

Overview and prospects of edible and medicinal mushrooms: Production, consumption, and marketing in Taiwan

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Introduction

The cultivation of edible mushroom has been starting quite earlier in the midst of 20th century in Taiwan and resulted quickly in developing its canned mushroom (common white mushroom) exporting market led the world for more than a decade in 1970s. During the high time of maintaining its exporting market, the farmer grown common white mushroom mainly in a rather simple plastic house which was constructed with local materials of bamboo or wood and covered with a sheet of red mud plastics to keep away from raining and sun lights. The mushroom house was installed with a simple ventilator and a plastic duct for keeping ventilation and re-circulation of air. To maintain steady supply and demand for the exporting market, more than ten thousands of farmers were keeping on line to fully utilize these simple constructed mushroom houses to cultivate the common white mushroom during cooler months of the year from October to March.

Thus, incentive measures were established to encourage mushroom growers/farmers such as they could get subsidiary payments from government to build their own mushroom house or to buy pesticides or other agricultural chemicals to control mushroom diseases and insects. In addition, to improve their technology to grow the mushroom, farmers could also get needed information and training from local Farmers' Association. The latter obtained financial supports

from the government. In order to maintain the consistent production of the common white mushroom, the farmers were obligated to buy mushroom spawn from domestic registered spawn makers who got the mother culture of the common white mushroom from the governmental research institute (TARI). The institute conducted the research on the improvement and maintenance of living mushroom cultures and supplied new hybrids to the spawn makers for making and selling mushroom spawn to mushroom farmers.

Mushrooms thus produced were brought by mushroom farmers themselves to collection farm gate/station for weighing, recording and pre-washing were done by the staffs from canneries prior shipping to mushroom canneries/factories. Furthermore, all mushrooms were sold at a guarantee price which was settled down by negotiation by both parties of the government and canneries.

Since mid-1980s, however, due to increased production costs and the appreciation of New Taiwan dollar against US dollar, these have resulted in great impact on its competitiveness edge of Taiwan's canned mushrooms in international markets. The government authority decided to pull out its production system for common white mushroom for exporting market during the crop year of 1993/1994. Since then the production of common white mushroom along with other kinds of edible mushrooms was directed toward their marketing mainly for domestic consumption. To meet demand for local consumption, more and more mushroom farmers joined in to expand to add in growing a variety of edible or medicinal mushrooms, to name a few such as *Volvariella volvacea*, *Auricularia* spp., *Lentinula edodes*, *Pleurotus* spp., *Ganoderma* spp. etc. mainly for domestic markets and limited for exportation. Along with the demand in mushroom industry in Taiwan, earlier for exporting market and in recent years to meet the demand for domestic consumption, greater efforts have been driving toward research and professional enhancement in harnessing technology for sustainable development of mushroom production. For example, in addition to grow a variety of conventional edible mushrooms, several new mushroom species were also developed for large-scale commercial cultivation in environmentally controlled

facilities/rooms or traditional plastic mushroom houses during the past 20 to 30 years, such as *Flammulina velutipes*, *Agrocybe cylindracea*, *Pleurotus eryngii*, *Hypsizigus marmoreus*, *Hericium erinaceum*, *Pleurotus sajor-caju*, *Pleurotus citriopileatus*, *Agaricus braziliensis*, *Clitocybe nuda* etc. All these mushrooms are produced mainly to meet an increase in demand for domestic market and consumption and a small portion of them for export.

Major edible and medicinal mushrooms grown in Taiwan

My report will confine to the most recent situation of the development of major edible and medicinal mushrooms commonly grown in Taiwan. There is no official statistic data available yet for the production and consumption of various major commonly grown edible and medicinal mushrooms for the crop year of 2009/2010 in this country. I'll use the estimated figures based on data supplied by local mushroom traders and mushroom spawn suppliers or their inoculated substrate used in the mushroom production areas. Therefore the production data of these mushrooms reported here is an estimated figure as shown in Table 1. The major commonly grown and consumed edible and medicinal mushrooms in Taiwan are described below.

• Golden mushroom—*Flammulina velutipes*

Nowadays, golden mushroom is grown exclusively on a sawdust substrate filled in bottles in an environmentally controlled room and the sawdust used is derived mainly from the tree of *Cunninghamia lanceolata* var. *lanceolata* or broad leaf trees. Rice bran is commonly used as the major nutritional supplement with a small portion of wheat bran and soybean meal. Operation of most growing processes, including substrate filling, sterilization, inoculation and removing out of old inoculants and spent substrates are conducted with automatic machines. It takes 55 days to 60 days from inoculation up to the end of crop harvest.

