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ARTICLE

Overview of the Chinese edible fungi industry of and developing trends analysis

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Abstract

Edible fungi possess high nutritional and medicinal values, and are playing an increasingly important role in promoting human health worldwide. Since 2000, China has become the world's largest producer and consumer of edible fungi. Based on comprehensive data on the edible fungi industry in China since 2014, as well as related scientific literature, we present an overview of the edible fungi industry in China in the recent decade and analyze developing trends. In recent years, the rapid development of cultivation and breeding technologies has driven high output and quality production of edible fungi. According to the data from the China Edible Fungi Association and the Food and Agriculture Organization of the United Nations, the total edible fungi production value in China increased from 225.81 billion RMB (33.95 billion USD) in 2014 to 388.72 billion RMB

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(47.17 billion USD) in 2022, and the global mushroom market size is 53.94 billion USD in 2022, thus the Chinese mushroom market accounting for 87.45% of the global annual production value. Our linear regression analysis predicts that this trend will continue, and China's edible fungi production value is expected to increase to 527.39 billion RMB by 2030. These developments position edible fungi as a strategic component for global food security and climate-resilient agriculture, given their efficient resource utilization and adaptability.

In China numerous species have been successfully domesticated with widespread cultivation, 24 species with rapidly expanding production since 2014 are introduced, including *Auricularia* spp., *Coprinus comatus*, *Cordyceps militaris*, *Cyclocybe cylindracea* complex, *Ophiocordyceps sinensis*, *Ganoderma* spp., *Grifola frondosa*, *Hericium* spp., *Hymenopellis raphanipes*, *Lentinula edodes*, *Lyophyllum decastes*, *Morchella* spp., *Naematelia aurantialba* complex, *Phallus* spp., *Phlebopus portentosus*, *Pholiota microspora*, *Pleurotus* spp., *Sanghuangporus* spp., *Schizophyllum commune*, *Sparassis latifolia*, *Stropharia rugosoannulata*, *Tremella fuciformis*, *Volvariella volvacea* and *Wolfiporia hoelen*. The various cultivated species and geographical conditions make the production model of edible fungi highly diversified. This has resulted in the transition from scattered household cultivation to cooperative production involving "Company + Farmer" coupled with the development of large-scale industrialized cultivation. Parallel advancements in processing technologies have been evident, as evidenced by the proliferation of commercial products; processed mushroom products have become increasingly common in the market. Bibliometric analysis of recent research (2014-2023) reveals accelerated innovation of edible fungi in four domains: genetic breeding, cultivation technology, bioactive components, and processing. A shift of the global innovation centre for edible fungi towards China is evident.

Keywords – Domesticated mushroom species – Edible fungi market trends – Industrial cultivation models – Mushroom processed products

CONTENTS

INTRODUCTION

Edible fungi, which are rich in vitamins, minerals, dietary fiber, and bioactive polysaccharides, with low fat and calorie content, and superior protein quality, have become a preferred choice for promoting human health (Wang & Zhao 2023). With the continuous improvement of scientific research and the increase in living standards, awareness of edible fungi has been steadily rising (Bao & Tan 2024). As a crucial component of the recommended "one meat, one vegetable, one mushroom" tripartite human health dietary structure by the World Health Organization and the Food and Agriculture Organization (Zhao 2023), the consumption of edible fungi has been steadily increasing, contributing to the continuous growth of global trade in edible fungi.

China is one of the earliest countries to recognize and utilize edible fungi. Over 2,000 years ago during the Eastern Han Dynasty, the first complete pharmacological work in China, “Divine Farmer’s Classic of Materia Medica” (Shennong Ben Cao Jing) (Fig. 1a), detailed the medicinal properties of fungi such as *Ganoderma* spp. and *Wolfiporia hoelen* (Fr.) Y.C. Dai & V. Papp. In the Ming Dynasty, Li Shizhen documented the medicinal value of 32 types of fungi in "The Compendium of Materia Medica (Ben Cao Gang Mu)", such as *Lentinula edodes* (Berk.) Pegler (also known as shiitake mushroom), *W. hoelen*, *Auricularia* spp. The cultivation of edible fungi began around the year 600, with the earliest recorded being *Flammulina filiformis* (Z.W. Ge et al.) P.M. Wang et al. (also known as enoki mushroom) [during the Tang Dynasty in the book "Outline of the Four Seasons (Si Shi Zuan Yao)"] (Fig. 1b), and then *Auricularia heimuer* F. Wu, B.K. Cui, Y.C. Dai (7th century), *Len. edodes* (800 years ago), *Volvariella volvacea* (Bull.) Singer [1822 in "General Records of Guangdong (Guangdong Tong Zhi)"] (Fig. 1c), and *Tremella fuciformis* Berk. (1865) (Zhang et al. 2015, Wu et al. 2020b), but all heavily relied on the natural conditions.

