profitability for farmers and served as a key factor for the development of Chinese mushroom industry. The increase of the domestic and world markets also is an important factor in the expanding cultivation of edible mushrooms [3]. In this overview, we examined the techniques and costs of production practices in China, which include low cost raw materials, labor, management, utilities and energy. The cultivation of *Lentinula edodes* is used as an example. The information provided is based on production cost estimates of selected growers. Our objective is to present these data in hopes that it may help growers and researchers enhance the productivity and reliability of mushroom production.

Materials and methods

Lentinula edodes was first cultivated in China about 1100AD [1, 2, 4, 6]. It was originally cultivated on natural logs using a hatchet-notching technique. In the 1960s, pure culture spawn was used to inoculate natural wood logs and this technique is still used in some areas in China. Beginning in the 1980s, sawdust-based cultivation became the major technique for production and this innovation greatly enhanced the shiitake industry in China [3]. The main advantage of this technique over natural logs is reduced time and increased efficiency [7]. The materials used and their costs in Songyang County, Zhejiang Province, China are listed in Table 1. Song Yong County is one of the most productive counties of cultivated mushrooms in China. It produced US\$15 million in mushroom value in 1996. The major substrate ingredient used is hardwood sawdust obtained from a sawmill. Some growers make their own sawdust from ground-up natural logs. Other raw materials used include bran, red sugar and gypsum. All ingredients are combined, mixed and filled in plastic bags. String is used to tie ends of the bags. Farmers usually purchase spawn from commercial spawn companies or research institutes. The average raw materials cost of producing 1000 kilogram of shiitake in Songyang County in 2001 was US\$118.95.

Table 1. Estimated materials cost of producing 1000 Kilogram of shiitake in Songyang County, China (2001).

Item	Cost (\$US)
Sawdust	52.48
Bran	35.95
Gypsum	0.54
Red sugar	0.54
Bags	16.06
String	2.68
Spawn	10.71
Subtotal	118.95

Sawdust cultivation techniques also are used in other countries for shiitake production, such as the United States. In the United States, growers usually add supplements of wheat bran, millet and rye in the material mix as nutrients [7]. The unit price for all raw materials in the United States is higher than the price of the same nutrients in China. We estimate that it costs US\$850-1,000 for a mid-size US farm for raw materials to produce 1,000 kilogram of shiitake.

Labor

Mushroom cultivation in China is a labor-intensive endeavor. The small-scale, family-oriented production farming involves a large population in this industry. In 1995, the number of mushroom growers in China was over 20 million. There were 25,400 mushroom growers in Qingyuan County, Zhejiang Province, which accounted for 60.3% of the agricultural population. In 1995, Qingyuan County produced US\$30.7 million (RMB 255 million) worth of mushrooms. In most of the mushroom production counties in China, 30-40% of the population is mushroom growers. The average grower (or family) manages 5,000 to 10,000 bags of shiitake substrate.

For cultivation of shiitake on nutrient-supplemented sawdust, raw materials are first combined, mixed and bagged. Then the substrate in the bags is pasteurized (80-95°C, 10-12 hours) and cooled down for inoculation. After spawn run and curing, the logs are moved to a production room for fruiting. The labor cost of producing 1,000 kilogram of shiitake at Songyang County is shown in Table 2. Materials and substrate preparation requires most of the labor. Since machines are not commonly used in production, materials are mixed and filled into bags by hand. To make 1,500 bags, two men and six women are needed. Two men are used to pasteurize the substrate contained in bags. Management accounts for more than 50% of the labor cost.

A farm in the US may use less labor to make the same amount of logs. However, the labor cost would be much more

than the labor cost in China. We estimate a US\$600 to US\$700 labor cost for producing 1,000 kilogram of shiitake on a mid-size US farm.

Table 2. Labor cost for producing 1,000 kilogram of shiitake in Songyang County, China (2001).

Item	Cost (US\$)
Materiales preparation and Making bags	18.38
Pasteurization and cool down	9.99
Inoculation	7.14
Spawn run and curing	1.78
Moving logs to production room	10.71
Management	64.26
Subtotal	112.27

Other costs

Other costs in mushroom production include utilities, growing facilities and equipment. In China, most of the mushrooms are grown under natural environment conditions. Farmers have developed many cultivation techniques to exploit the prevailing ecological conditions thereby reducing cultivation costs. For example, in Qingyuan and Shounin County, shiitake logs are placed on bamboo shelves in sheds or outdoors under the shade of trees. When pins appear, holes are cut to expose the young mushrooms to the prevailing environmental conditions. Since there is no humidity control, plastic bags are needed to keep the moisture inside the bags. In Mingxi, Ninhua, Yunhe, and Changting County, shiitake logs are placed on the ground after spawn run. A layer of casing soil is applied to provide constant moisture levels. Cultivation can be practiced year round. In many areas in Zhejiang province, specialty mushrooms are grown in simple polyethylene-clad tunnels or houses covered with straw matting [5]. Production follows climatic conditions without heating, air conditioning or air circulation systems.