Due to the increasing costs of energy and raw materials, including sawdust and nutritional supplements, and the long standing low price of golden mushrooms in recent years, some small

mushroom farms were forced to reduce or even abandon their production, while some other farms have switched to growing other profitable mushroom species, such as *Pleurotus eryngii* and *Hypsizigus marmoreus*. Currently, there are 25 golden mushroom growers with their production amounts to an estimated 24,000 MT in the crop year of 2009/2010 and were about 30,000 MT in the last crop year 2008/2009. Farm gate price for golden mushroom was about US\$ 0.8~1.3/kg varying depending on the season of the year. This mushroom is consumed mostly in cool months or cold winter season and festivities by serving with cooking in a hot pot with assorted meats, vegetables and other food ingredients. Again, due to its low price and the introduction of some newly emerged mushroom species into markets instead, it is foreseeable that the production and consumption of golden mushroom shall be declining in the coming years.

• **Shiitake—*Lentinula edodes***

Shiitake has been one of the oldest mushroom favorite consumed in Taiwan and used to be mostly cultivated on wood logs or decayed tree cuts. In recent decades, however, the production techniques have been gradually changing to use sawdust substrate filled in a PP bag instead in replacement of wood logs. Nowadays, the majority of mushroom growers are using sawdust substrate to cultivate the mushroom. The sawdust used for Shiitake cultivation is mostly derived from the hard wood trees such as *Acacia confusa* and *Liquidamber formosana* and/or some others. Rice bran is the main nutritional supplement with addition of a small portion of wheat bran and corn meal. Filling of substrate into bags is conducted by a filling machine. The substrate is pasteurized at ca 98~100°C for at least 4 hours. Wheat grain spawn is used for inoculation of the pasteurized substrate. After incubation it usually takes 3 to 4 months before stimulation for fruiting.

In the crop year of 2009/2010 seasons, total production of shiitake was an estimated 28,000 MT, comparing to 36,000 MT of the last crop year 2008/2009 up to current. This reduction in total production was due partly to the drastic change in weather extreme

conditions, either too cold or too hot, to decreasing quality of sawdust and to a possible change in genetic make-up of shiitake spawn supplied by a few spawn makers. The current farm gate price of fresh shiitake rose to about US\$3.1~3.5/kg in comparing to US\$2.6~3.1/kg of the last crop year. Difference in the consumption pattern of Shiitake mushroom in a year may be not significant as that of the declining of golden mushroom because of their different cooking ways and prices of the two mushroom species which both determine the amount of consumption. Shiitake has been extensively used in Chinese cuisine and not easily replaced by other edible mushrooms species. The price of this mushroom is quite stable, either fresh or dried products in the marketplaces, comparing to other mushroom species. As long as the genetic stability of the spawn strain and the reliability of sawdust sources can be maintained and solved, shiitake is still a profitable crop in the future.

• **King oyster mushroom—*Pleurotus eryngii***

This mushroom was firstly developed by Taiwan Agricultural Research Institute for growing on the substrate filled in a bottle because such way of cultivation can be highly automatic with consistent production in an environmentally controlled mushroom house. It can be grown with the same machineries and facilities as those for growing golden mushroom during the period of low mushroom price of the latter, i.e. in summer. King oyster mushroom can be grown on rice straw or sawdust substrate, however it is more convenient to use sawdust rather than rice straw due to the easiness of operation during cultivation when using sawdust as basic raw material. Rice bran is the main nutrient supplement with a small proportion of wheat bran. The sawdust substrate can also be filled in a PP bag for sterilization or pasteurization. After such heat treatment, the substrate is ready for inoculation when it cools down to 20°C. Incubation for spawn running at 21°C usually takes 35 to 40 days prior to reducing temperature to initiate fruiting. Mature fruiting bodies can be harvested 15 to 20 days after stimulation depending on the spawn strain used.

The technology for growing king oyster mushroom using bottle system has been developed for almost 20 years. Due to its excellent culinary characteristics and unique texture of its cap and stalk it has been accepted and become the favorite food of many people. It can be cooked in many ways enhancing the consumption of this mushroom. There are more than 50 growers to cultivate this new king oyster mushroom species with an estimated total yearly production of about 12,000 MT for the crop year of 2009/2010. The fresh products of king oyster mushroom are classified into four grades, i.e. A, B, C and D. The farm gate prices for the above grades are US\$2.6~3.3, 2.2~2.6, 1.6~1.9 and 1.0~1.3/kg respectively.