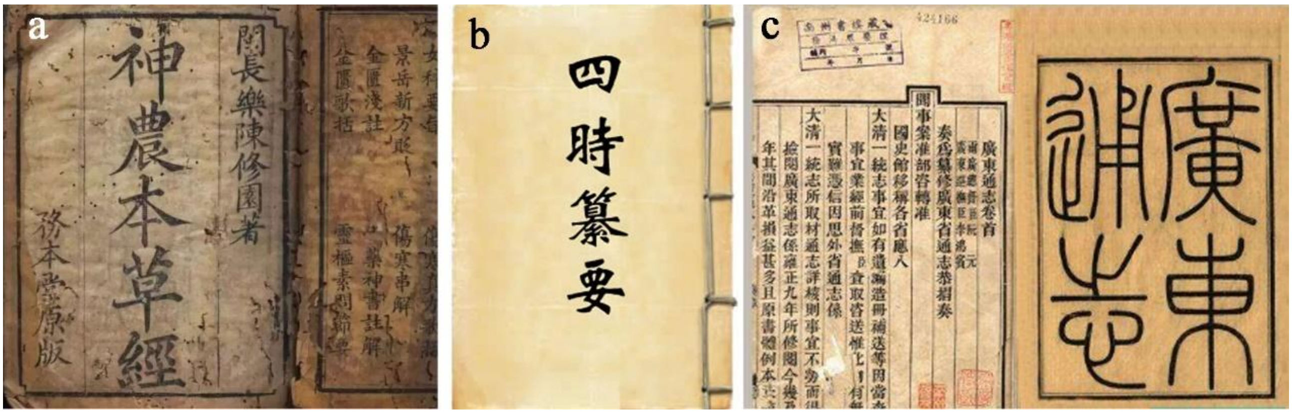

Figure 1 – Ancient Chinese texts recording edible fungi. **a** The Compendium of Materia Medica (Ben Cao Gang Mu). (Image from the web page: https://k.sina.com.cn/article_6526536805_185030c6500100da9t.html). **b** Outline of the Four Seasons (Si Shi Zuan Yao). (Image from the web page: https://www.diancang.xyz/xueshuzaji/sishizuanyao/). **c** General Records of Guangdong (Guangdong Tong Zhi). (Image from the web page: https://baike.baidu.com/item/%E5%B9%BF%E4%B8%9C%E9%80%9A%E5%BF%97/3494711).

The industrial development of edible fungi began in the mid-20th century in Western countries (Kapahi 2018, Svanberg & Lindh 2019, Tan 2024). The Netherlands pioneered the factory-based production of *Agaricus bisporus* (J.E. Lange) Imbach (also known as button mushroom), followed by the promotion of similar practices in European and American countries (Royse et al. 2017). In the 1960s, Japan adopted factory-based cultivation for wood-rotting mushrooms, represented by the white *F. filiformis*, developed technologies for *F. filiformis*, *Grifola frondosa* (Dicks.) Gray, *Hypsizygus marmoreus* (Peck) H.E. Bigelow, *Pholiota microspora* (Berk.) Sacc., *Pleurotus eryngii* (DC.) Quél. and others that suited Asian dietary habits (Mori 1987, Tan 2024). Subsequently, South Korea and Taiwan area of China also replaced traditional methods with factory cultivation, and mainland China began importing factory production lines (Bao et al. 2022b, Tan 2024). By the late 1980s, the edible fungi industry in Asia, especially in China, experienced rapid growth, with China's share of global edible fungi production continually increasing (Fig. 1). In the 21st century, China's edible fungi production increased by 204.36% from 1999 to 2000, accounting for 75.67% of the world's annual production (Fig. 1). The global edible fungi market rapidly shifted towards China. In terms of the species of edible fungi, there are 2,189 edible species globally (Li et al. 2021a). China reports 1,789 edible fungi, 798 medicinal fungi, and 561 are dual-purpose, serving both food and medicinal purposes. In 2018, more than 100 species of edible fungi were successfully domesticated, and approximately 60% of these can be cultivated for commercial purposes in China (Kew 2018). In 2023, there are 192 species of edible or medicinal fungi that have been domesticated and cultivated in China (Hou et al. 2023).

In recent years, rapid advancements in China's edible fungi breeding and cultivation technologies have driven large-scale, high-quality production in the edible fungi industry, resulting in a continuous annual increase in China's edible fungi production (Bao 2021, Tan 2024). According to the statistical survey conducted by the China Edible Fungi Association (CEFA) on 28 provinces, autonomous regions and municipalities across China (CEFA 2021, 2022, 2023, 2024, 2025), China's edible fungi production reached 43.34 million tons in 2023, with a value of 396.56 billion RMB (http://bigdata.cefa.org.cn/) (CEFA 2025), making it the fifth-largest agricultural planting industry in China after cereals, vegetables, fruit trees, and oil crops (Li 2022). Among the categories of edible fungi in China, *Len. edodes* have the highest production share, followed by *Aur. heimuer*, *Pleurotus ostreatus* (Jacq.) Quél., *Auricularia cornea* Ehrenb., *F. filiformis*, *Ple. eryngii*, and *Aga. bisporus* (http://bigdata.cefa.org.cn/). Edible fungi have significant advantages and hold a prominent position in China's agricultural development, serving as a major source of income for rural areas and farmers, as well as a pillar industry in modern agriculture (Li 2018, 2021). The development of the edible fungi industry has become a crucial pathway for poverty alleviation in rural areas and an integral part of modern agriculture in China (Li 2018, 2021). Additionally, based on the health benefits of edible fungi and the advancement of processing technologies, numerous processed mushroom products have become increasingly diverse in the Chinese market, creating additional value (Bao et al. 2022).

