



# The technological progress of traditionally cultivated Mushrooms in China: *Lentinula edodes*

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## Abstract

*Lentinula edodes* is one of the five traditionally cultivated large fungi in China. There are detailed records of its cultivation in ancient Chinese literature. In ancient times, wood cutting cultivation was found on trees after logging, and mushroom spores would freely fall and inoculate, thus growing fragrant mushrooms. Western mycological knowledge and Japanese mushroom cultivation techniques were disseminated during the Republic of China period. Along with improved cultivation techniques, experiments were also conducted to study the improvement of bacterial strains, resulting in the emergence of 'spore powder', 'mushroom wood powder', and 'seed wood' strains. It was not until the 1950s that pure mycelium strains were successfully developed and promoted for use in production.

**Keywords** Cultivation · *Lentinula edodes* · Wood cutting cultivation · Spores · Mycological

## 1 Introduction

China is the birthplace of mushroom cultivation, and *Lentinula edodes* is one of the world's most important cultivated varieties of edible fungi. Since the invention of the most primitive 'wood cutting cultivation', *L. edodes* has a cultivation history of many years (Yang, 1988). China has the world's richest mushroom germplasm resources and has successfully invented advanced mushroom cultivation techniques. Among the three major elements of *L. edodes* production (strain, culture medium, and cultivation management), strain is the most important basic production material and a key factor affecting mushroom yield and quality composition. One of the main reasons for the rapid development of *L. edodes* production in China is the introduction and breeding of a large number of high-quality, high-yielding, and strong stress-resistant strains (Pan et al., 1998). The development process of mushroom breeding in China has divided the *L. edodes* breeding work into the initial stage,

introduction stage, single spore hybrid breeding stage, and the application of protoplast technology to select strains stage. A systematic review and analysis were conducted on the development process of mushroom breeding in China (Tan et al., 2000). However, no article currently elaborates on the cultivation techniques of *L. edodes* from ancient times to the 1950s. This article provides a detailed explanation of this cultivation process.

## 2 Records in ancient books (before 1890)

*L. edodes* is one of the five traditional cultivated large fungi in China. There are detailed records of its cultivation in ancient books such as the *Agricultural Book* (1313 CE) by Wangzhen (Yuan Dynasty). The 'Mushroom Seed' section of the 'Volume 8: Hundred Grain Genealogy 4: Vegetable Genus' states: "Mushrooms are planted in the mountains today, and the same method is used. However, choose the appropriate wood (maple, castanopsis, and other trees) when oriented towards shady areas. Cut it down, chop it up with an axe, and cover it with soil. After years of tree decay, the mushroom was crushed and filed, evenly distributed within the ridge, and covered with wormwood leaves and soil. Watering with swill and counting, hitting the tree with a mallet is called 'startled mushroom'. In addition to rain and dew, if the weather is warm and humid, *L. edodes* will

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grow." Although profits are made over the years, the benefits are vast. After harvesting, there was still a recurrence the following year. It is suitable for different seasons and different generations. Newly picked, cooked fresh, and fragrant. Exposed mushrooms are dried *L. edodes*. The people of the deep mountains and poor valleys today are using this as a substitute for farming, and they are thriving on this product in order to inherit its benefits (Wang, 1313). Using mushrooms to crush files and evenly distribute them within the ridge' refers to evenly spreading mature fruiting body fragments onto the cut flowers of a wood segment. This is the earliest record in China of inoculating fruiting body 'fragments' onto a wood segment. Unfortunately, this method is only recorded in the 'Wang Zhennong Shu'. It has not been applied in the production of mushroom cultivation in practice, nor has it appeared in other literature. However, the description of the techniques of 'using axes to break and chop into ridges' and 'shocking mushrooms' is not only the first time recorded in history, but also an important technical measure in mushroom cultivation practices for thousands of years to come.

There is also a more detailed record of the cultivation of *L. edodes*, which is recorded in Volume 14 of the 'Shuyuan Miscellaneous Records' by Lurong (Ming, 1436–1494 CE), which includes five records: copper mining, silver mining, celadon, Shaofen, and *Lentinula edodes*. Mushrooms are described as follows: "Mushrooms are found only in the depths of the mountains to the depths of darkness. Their method is to use dry heartwood and olive wood, named 'Mushroom Terrace'. First, they were cut down and fell to the ground at the foot of the mountains, and then they were spotted and filed on the wooden skin with an axe. After being soaked, they only emerged in two years. In the third year, the mushrooms were spread (all over). After the beginning of spring, when the earth's energy is released and thunderstorms shake, it is handed over to the wooden platform before taking action. Hang it with bamboo strips and bake it. When workers repeatedly knock on the wood at the turn of autumn and winter, the mushroom emerges and is named 'Surprising Mushroom'. But when it rains, it produces more and is made like the method of spring, but not like the thick ears of spring mushrooms. The thick and small ones have excellent fragrance."