King oyster mushroom is a weak fungus and vulnerable to the competition of nutritional requirements from other harmful microorganisms and thus, preventive management measures need to be taken to keep away of contamination. In addition, the growth and development of this mushroom is also very sensitive to the changes in environmental factors during cultivation, such as temperature, humidity, concentration of carbon dioxide, movement of air ventilation and light intensity. These results lead to difficult to maintain its stability for production and thus prone to risk to lose of profitability. Due to the difficulties in the management to grow this mushroom species, many growers shifted to growing a newly introduced mushroom species called Bunashimeji – *Hypsizigus marmoreus*, from Japan, thereby, resulting in shortage of the supply of king oyster mushroom and also in the rise of its farm gate price during the crop year of 2009/2010. Since this mushroom species has become very popular in the market and can be cooked in many ways in Chinese cuisine, the demand for this mushroom in the market will still be strong in the coming years. However its farm gate price might go down if the stability of the technology for this mushroom species can be solved or its import from Korea or other countries is greatly increased.

• **Phoenix tail mushroom—*Pleurotus sajor-caju***

This mushroom is grown exclusively on sawdust substrate filled in a PP plastic bag. The substrate is pasteurized or sterilized before

inoculation. It takes about three months for incubation prior to subjecting them in reducing temperature for the induction of fruiting. This mushroom is usually grown in a traditional plastic mushroom house without a climate control and is able to grow above 20°C. In order to have a uniform fruiting it is suggested that the fully colonized substrate be subjected to low temperature treatment (chilling). Four to six flushes or even more can be harvested with a yield of 300 to 400g per bag (with 1.2 kg of fresh substrate). Fruiting bodies of the spawn strain cultivated in Taiwan are small ones with a thin context of cap. Besides, the fruiting bodies grow very fast, so that the management of humidity in a mushroom house is extremely important to this mushroom strain. It is usually necessary to harvest the mushroom three times a day to keep the high quality level of the products. There were more than 100 mushroom growers to cultivate this mushroom species with a yearly production of an estimated 12,000 MT in the crop year of 2009/2010. Farm gate price for this mushroom was US\$1.8~2.7/kg, however it was US\$1.4~1.7/kg in the last crop year.

Due to the inefficient use of mushroom house and the vulnerability to green molds (*Trichoderma spp.* and *Penicillium spp.*) after the first flush, many growers who used to cultivate this mushroom with air-conditioning facilities switched to growing *Bunashimeji*. This resulted in the reduction of production and the rise of farm gate price of this mushroom in the crop year of 2009/2010. The price of this mushroom species may still keep high for a period of time, however the demand for this mushroom and its production as well may gradually reduce if the consumers are getting used to other new mushroom species.

- **Common white mushroom—*Agaricus bisporus***

There are still a few mushroom growers who cultivate the common white mushroom in a traditional plastic mushroom house without a climate control. These mushroom growers cultivate this mushroom mainly in cooler weathers during fall and winter seasons. After cropping/harvesting, most of the mushroom farmers use the spent composts again to grow other mushroom species, such as straw

mushroom (*Volvariella volvacea*) or hot mushroom (*Agaricus bitorquis*), so that maximize the utilization efficiency of spent compost and mushroom house facilities to cut down production cost.

In Taiwan, nowadays most mushroom farmers cultivate common white mushroom in a well insulated mushroom house with a climate control. However, the scale of their white mushroom production is not as big as those of developed countries and most often Taiwan's farmers own only 6 to 12 or a little more mushroom growing rooms. They also have one Phase I tunnel, two Phase II tunnels and two Phase III tunnels for making their own compost and spawn, run compost. Some mushroom growers do not have Phase I tunnel; they prepare Phase I compost outdoors instead.

Most mushroom growers cultivate only one mushroom species, however, very few of them manage to grow other species, i.e. *Clitocybe nuda*. There were about 20 mushroom growers with a year production of an estimated 3,000 MT in the crop year of 2009/2010, while farm gate prices fluctuated for domestic fresh markets for this mushroom kept at the level of US\$3.2~4.5/kg.