China's edible fungi industry maintains steady scale expansion, and scientific research advances rapidly. However, persistent challenges include rising costs, inconsistent product quality, and suboptimal economic returns, which dampen industrial development momentum. The translation of scientific achievements into practical applications remains insufficient to meet industrial demands. This study presents the first comprehensive analysis of China's edible fungi industry, integrating current industrial big data (2014 to 2023), domesticated species, industrial cultivation models, and scientific research innovations. We specifically aim to: (1) quantify China's evolving dominance in global edible fungi production using validated industry metrics; (2) analyze the technological drivers enabling the shift from traditional cultivation to industrialized models; (3) identify key innovation trends through bibliometric analysis of recent research.

MATERIALS AND METHODS

Data sources

The data on China's edible fungi industry, viz. production, value, exports, cultivated species, and factory production, are sourced from statistics released by the China Edible Fungi Association (CEFA, http://bigdata.cefa.org.cn/) (Table S1). The data of the global edible fungi industry, such as production and value of global countries and regions, comes from the Food and Agriculture Organization of the United Nations (FAOSTAT. Food and Agriculture Organization of the United Nations Statistic. 2024. Database: http://www.fao.org/faostat/en/#data. Accessed 20 Dec 2024) (Table S2).

Analytical methods

Changes of edible fungi production and value in China and the world (1961 to 2023) were calculated and visualized using the data from FAOSTAT, including the proportion of Chinese production and value in the world, the growth rate of Chinese annual production and value, and the growth rate of global annual production and value. The current situation of China's edible fungi industry in the past decade (2014 to 2023) and developing trends were analyzed and visualized using the data from CEFA, and linear regression was employed to predict the developing trends, including production and value of edible fungi in China, species number of common edible fungi in China, production of each edible fungi type (bulk species, small-scale cultivated species, rare species) in China, the number of edible fungi factories, and the proportion of annual factory production. The changes in each species' production from 2014 to 2023 were represented by compound annual growth rate (CAGR), standard deviation (SD), mean production, and coefficient of variation (CV).

ANALYSIS OF THE EDIBLE FUNGI INDUSTRY IN CHINA

Production and output value of edible fungi in China

Before the 1970s, the global edible fungi industry was mainly concentrated in developed Western countries such as France, Germany, Italy, the Netherlands, the United Kingdom, and the United States, with products primarily focused on *Aga. bisporus* (Tan 2024). During the same period, China's edible fungi cultivation was based on a small-scale household production model, resulting in a relatively low market share in the world (Fig. 2). According to the mushroom data from FAOSTAT (1961 to 2023), by the late 1980s, with the rapid development of edible mushroom industry in Asia, China started large-scale cultivation, entering a phase of high-speed growth (Tan 2024). China's edible fungi production increased by 204.36% from 1999 to 2000, accounting for 75.67% of the world's annual production; China's value of edible fungi production increased by 204.87% from 1999 to 2000, accounting for 55.65% of the world's annual value of production (Figs. 2,3). China has become the largest producer of edible fungi in the world, and the global edible fungi market has accelerated its shift towards China. Since 2014, China's annual edible fungi production has exceeded 92.48% of the world's annual production, and China's annual value of edible fungi production exceeded 83.68% of the world (Figs. 2,3).

Over the past decade, the rapid promotion of factory cultivation of edible fungi in China has led to a steady increase in total production. China's total edible fungi production increased from 32.70 million tons in 2014 to 43.34 million tons in 2023, with an increment of 10.64 million tons and a growth rate of approximately 32.54% (Fig. 4a). The compound annual growth rate (CAGR) over the years is around 3.18%. It is predicted that by 2030, China's edible fungi production will further increase to 51.57 million tons (Fig. 4a).

The total market value of the edible fungi has increased year by year (from 2014 to 2023) with the rise in production in China. However, the growth rate is influenced by various factors, resulting in considerable fluctuations. China's total edible fungi production value increased from 225.81 billion RMB in 2014 to 396.56 billion RMB in 2023, with an increment of approximately 170.75 billion RMB and a growth rate of about 75.62%. The CAGR is approximately 6.46%, significantly higher than the growth rate of production (Fig. 4b). It is predicted that China's edible fungi production value will increase to 527.39 billion RMB by 2030 (Fig. 4b). Although China is a major producer of edible fungi, the vast majority of the edible fungi produced in China are consumed domestically, based on customs import and export data, the annual export volume of edible fungi in China does not exceed 1.80% of the annual production (Table S1).