Table 3. Other costs of producing 1000 kilogram of shiitake in Songyang County, China

Item	Cost (US\$)
Bagging machine	3.12
Electricity and water	3.57
Disinfectant (including disinfectant, disinfection stove and firewood)	21.87
Growing facility (shed)	53.55
Land rental	3.57
Subtotal	85.68

The costs for utilities, growing facilities and equipment in Songyang County are listed in Table 3. A bagging machine is used to fill substrates into plastic bags. One bagging machine can be used to fill 40,000 bags per day. Bagging machines cost about RMB700 (US\$85) each. Although production facilities are very simple in China, they still account for about 63% of "other" costs.

Most of the mushroom farms in the United States use environmentally controlled production houses. Relative humidity is maintained by water atomizers or by humidifiers. Sufficient light is provided daily by cool-white fluorescent bulbs. Heating and air conditioning are used to maintain temperature in the houses. Exhaust fans maintain sufficient air changes. Energy and utility usage are significantly higher in the US compared to China. The estimated cost for producing 1000 kilogram of shiitake on a mid-size US farm is estimated at \$1800, which is 20 times the cost in China.

Summary

Total costs of producing one kilogram of shiitake in Songyang County, China and a medium sized US farm is summarized in Table 4. Chinese farmers are able to produce one kilogram of shiitake for about 1/10 the cost of producing one kilogram of shiitake on a medium sized farm in the United States.

The low input cultivation technologies are a

successful strategy for the Chinese shiitake industry. With a large agricultural population available and family-oriented farming in China, the cost of labor is only 19% of the cost for a US farm. The cost of materials is 87% lower due to the cheaper unit price of the materials and the low cost substrate formulation. The biggest production cost savings in China is all other expenses that include utilities, energy, growing facility, etc. This is mainly due to the diversified cultivation techniques, which adopted the local ecological condition.

Table 4. Total cost (\$US) of producing one kilogram of shiitake in Songyang County, China and a medium sized US farm (2001).

Item	Songyang	US farm	Ratio
Materials	0.12	0.85	0.13
Labor	0.11	0.60	0.19
Others (including Utilities, energy, Growing facility)	0.09	1.80	0.05
Subtotal	0.32	3.20	0.1

Similar cultivation techniques are used in China for other specialty mushrooms. Another example is *Pleurotus* spp. that have been widely grown in China. This genus accounted for 80% of the total national mushroom production in 1990. By 1997, its production dropped to 19% of the total. However, its production has been over 80% of the world *Pleurotus* spp. production from 1990 to 1997. It offers a low-cost technology for bioconversion of lignocellulosic wastes into nutritious food. Cultivation of oyster mushrooms in China is from processed substrate contained in bags, beds, blocks, or from colonized substrate buried in soil. Depending on the location of production, oyster mushrooms may be cultivated either indoors or outdoors in China. Mushrooms are cultivated between rows and in the shade of high stem crops, such as corn, sorghum, and sugarcane, in spring and fall. Burying-in-soil methods are also used more often [9].

Because of the economic importance of mushrooms in China, extensive research on genotypes, formulations and cultivation technique have been carried out in recent years. One example is germplasm research. Growers in China are able to obtain different strains from Institutes or a commercial spawn producer to suit their own growing conditions. In the case of oyster production, more than one hundred strains are used in different regions of China with nearly every province in China producing oyster mushrooms [9]. Currently, growers in North America are evaluating lines obtained from China for commercial use [8].

Demand for specialty mushrooms is still increasing. There is considerable potential for the Chinese mushroom industry to continue to grow. Although the Chinese produce more than 4,000,000 tons of mushrooms per year, per capita consumption is only three kg per year. It is anticipated that China will capture a greater international market share using their low input and improving technology.

In recent years, modern technology has been introduced to the Chinese mushroom industry including environmental controlled mushroom houses, automatic bottle or bag filling systems, temperature monitoring systems, etc. However, for the foreseeable future, the Chinese mushroom industry will still be small-scale and family based, but more organized and better managed.

Literature cited

1. Chang, S.T., P.G. Miles, 1987. Historical record of the early cultivation of *Lentinus* in China. *Mushroom Journal for the Tropics* 7: 31-37.
2. Chang, S.T., P.G. Miles, 1989. *Edible mushrooms and their cultivation*. CRC Press, Boca Raton, Florida.
3. Chang, S.T., 1999. World production of cultivated edible and medicinal mushrooms in 1997 with emphasis on *Lentinus edodes* (Berk.) Sing. in China. *International Journal of Medicinal Mushrooms* 1: 291-300.
4. Nakamura, N., 1983. *An historical study in shiitake (mushroom) culture*. Tosen Shuppon, Tokyo.
5. Noble, R., W. Cai, J. Fang, 2002. Growing specialty mushrooms in Zhejiang Province, China. *Mushroom News* 50(2): 16-21.
6. Royse, D.J., 1985. Effect of spawn run time and substrate nutrition on yield and size of the shiitake mushroom. *Mycologia* 77: 756-762.
7. Royse, D.J., 1997. Specialty mushrooms and their cultivation.

Horticultural Review 19: 59-97.

8. Royse, D.J., 2003. Moving toward improved *Pleurotus* quality. Mushroom News 51(2): 6-11.

9. Shen, Q., H. Dan, Y. Chen, D.J. Royse, 2002. Comparison of oyster

mushroom production practices in China and the United States.

In: Sánchez, J.E., G. Huerta, E. Montiel (eds.), Mushroom Biology and Mushroom Products. UAEM, Cuernavaca. Pp. 409-416.