The price of the common white mushroom appears quite stable in most parts of the year but the price may drop to some extent in the winter due to competition from the cheap mushrooms grown in a traditional mushroom house. Growing common white mushroom is labor intensive and hard working, fewer farmers want to involve in its cultivation, so that there is a tendency in the number of the common white mushroom growers to reduce in the recent years. However, there is no competition from imported mushrooms, the above mushroom price and the consumption of this mushroom species anticipate stable for the years to come.

• **Bunashimeji—*Hypsizigus marmoreus***

This new mushroom species was introduced into Taiwan markets from Japan by one of our mushroom traders several years ago. It appears good market potential and acceptable by local consumers. Some mushroom growers start growing this mushroom and the Japanese supplier of this mushroom has already set up production premises in

southern Taiwan for commercial cultivation and has already started supplying the mushroom to marketplaces. Bunashimeji mushroom can be grown with a bottle or bag system in good control modern facilities. When using bottle system the operation of growing processes can be very automatic.

Now there are two strains of this Bunashimeji mushroom species on the markets, one is brown and another is white. The brown one is exclusively grown in a bottle, while the white one can be grown in a bottle or in a bag. The fruiting bodies of the Bunashimeji grown in a bottle have a small cap and a short stalk with a solid texture, while those grown in a bag usually appear to have a larger cap and a longer stalk with a softer texture than the one grown in a bottle. When using bottle system, incubation of the above two bunashimeji strains takes nearly three months before they can be stimulated to initiate fruiting by reducing temperature and increase ventilation in giving supply of more fresh air. When using bag system, the white strain also needs three months for incubation of the inoculated substrate. It takes about 30 days from stimulation to harvest no matter what cultivating system is used. When using bag system, 300 to 400 grams of mushroom can be harvested from one bag which has 1.2kg of fresh substrate. The growers usually harvest one flush only.

Due to the easiness to get initiation of fruiting, the stability and profitability of production as well as the less labor cost, many mushroom growers who used to cultivate king oyster mushroom or phoenix tail mushroom, shifted to growing Bunashimeji in the last crop year 2008/2009. This resulted in lowering of the farm gate price of this mushroom. The total production of Bunashimeji in the crop year of 2009/2010 was an estimated 2,000 MT and the farm gate price for the one grown/harvest in a bottle was in the range of US\$ 4.8~9.7 /kg, while the one grown in a bag was at the level of US\$2.3~3.2/kg.

The difference in farm gate prices between golden mushroom and Bunashimeji is so evident that it is anticipated the growers of the former will have a strong tendency to shift to growing the latter for profitability for the years ahead. This may result in gradually lowering of the price of Bunashimeji mushroom. Besides, the golden mushroom

growers may have the advantage to fully utilize their existing facilities and bottle system to cultivate Bunashimeji mushroom than growers whom are cultivating king oyster mushroom or phoenix tail mushroom.

• **Jew's ear-- *Auricularia* spp.**

This fungus is grown on a sawdust substrate filled in a bag and the substrate is pasteurized before inoculation with sawdust spawn. Incubation takes about one month before stimulating it to fructify. Most of the fungal growers do not prepare their own bags of substrate -- they just buy them from the professional substrate bag makers. The fungus is cultivated under a mushroom shed covered with plastic sheet and black plastic net. It takes about 21 days from initiation of fruiting bodies to harvest. Four to six flushes can be harvested before termination of the crop. The total production of Jew's ear fungus in the crop year of 2009/2010 in Taiwan estimated about 3,000 MT and the farm gate price for this fungus ranges at the level of US\$ 1.3~1.9/kg. The price of Jew's ear mushroom is comparatively low in comparing with the prices of most of other mushroom species. Nevertheless, since consumers recognize its nutrient value and medicinal benefits to health, the consumption of this fungus remains steady increases in the recent years.

• **Straw mushroom—*Volvariella volvacea***

This mushroom is usually to be grown on a pasteurized cotton waste which is covered on the top of spent mushroom compost in a traditional plastic mushroom house. The same spent substrates can be repeatedly used for cultivation of straw mushroom four to five times in the same mushroom house without removing the old spent substrates prior to again starting a new crop of the common white mushroom. Two to three flushes can be harvested for each crop of straw mushroom with a yield of 900 to 1,200 kg in a mushroom house of which bed surfaces are 165 square meters. The total production of straw mushroom in the crop year of 2009/2010 estimated about 1,000 MT and the farm gate price for this mushroom ranges at the level of

US\$ 1.3~1.7/kg, in Taiwan. All fresh straw mushrooms produced were sold to the markets for domestic consumption.