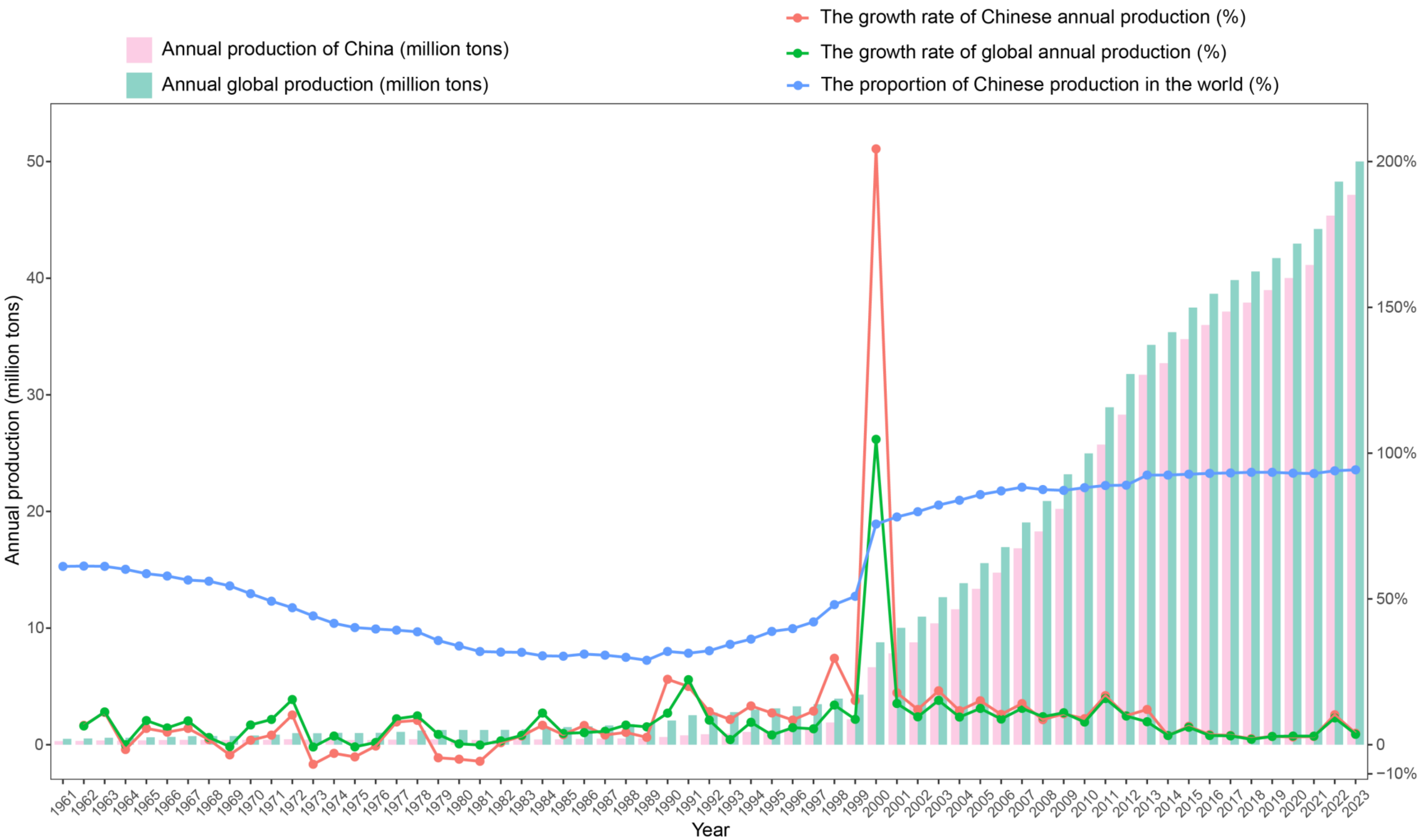

Figure 2 – Changes of edible fungi production in China and the world (data from FAOSTAT. Food and Agriculture Organization of the United Nations Statistic. 2024. Database: http://.fao.org/faostat/en/#data. Accessed 20 Dec 2024).