Another type of mushroom that grows naturally on a tree during the Qingming Festival is called 'Ri Mu'. This mushroom is particularly good, but rare. This spring mushrooms are dried in the sun, also known as 'day mushrooms', and their fragrance is also good (Lu, 1493). In his self-annotation, Lu Rong said, 'Five articles have been published in the *Longquan County Annals*... The mushroom character was originally written as a mule, but the local pronunciation is false, which is now true'. The cited *Longquan County Annals* was written when and by whom, but Lu Rong's

annotation was vague. The cultivation method of *L. edodes* introduced by Lu Rongyin in the *Longquan County Annals* is basically the same as the techniques used in the *Wang Zhen Nong Shu*, but there is no such technique as "using mushrooms to crush files and evenly distribute them within the chop down trees which involves inoculating crushed fruit bodies into the chop down trees".

The academic community has different opinions on the origin of the 185 methods describing mushroom cultivation, cited in the *Longquan County Annals*. One view is that Lu Rong's *Shuyuan Zaji* cited the 185 characters of mushrooms from the Ming orthodox *Longquan County Annals*. Another viewpoint is based on the Qing Dynasty Qianlong's *Longquan County Annals*, which suggests that Lu Rong's *Shuyuan Zaji* cites 185 characters of Xiangmu from Song He Dan's *Longquan Annals* (1209 CE). However, Song Xi conducted research in the *Compilation and Examination of the Chronicles of the Ming Chenghua Prefecture* (Song, 1990) and believed that Lin Yingchen and Pan Hui wrote the Song *Longquan Chronicles* (1209 CE). He participated in politics as a preface. The 1994 edition of the *Longquan County Chronicles* defined the 185 characters cited by Xiangmu in the *Shuyuan Miscellaneous Records* of the *Longquan County Chronicles*. In the absence of clear indication of the author and version of the cited *Longquan County Chronicles* by Lu Rong, as well as other sufficient research evidence, the conclusion is: *The Longquan County Annals* referred to should be the lower limit of Ming Dynasty Zhengtong (1436–1449) and the upper limit of the second year of Jiading in the Southern Song Dynasty (1209) version (already lost). (Long, 1994). This conclusion is relatively objective and serious.

In addition to the cultivation methods recorded in Wang Zhen's *Nongshu* and Lu Rong's *Shuyuan Zaji*, there are also some ancient books or local chronicles that record *L. edodes* cultivation. Due to space limitations, they are not cited here.

### 3 Records of the Late Qing Dynasty (1890–1911)

Fujian *Lentinula edodes* mushroom cultivation method is described in an article "*L. edodes* breeding method" in Volume 25 of the Hubei Business Daily in the late Qing Dynasty in 1899. Mushrooms are commonly found in various places, especially in Fujian Province. In the area around Jianning Prefecture, it is the West Stream, and in the area near Taohua Ridge, it is the East Stream. The annual output of these two places is not less than 300,000 tons. Many workers in this field live in Longyou, Xi'an, Changshan, Jiangshan, and four counties under Zhejiang Qu's jurisdiction. The method of growing mushrooms involves first taking their huge miscellaneous trees, removing their branches and leaves, and



horizontally placing them in deep mountain thickets. With a pointed axe, they are chiseled obliquely to ensure that the small holes in the tree are dense like fish scales, and the top is covered with decaying grass. Once again, let it rain and moxibustion on the sun, and the damp and hot qi will accumulate in the hole. In one or two months, it will grow into *L. edodes* (Anonymous, 1899).

In the Mushroom section of the 10th issue of the *Education Journal* in 1909, mushroom cultivation methods are described: First, cut the oak and mistletoe trees into wood, about four feet long, and discard them for more than a year. After the wood dries and solidifies, take it out and place it in a warmer garden. Sprinkle it with water, and for a total of three years, the mushrooms gradually appear on the surface of the wood. According to cultivators, if the wood prepared by the above method is hammered at one end, it will reproduce faster and thrive. The effectiveness of this method is unknown (Yan, 1909).