• **Summer oyster mushroom—*Pleurotus cystidiosus***

This mushroom species has been growing for more than 40 years in Taiwan. Even with easiness in the cultivation of summer oyster mushroom whole year round in Taiwan, nevertheless, due to the emerging development or introduction of some new edible mushroom species in recent years, such as phoenix tail mushroom, king oyster mushroom and Bunashimeji, the summer oyster mushroom is facing increased competition in its market share from those new mushroom species. The total production of this mushroom in the crop year of 2009/2010 estimated about 600 MT and the farm gate price for this fungus ranges at the level of US\$ 0.4~0.6/kg.

• **Yuhuanmo—*Pleurotus citriopileatus***

This mushroom is usually grown on a pasteurized sawdust substrate filled in a bag. The growers buy inoculated substrate bags and incubate them in their own mushroom house or shed. It takes about one month for colonization of spawn mycelium prior to initiating/stimulation for fruiting. In Taiwan, the total production of this mushroom in the crop year of 2009/2010 estimated about 300 MT and the farm gate price for this fungus ranges at the level of US\$ 0.6~1.1/kg.

• **Brown swordbelt—*Agrocybe* spp.**

This mushroom can be cultivated either on sterilized or pasteurized sawdust substrates filled in a bottle or in a plastic bag depending on the mushroom strain used. High temperature strain of brown swordbelt is usually grown in bags without a climate control, while the low temperature one is grown in bottles in a well insulated mushroom house with an environmental control. In Taiwan, the total production of *Agrocybe* spp. in the crop year of 2009/2010 estimated about 300 MT and the farm gate price for the one grown in a bottle ranges at the

level of US\$ 3.2~4.8/kg, while the one grown in a bag ranges at the level of US\$2.9~3.9/kg.

• **Sunny mushroom—*Agaricus braziliensis***

Sunny mushroom is mostly grown on a pasteurized sawdust substrate filled in a bag. After the substrate has been fully colonized by the fungal mycelium, it is necessary to cover the substrate surfaces with a layer of casing soil for fruiting. Some farmers cultivate this mushroom on rice straw compost. The total production of *A. braziliensis* in the crop year of 2009/2010 was an estimated 350 MT and the farm gate price for fresh mushroom ranges at the level of US\$ 7.1~9.7/kg, while for the dried products was in the range of US\$96.8~112.9/kg.

• **Oyster mushroom—*Pleurotus ostreatus***

The oyster mushroom is usually grown on a pasteurized sawdust substrate filled in a bag. When the pasteurized sawdust substrate has been fully colonized by the fungal mycelium grown out from wheat grain spawn, the substrate bags are moved to a well insulated mushroom house of which environmental factors, such as temperature, relative humidity and carbon dioxide concentration and light, are strictly monitored and well controlled. About 200 to 250 grams of fresh mushrooms can be harvested in the first flush from each bag with 900 grams of fresh substrate. In Taiwan, the total production of oyster mushroom in the crop year of 2009/2010 estimated to reach 100 MT and the farm gate price for fresh mushroom was in the range of US\$ 2.6~3.2/kg.

• **Shaggy cap—*Coprinus comatus***

This mushroom is grown on a pasteurized sawdust substrate filled in a bag. When the Shaggy mushroom mycelium has fully grown through the substrate, the plastic bags are completely removed then a layer of casing soil is laid on the surfaces of exposed substrate for inducing fructification. In Taiwan, the total production of shaggy cap in the crop year of 2009/2010 estimated to reach 50 MT and the farm gate price for fresh mushroom was in the range of US\$4.0~5.2/kg.

- **Lingzi—*Ganoderma* spp.**

Lingzi is a medicinal mushroom which is usually grown on a sterilized sawdust substrate filled in a bag under a plastic mushroom shed. It takes about one month for incubation prior to it can be stimulated for fruiting and then takes a duration three weeks to one month for the development of fruiting bodies to the stage to be harvestable. The Lingzi products of harvested fruiting bodies are usually dried for direct sale or to be processed for extraction of useful components either to make capsules or as liquid drinks. The total production of dry Lingzi products in the crop year of 2009/2010 estimated about 15 MT and the farm gate price for dry Lingzi mushroom ranges at the level of US\$15.4~21.5/kg.