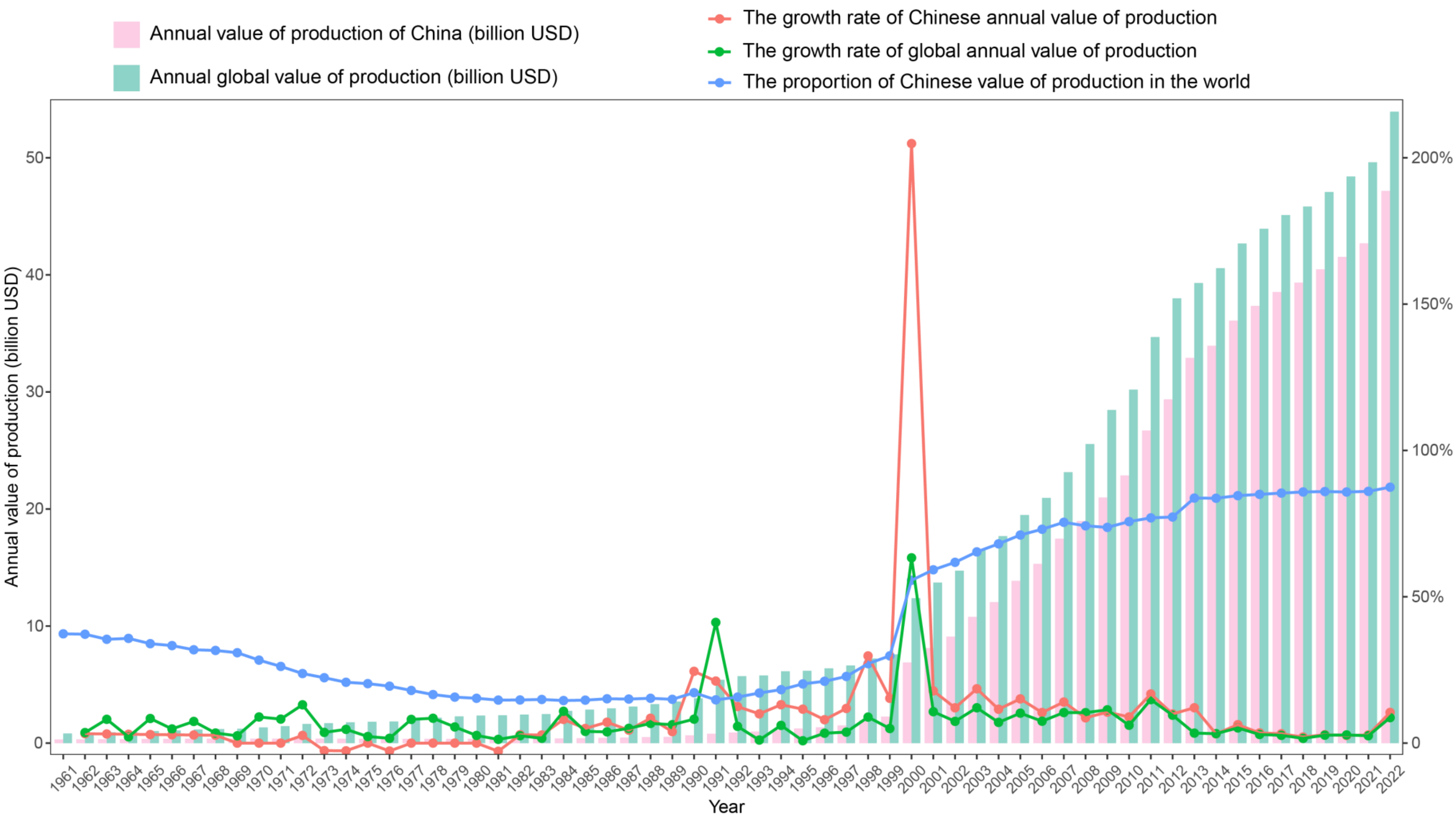

Figure 3 – Changes of value of edible fungi production in China and the world (data from FAOSTAT. Food and Agriculture Organization of the United Nations Statistic. 2024. Database: http://.fao.org/faostat/en/#data. Accessed 20 Dec 2024).

Figure 4 – Changes and prediction of edible fungi production in China. **a** Annual production and its growth rate of edible fungi in China. **b** Annual production value and its growth rate of edible fungi in China.

Rich edible mushroom species in the Chinese market

China has a diverse climatic environment and abundant edible fungi resources, allowing for the cultivation of various fungi that are adapted to different climates. The earliest cultivation records of edible fungi are mostly found in China (Zhang et al. 2015). With technological innovations from numerous research institutions, universities, and companies, new cultivation techniques and novel species of edible fungi continue to emerge. Currently, there are more than 30 common species of cultivated edible fungi in China (Fig. 5), and the annual production of 29 species exceeds 10 thousand tons (Table S1). Over the past decade, the number of edible fungi species with a certain cultivation scale has continued to increase (27 to 34), becoming common edible fungi in the market, with a CAGR of 2.51%. It is predicted that by 2030, the number of common edible fungi in China will increase from the current 34 to 40 (Fig. 6) (Table S1).

Bulk species

Seven species with an annual production exceeding 1 million tons are referred to as bulk species, and they are *Aga. bisporus*, *Aur. cornea*, *Aur. heimuer*, *F. filiformis*, *Len. edodes*, *Ple.*

eryngii, and *Ple. ostreatus*. These bulk species account for over 80% of China's annual edible fungi production (Table S1), with a CAGR of approximately 2.92% over the past decade. *Lentinula edodes* is the most productive species in China, and the production has exceeded 10 million tons since 2018. Production of *Len. edodes*, *Aur. cornea*, *Aur. heimuer*, *Ple. eryngii* and *Ple. ostreatus* have maintained stable growth in the recent decade, with CAGR of 1.30% to 7.19%, and with coefficient of variation (CV) of the annual production of 7.54% to 23.50% (Table 1, Fig. S1). While *Aga. bisporus* and *F. filiformis* have slightly decreased, with CAGR of -4.21% and -3.21%, and with CV of 29.30% and 11.69% (Table 1, Fig. S1). It is predicted that by 2030, the production of bulk species will reach 41.34 million tons (Fig. 7).

Rare species

Apart from the bulk species, other edible fungi are referred to as rare species (Dong et al. 2024). They are cultivated or wild edible species, and are increasingly favored by the market, becoming a new growth point in the edible fungi industry. Rare species are representing an increased proportion of annual edible fungi production from -8.52% in 2015 to 8.12% in 2023, the annual production of rare species accounted for 16.91% of China's annual edible fungi production in 2014, and it increased to 20.06% in 2023 (Table S1), with a CAGR of approximately 5.15% over the past decade.

There is a significant fluctuation in the CAGR of the recent decade and the CV of annual production among rare species. The production of *Agaricus subrufescens* Peck, *Cordyceps militaris* (L.) Fr., *Cyclocybe cylindracea* (DC.) Vizzini & Angelini complex, *Ganoderma* spp., *Gri. frondosa*, *Hericium* spp., *Hymenopellis raphanipes* (Berk.) R.H. Petersen, *Hyp. marmoreus*, *Lyophyllum decastes* (Fr.) Singer, *Morchella* spp., *Ophiocordyceps sinensis* (Berk.) G.H. Sung et al. *Phallus* spp., *Phlebopus portentosus* (Berk. & Broome) Boedijn, *Pleurotus citrinopileatus* Singer, *Pleurotus pulmonarius* (Fr.) Quél., *Russula vinosa* Lindblad, *Sanghuangporus* spp., *Stropharia rugosoannulata* Farl. ex Murrill, *Tre. fuciformis* and *Tricholoma matsutake* (S. Ito & S. Imai) Singer, *W. hoelen* have continuous growth in the recent decade with CAGR of 1.79% to 75.94% and CV of 5.25% to 121.42% (Table 1). It is worth noting that the production of *Hym. raphanipes*, *Lyo. decastes* and *Morchella* spp. increased visibly, with CAGR > 50% (Table 1), due to the significant progress that their cultivation technologies have made in the recent decade. While the production of *Coprinus comatus* (O.F. Müll.) Pers., *Macrocybe lobayensis* (R. Heim) Pegler & Lodge, *Pho. microspora*, *Pleurotus tuoliensis* (C.J. Mou) M.R. Zhao & Jin X. Zhang, *Sparassis latifolia* Y.C. Dai & Zheng Wang, *V. volvacea*, have consistently decreased, with CAGR of -35.30% to -1.66%, and with CV of 2.02% to 166.58% (Table 1). It is predicted that by 2030, the rare species will reach 12.03 million tons (Fig. 7).