According to the records of the above two articles, the first one only chops down the trees that grow *L. edodes*, ‘chiseling them with a pointed axe to make the small holes in the tree as dense as fish scales,’ and then allows them to naturally grow *L. edodes* through the inoculation of *L. edodes* spores that freely fall and spread. The latter made progress by cutting down fallen trees and allowing spores to freely fall for cultivation. It also recorded the ‘stimulating fruiting by log taping’ technique of ‘hitting one end with a hammer, and it propagates more quickly and vigorously’.

#### 4 Records of the Republic of China era period (1912–1949)

During the Republic of China era, the cultivation and strain improvement of *L. edodes* were at the intersection of traditional and new cultivation methods. *L. edodes* was the most prominent among the five large fungi cultivated in China. This is due to the dissemination of theoretical knowledge in Western mycology, cultivation techniques for *Agaricus bisporus*, and cultivation technology for Japanese *L. edodes*.

The most representative record of Tang Xueqing's "Winter Wild Mushroom (i.e., *Cortinellus shiitake* Henn) Cultivation Method" dates back to 1935. The description in "Types of Cultivation Methods" states: "There are two methods for promoting the emergence of winter mushrooms on trimmed cultivation trees, namely natural cultivation and artificial cultivation. In the place where winter mushrooms are produced, the seeds are scattered everywhere. If the cultivation wood is accumulated in a suitable place, a considerable number of winter mushrooms can be found; if four or five seeds are inserted into every hundred cultivation trees (i.e., seeds with winter mushrooms and mycelium), old cultivated wood is more prone to occurrence. However, natural cultivation

methods may not necessarily have excellent results, and artificial cultivation methods are relatively reliable". The following focuses on artificial cultivation methods (Tang, 1935). It is stated in 'Cytocyte and Mycelial Bottom Extraction Method' that: Collect the bottom of the sperm by using the method of collecting the bottom of the sperm, which is fully grown in the bottom folds of the winter bamboo umbrella. When the umbrella is already open but not fully open, it will fly away, so do not miss the opportunity when taking it. When the umbrella is about seven or eight minutes open, gently cut off the stem of the mushroom, but do not touch its folds. After the winter bamboo is cut, hold it in a clean cup, with the folds facing down, and arrange it cup by cup on a glass plate. After the arrangement is complete, cover it with newsprint or wrapping, move it to a well-ventilated place, let it sit for one or two days and nights, and the cups and glass panels will be covered with thin and white cells. Dip a brush or pen in clean water, sweep the seeds into a clean container, and add appropriate water to stir well for vaccination. The method of using B mycelium base adopts the seed wood used for mycelium cultivation (i.e., the wood that needs to be cultivated with seeds), and it is appropriate to use the seed wood three years after the occurrence of winter bamboo, which is the so-called three-year planting wood. If the diameter of the fruit is small and the age of the tree is young, even if it is planted two years after its occurrence, it can still be used. The most important thing is to remove a large amount of mycelium from the thriving few species. Those that are too old or contain other miscellaneous fungi should not be used as seeds. This should be noted and noted! This part of the wood that is spread by the winter mushroom hyphae has a yellow brown white color, giving it a smell of winter mushroom. Based on its color and fragrance, suitable seed trees can be selected. The second method is to use the mycelium bottom. First, peel off the old culture wood bottom skin from the seed, and carefully scratch the decayed part of the mycelium. The mycelium at the bottom of the decayed part is in a thick state, which is about one inch thick. The decayed part is about one inch thick for mature trees grown in three years, and the mycelium is also quite strong on the wood. Most of the time, scratch the soft part of the mycelium first, and be careful not to mix other fungi when scratching. Never let it get mixed up! Scratch the mycelium and grind it in a bowl. After grinding, sieve it several times to make it as thick and fine as soybean flour. Discard any too coarse residue and add appropriate water to the screened mycelium for planting purposes" (Tang, 1935). Tang Xueqing's article introduces two methods for isolating bacterial strains. One is to collect and use the spores by "injecting appropriate water and stirring well for vaccination". Another method is the collection of mushroom wood powder, "which involves adding appropriate water to the screened mycelium powder for planting."



In chapter ten, seven sections on technology are in the book *Improved Mushroom Planting Technology for Basswood* written by Li Shiyi in 1939 (Li, 1939). The first to seventh sections were the tree cutting method, cutting and chopping wood, raw wood, secret technique of carving and transforming, four stages of carving and transformation secret method, cutting method, and sowing mycelium, respectively.