Marketing and distribution of mushroom products

There has been well established for stakeholders in dealing with the marketing and distribution of fresh or dried mushroom products. Small volume growers generally market their fresh mushrooms to jobbers (secondary wholesalers) or shippers, while large volume growers usually market their mushrooms to shippers and wholesalers. Jobbers sell their mushrooms to traditional markets (retailers), restaurants, groceries and institutions. Shippers collect and buy fresh mushrooms from both small and large volume growers and sell their mushrooms to jobbers, traditional markets, supermarkets, hypermarkets and wholesalers as well as restaurants and Institutions. Wholesalers sell their mushrooms to supermarkets or hypermarkets (Fig. 1).

Fresh mushrooms are packed loose in bulk bags or in various sizes of boxes, or in food-service and retail packages supplied by both small and large growers. To keep fresh mushrooms in good quality and wholesomeness, products packed loose in bulk bags or boxes are usually re-packed by shippers and wholesalers, and kept in refrigerated conditions. Then shippers and wholesalers transport the packed fresh mushrooms to marketplaces by refrigerated truck during distribution.

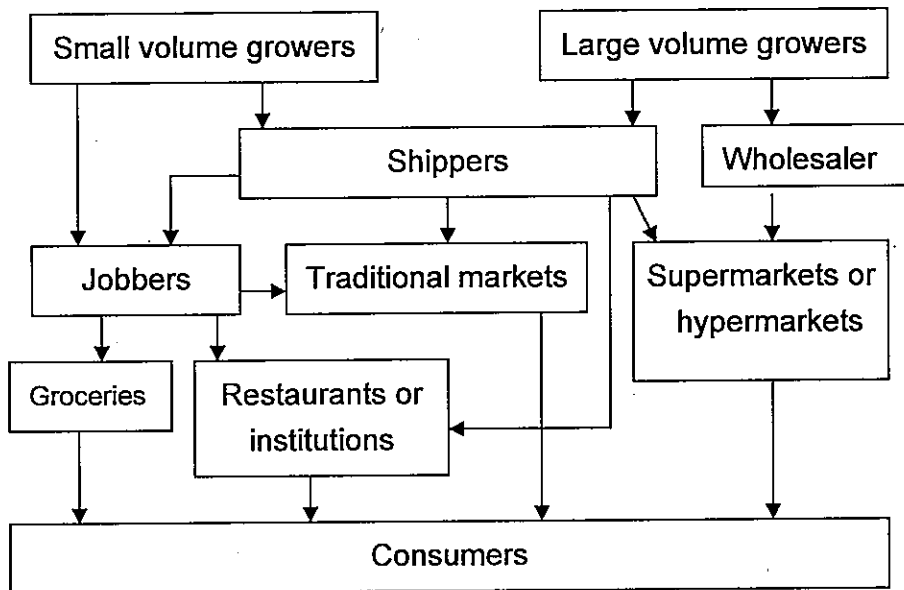


Fig. 1. Major distribution channels for Fresh mushroom sales in Taiwan.

Table 1. Estimated production of edible and medicinal mushrooms in the crop year of 2009/2010 in Taiwan

Common name	Scientific name	Estimated production (MT)	Unit price (US\$/kg)
Golden mushroom	<i>Flammulina velutipes</i>	24,000	0.8-1.3
Shiitake	<i>Lentinula edodes</i>	28,000	3.1-3.5
King oyster mushroom	<i>Pleurotus eryngii</i>	12,000	2.6-3.2
Bunashimeji	<i>Hypsizigus marmoreus</i>	2,000	Bottle:4.8-9.7 Bag:2.3-3.2
Phoenix tail mushroom	<i>Pleurotus sajor-caju</i>	10,000	1.8-2.7
Jew's ear	<i>Auricularia spp.</i>	3,000	1.3-1.9
Common white mushroom	<i>Agaricus bisporus</i>	2,000	3.2-4.5
Straw mushroom	<i>Volvariella volvacea</i>	1,000	1.3-1.7
Summer oyster mushroom	<i>Pleurotus cystidiosus</i>	600	0.4-0.6
Yuhuanmo	<i>Pleurotus citriopileatus</i>	300	0.6-1.1
Brown swordbelt	<i>Agrocybe spp.</i>	300	Bottle:3.2-4.8 Bag:2.9-3.9
Sunny mushroom	<i>Agaricus braziliensis</i>	350	7.1-9.7
Oyster mushroom	<i>Pleurotus ostreatus</i>	100	2.6-3.2
Shaggy cap	<i>Coprinus comatus</i>	50	4.0-5.2
Lingzi	<i>Ganoderma spp.</i>	15 (dry)	15.4-21.5