Wild edible mushrooms

Wild edible mushrooms are extensively harvested and sold in China (Li & Xu 2022). China possesses over 1,000 species of wild edible mushrooms, approximately 300 of which are commercially traded, with an annual trade volume of 500,000 to 600,000 tons, accounting for approximately 2% of the edible fungi production (Jiang et al. 2025). In 2023, the output value of the wild edible mushroom trade was estimated at 25 to 30 billion RMB, representing 7% to 10% of the edible fungi production value (Jiang et al. 2025). Yunnan is one of the global biodiversity hotspots, and it nourishes a rich diversity of wild edible mushrooms (Zhang et al. 2021). Therefore, Yunnan Province has the richest wild edible mushroom resources (Fig. 8). Presently, over 70% of the wild edible fungi products in China come from Yunnan Province, making it the top region in terms of suitable areas, production volume, and production value. In 2022, the annual natural production of wild edible fungi in Yunnan Province exceeded 500,000 tons, with an annual trade volume of over 316,100 tons worth 25 billion RMB (https://global.chinadaily.com.cn/a/202307/25/WS64bf16bea31035260b81841d.html), which represents 6.43% of the Chinese edible mushroom output value in 2022. Based on rough statistics, Yunnan has more than 600 species of wild edible mushrooms, of which over 80% are mycorrhizal (Yu et al. 2020). Approximately 321 species of wild edible mushrooms are sold in the province, with 164 commonly traded on local markets (Yu et al. 2020). The "Four Famous Mushrooms" (*Boletus* spp., *Cantharellus cibarius* Fr., *Tri. matsutake*, and *Tuber melanosporum* Vittad.) account for over two-thirds of production in China and half of global production.

Diversity in production models of edible fungi in China

China's natural geographical conditions are diverse, and edible fungi species are extremely rich. The level of regional economic development varies significantly, resulting in a diversified production model for the edible fungi industry (Tian et al. 2024a). The agricultural production model has been inherited from ancient times and remains prevalent in the cultivation of certain edible fungi species with long growth cycles and low unit output (Bao et al. 2022c). This has led to the persistence of scattered household cultivation models. On this basis, a "Company + Farmer" production model has been widely developed in rural areas of China (Bao et al. 2022c). In this model, enterprises are responsible for the production process, including making mushroom sticks, inoculation, and fruiting, while farmers are solely responsible for mushroom management and harvesting. Afterward, the enterprises uniformly purchase the edible fungi. This model has expanded edible fungi production and sales beyond individual households, incorporating the participation of enterprises.

In the 1980s, mainland China began introducing factory production lines for *Aga. bisporus* and *F. filiformis*. Since then, the cultivation of edible fungi in factories in China has gradually increased (Ren et al. 2025). The factory cultivation model ensures a balanced market supply throughout the year, overcoming the impact of seasonal changes and climate variations at different latitudes. Since 2006, the proportion of factory cultivation in edible fungi production has continued to rise. The number of enterprises engaged in factory cultivation increased from 47 in 2006 to 788 in 2012, marking a 16-fold increase and reaching the highest level in history (Fig. 9). The rapid expansion led to intense market competition. Starting from 2013, the number of edible fungi production enterprises has experienced consecutive years of negative growth. By 2023, the number of edible fungi production enterprises had decreased to 316, a 59.90% reduction from the peak in 2012. However, competition has also driven the concentration of factory cultivation in China towards dominant enterprises, such as Junesun Fungi, Xuerong Biotechnology, Hunan Hualv Biotechnology, and Wanchen Biotechnology. The industry concentration has continuously increased over the past decade (Fig. 10). In the last ten years, the CAGR of annual production from the factory is 8.10%. The total output of edible fungi produced by the factory was 3.93 million tons in 2023, accounting for 9.07% of the annual output (Fig. 9). Currently, the species produced through factory cultivation in China mainly include *Aga. bisporus*, *F. filiformis*, *Hyp. marmoreus*, and *Ple. eryngii*, with fewer species compared to agricultural cultivation.