The method of sowing mycelium varies, depending on the type of wood cutting cultivation described in the seventh section of the method of sowing mycelium. The blank wood with a drooping eyebrow shape should be coated with type A mycelium inside the axe mark (refer to the type A mycelium blending method). Vertical eyebrow-shaped and snake eye-shaped raw wood, using type B mycelium is sown in the axe hole (refer to type B mycelium blending method). Six-shaped blank wood, using type C mycelium (refer to type C mycelium blending method) is sprinkled inside the axe mark (refer to type C mycelium blending method) (Chen, 1959; Li, 1939).

At the end of this section is the hyphal preparation method, which includes A and B. The mixing method for three types of mycelium: (Type A) Take seven parts of the mycelium scraped from the old valve wood and add three parts of the thickest yeast to form a pulp. (Type B) Take nine parts of the mycelium scraped from the old valve wood, add one part of the glutinous rice, and swill to form a pulp. Use non-drying, non-wetting, non-scattering, and non-sticking as the degree. (Type C) Take the mycelium scraped from the old valve wood and form a sawdust-like mycelium, making it powdery and not wet (Li, 1939).

The above shows that the mycelium used by Li Shiyi in the book *Improved Duanwu Seed Rice Technique* is made from the mycelium and sawdust scraped from the old mushroom wood, and supplemented with other supplementary materials. In fact, it is mushroom wood powder.

In his book *The Reproduction Law of White Fungus and Wild Rice*, published in 1940, Li Shiyi further studied wild rice strains and made new progress. The eighth part of the book states that *L. edodes* seed wood is used for extracting hyphae for introduction (see instructions). *L. edodes* spores are used for propagating hyphae for introduction, and either seed wood or spore can be selected. The ninth part of the Technology section states that: 'Fragrant Zizania Seed Wood', extract mycelium for preparation and application, is produced by the Limin White Fungus Fragrant Zizania Seed Farm. The self-harvesting method is attached. The Appendix to Part 11 states that: First, cut blue paper into two square inches, then pick the mature and moderately fragrant mushroom, cut off the handle, and place it on the paper that has been cut into two square inches. The umbrella should be facing upwards, folded with stickers, and then cover each one with a bowl or cup, depending on the size of the mushroom.

Be sure to cover the mushroom completely. After sixteen hours, remove the mushroom spores completely from the paper! Note: The fragrant mushroom used for spore collection must be collected when the growth ring is not fully developed, and the best time is when the protective film is broken. More spores must be collected. If the spores are immature too early, the reproductive ability is low. If they are too old, the spores have fallen off, and there is not much left! The selection of fragrant wild rice seed wood requires selecting the most prosperous part of the host during the peak production period, and then cutting through about five annual rings with a knife or saw, taking them off one by one, to extract and reproduce mycelium. The method of selecting a host must be based on sticky wood rings with a yellow and light aroma. It is better to have rodent eaters, and those with torn skin and gray, white, and black growth rings are not taken" (Li, 1940).

From the above, it can be seen that in the book *The Reproduction Method of White Fungus Fragrant Wild Rice*, the 'Fragrant Wild Rice Seed Wood' refers to the "selection of the most prosperous part of the host during the peak production period, and then cutting into about five annual rings with a knife or saw, one by one, to extract and reproduce mycelium." Collect the mature and moderate fragrant mushrooms, cut off the stalks, and place them on paper, cut into two square inches. The umbrella should be facing upwards, folded with stickers, and then cover each one with a bowl or cup, depending on the size of the mushroom. Be sure to cover the mushrooms completely. After sixteen hours, remove the mushrooms, and all the spores will fall on the paper."

## 5 Narration of the 1950s

In 1959, Chen Meipeng first introduced his book *Cultivation of Edible Mushrooms* and then *Pure Strain Culture Method for Mushrooms*. The first book dealt with the tools and equipment required for cultivating pure mushroom strains, and the second dealt with the configuration methods of various culture media used for cultivating pure mushroom strains (Chen, 1959). The pure strain breeding method states that Shiitake mushrooms are used to reproduce their offspring. In addition to the basidiospores produced from their folds, they are the main reproductive organs. Cutting any part of their entire body tissue for cultivation can also germinate mycelium and grow to produce fruiting bodies. To separate *L. edodes* strains, *L. edodes* spores, or *L. edodes* mushroom tissues can be used to cultivate pure shiitake mushroom strains after dividing the tissue into culture and spore isolation culture methods. In its "Cultivation and Selection of Species and Reproduction", it is described that once the mycelium of the isolated single spore grows and develops to cover the