Figure 5 – Common Species of Edible Fungi in China. Bulk species: a-g. **a** *Lentinula edodes*. **b** *Auricularia heimuer*. **c** *Pleurotus ostreatus*. **d** *Auricularia cornea*. **e** *Flammulina filiformis*. **f** *Agaricus bisporus*. **g** *Pleurotus eryngii*. Rare species: h-p. **h** *Cyclocybe cylindracea*. **i** *Pholiota microspora*. **J-k** *Pleurotus pulmonarius*. **l** *Tremella fuciformis*. **m** *Volvariella volvacea*. **n** *Coprinus comatus*. **o** *Pleurotus tuoliensis*. **p** *Stropharia rugosoannulata*. Rare species: q-ai. **q** *Wolfiporia hoelen*. **r** *Ganoderma* spp. **s** *Phallus* spp. **t** *Agaricus subrufescens*. **u** *Phlebopus portentosus*. **v** *Cordyceps militaris*. **w** *Morchella* spp. **x** *Hericium erinaceus*. **y** *Grifola frondose*. **z** *Lyophyllum decastes*. **ab** *Oudemansiella raphanipes*. **ac** *Tricholoma matsutake*. **ad** *Pleurotus citrinopileatus*. **ac** *Russula vinosa*. **af** *Macrocybe lobayensis*. **ag** *Sparassis latifolia*. **ah** *Sanghuangporus vaninii*. **ai** *Ophiocordyceps sinensis* (pictures **o**, **t**, **ae**, **ai** come from web pages,
o: http://.bymushroom.com/?c=index&a=show&id=42;
t: https://.thepaper.cn/newsDetail_forward_9176934;
ae: https://baijiahao.baidu.com/s?id=1653879951839966330&wfr=spider&for=pc;
ai: http://food.hec.cn/).

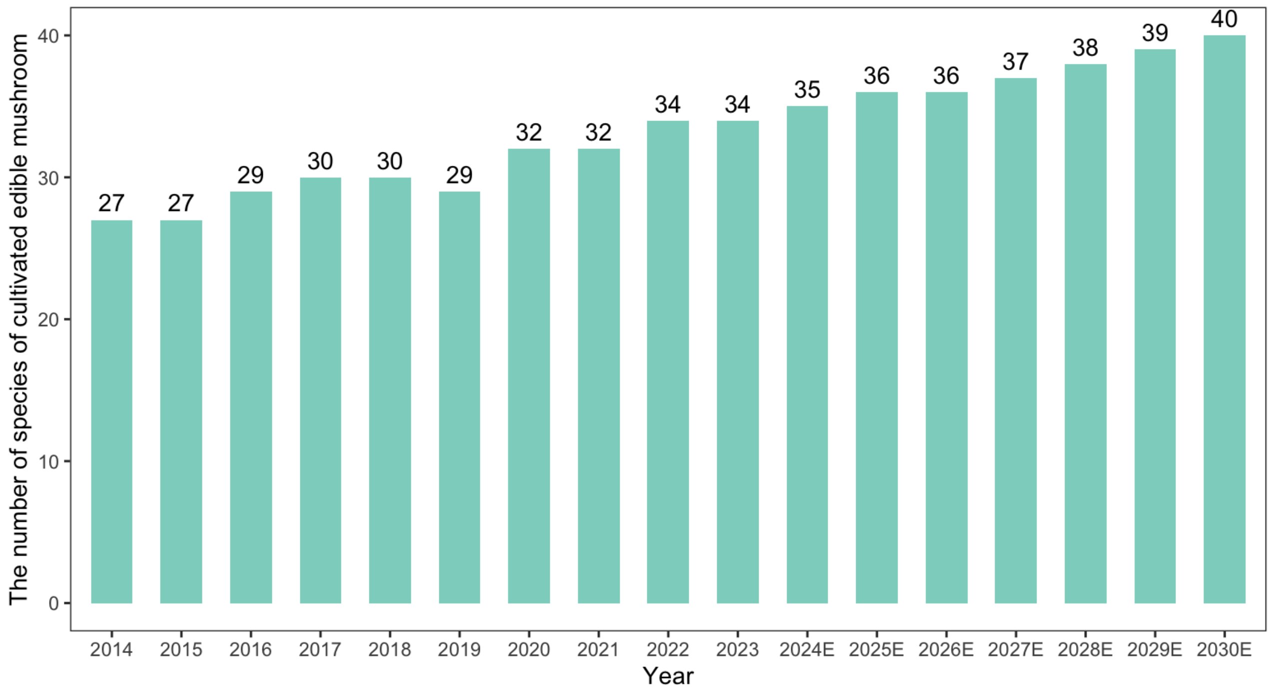

Figure 6 – Changes and prediction of species number of common edible fungi in China