entire surface of the culture medium, it can reproduce and is the mother species, if a small amount of mother weight is required, when the first isolated single spore mycelium fills the surface of the seaweed potato culture medium, it can be transplanted into a bottle of sawdust culture medium. Each test tube can be used for about 40–50 bottles of inoculation. After inoculation in the sawdust culture medium, it should also be cultured under the environmental conditions mentioned in the previous section, and the mycelium can fill the entire bottle in about 45–50 days. The cultivated mycelium can be used for breeding and cultivation. The strain is called the original strain. Each bottle of original seeds can be divided into 400–500 bottles for cultivation purposes (Chen, 1959). At this point, Chen Meipeng utilized the theories and experiences of predecessors and personally conducted experiments to summarize and improve the use of pure cultured mycelium mother species, original species, and cultivated species.

The experiment on pure *L. edodes* cultivation and the innovation of *L. edodes* cultivation technology began in 1957 at the Shanghai Agricultural Experimental Station. Thanks to the Party's correct leadership and strong support, a series of successful experiments on pure *L. edodes* cultivation and artificial inoculation of pure *L. edodes* on wood and sawdust were quickly achieved in the winter of the same year (Chen, 1959). As soon as these experimental research results were announced, they were immediately adopted by the Ministry of Commerce of the People's Republic of China. In late March and early April 1958, an on-site meeting with over 100 representatives from 11 provinces and regions was held in Jingdezhen, Jiangxi, to demonstrate the artificial inoculation of pure mushroom strains. After this meeting, in addition to using the on-site demonstration mushroom farm of Ruopishan in Jingdezhen, Jiangxi, as a nationwide mushroom experimental field with representatives from all provinces was organised. They have also held *L. edodes* test fields since they returned home. So, the development of *L. edodes* mushrooms and the innovation of *L. edodes* mushroom cultivation techniques have not been widely promoted, but they are blooming everywhere. To support the urgent needs of various regions, Shanghai Agricultural Experimental Station not only worked overtime to cultivate 140,000 bottles of pure mushroom strains for supply, but also helped provinces such as Jiangxi, Guangdong, and Fujian establish 1–2 pure mushroom strain farms each. In addition, we have trained over 340 technical talents in edible mushrooms for 24 provinces and cities, including Jiangxi, Fujian, Guangdong, Guangxi, Hunan, Hubei, Yunnan, Sichuan, Guizhou, Shaanxi, Gansu, Shanxi, Shandong, Hebei, Beijing, Tianjin, Liaoning, Jilin, Heilongjiang, Anhui, Jiangsu, Nanjing, Zhejiang, Hangzhou, etc. (Chen, 1959). From the above situation and examples, it can be seen that the technological innovation of *Lentinula edodes*

mushrooms has reached a climax throughout the country, and soon it will completely replace the cultivation method that relied on nature for nearly 800 years, and write a new page in the history of *L. edodes* cultivation.

## 6 Summary and Discussion

The above content shows that the traditional (before the 1950s) cultivation of *L. edodes* in China can be mainly divided into four stages: (i) Before 1890, ancient mushroom farmers relied entirely on the weather to make a living. In nature, the strains used for *L. edodes* cultivation were 'wood cutting cultivation' on the tree after felling, allowing the mushroom spores to freely fall and inoculate, resulting in the growth of fragrant mushrooms. (ii) In the late Qing Dynasty (1890–1911), there were advances in traditional 'wood cutting cultivation', including cutting down fallen trees to allow spores to freely fall and cultivate, as well as recording the technique of 'stimulating fruiting by log taping' by hitting one end with a hammer to promote faster and more vigorous reproduction. (iii) During the period of 1912–1949, due to the spread of Western mycological knowledge in China and the dissemination of Japanese *L. edodes* cultivation technology in China, in addition to improving cultivation technology, experiments were also conducted to study the improvement of bacterial strains, resulting in the emergence of 'spore powder' strains, 'mushroom wood powder' strains, and 'seed wood' strains. (iv) In the 1950s, Mr. Chen Meipeng, the first director of the Institute of Edulis Fungi of Shanghai Academy of Agricultural Sciences, successfully developed pure mycelial strains and promoted their use in production. The innovation in *L. edodes* cultivation technology has completely replaced the traditional cultivation method of relying on the weather for food that has existed for nearly 800 years.

## Declarations

**Conflicts of interest** The Authors declare no competing interests.

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