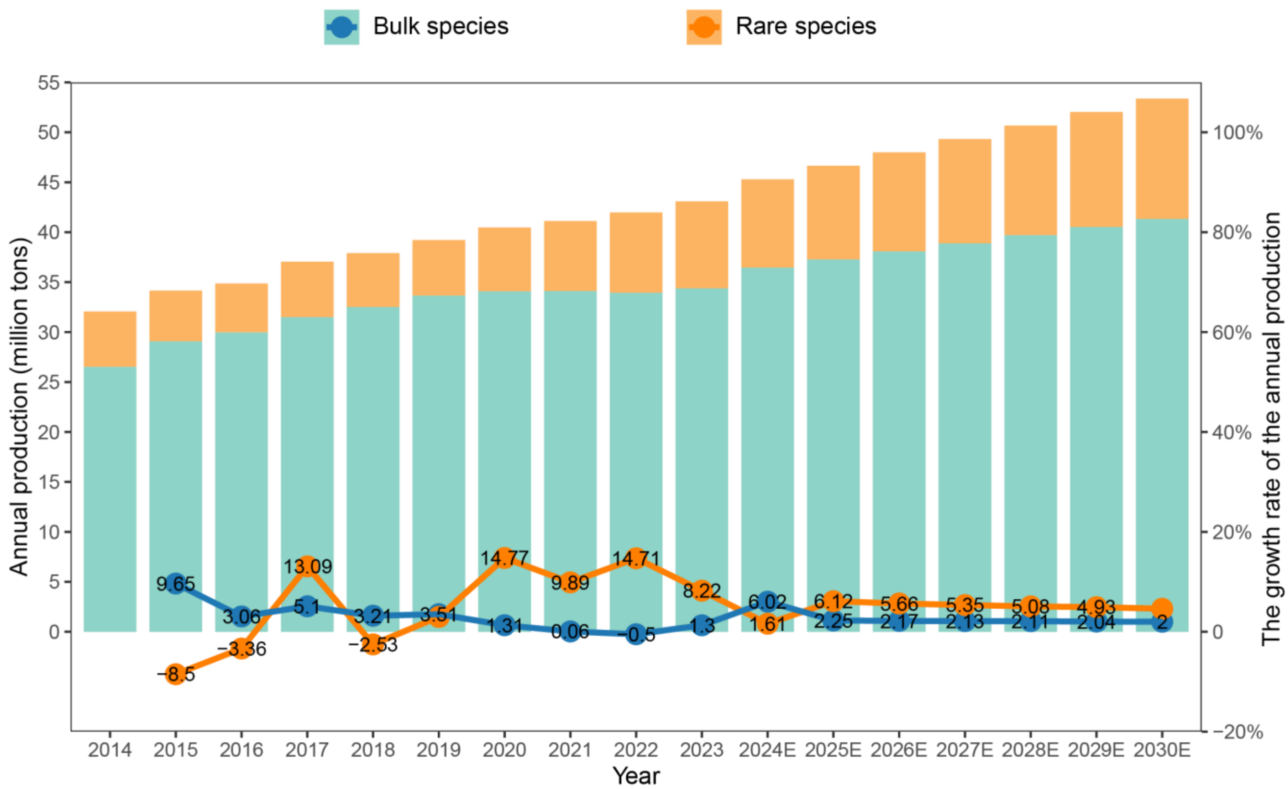

Figure 7 – Trends of annual production of each edible fungi type in China

Table 1 Statistics of edible fungi production in the recent decade (from 2014 to 2023).

Categories	Species	Compound annual growth rate, CAGR	Standard deviation, SD	Mean production ($\times 10^4$ ton)	Coefficient of variation, CV
Bulk species	*Agaricus bisporus*	-4.21%	68.82	234.92	29.30%
	Auricularia cornea	7.19%	38.18	196.36	19.44%
	Auricularia heimuer	2.36%	51.99	689.33	7.54%
	Flammulina filiformis	-3.21%	27.79	237.64	11.69%
	Lentinula edodes	6.04%	208.72	1066.29	19.57%
	Pleurotus eryngii	4.00%	39.15	166.6	23.50%
	Pleurotus ostreatus	1.30%	53.75	607.36	8.85%
Rare species	*Agaricus subrufescens*	5.45%	2.93	9	32.56%
	Coprinus comatus	-14.01%	5.95	14.69	40.54%
	Cordyceps militaris	23.01%	2.24	7.56	29.58%
	Cyclocybe cylindracea complex	2.04%	9.67	81.68	11.84%
	Ganoderma spp.	4.94%	4.7	16.5	28.50%
	Grifola frondosa	4.21%	1.06	3.34	31.75%
	Hericium spp.	1.79%	3.41	9.8	34.77%
	Hymenopellis raphanipes	66.00%	3.03	4.69	64.59%
	Hypsizygus marmoreus	19.79%	15.81	38.26	41.33%
	Lyophyllum decastes	75.94%	6.97	5.74	121.42%

Categories	Species	Compound annual growth rate, CAGR	Standard deviation, SD	Mean production ($\times 10^4$ ton)	Coefficient of variation, CV
	Macrocybe lobayensis	-35.30%	2.07	1.25	166.58%
	Morchella spp.	69.18%	10.42	8.8	118.47%
	Ophiocordyceps sinensis	40.4%	0	0.01	56.76%
	Phallus spp.	15.38%	8.18	17.08	47.89%
	Phlebopus portentosus	16.37%	3.92	8.08	48.54%
	Pholiota microspora	-1.66%	4.78	61.33	7.79%
	Pleurotus citrinopileatus	46.52%	3.88	3.81	101.90%
Rare species	*Pleurotus pulmonarius*	7.16%	14.92	44.41	33.61%
	Pleurotus tuoliensis	-15.12%	2.85	6.42	44.33%
	Russula vinosa	3.99%	0.06	0.38	14.94%
	Sanghuangporus spp.	7.72%	0	0.06	5.25%
	Sparassis latifolia	-2.82%	0.01	0.7	2.02%
	Stropharia rugosoannulata	28.25%	16.51	16.84	98.03%
	Tremella fuciformis	3.31%	4.67	52	8.98%
	Tricholoma matsutake	12.98%	0.81	1.1	74.01%
	Volvariella volvacea	-3.06%	2.23	22.54	9.91%
	Wolfiporia hoelen	20.89%	9.34	18.21	51.31%

Figure 8 – Mushuihua wild edible mushroom market in Kunming, Yunnan (Image source: https://.yunnan.cn/). **a-d** The scene of Yunnan Mushuihua wild edible mushroom market. **e** *Russula virescens* (Schaeff.) Fr. **f** *Termitomyces* spp. **g** *Tricholoma matsutake*. **h** *Thelephora* spp.

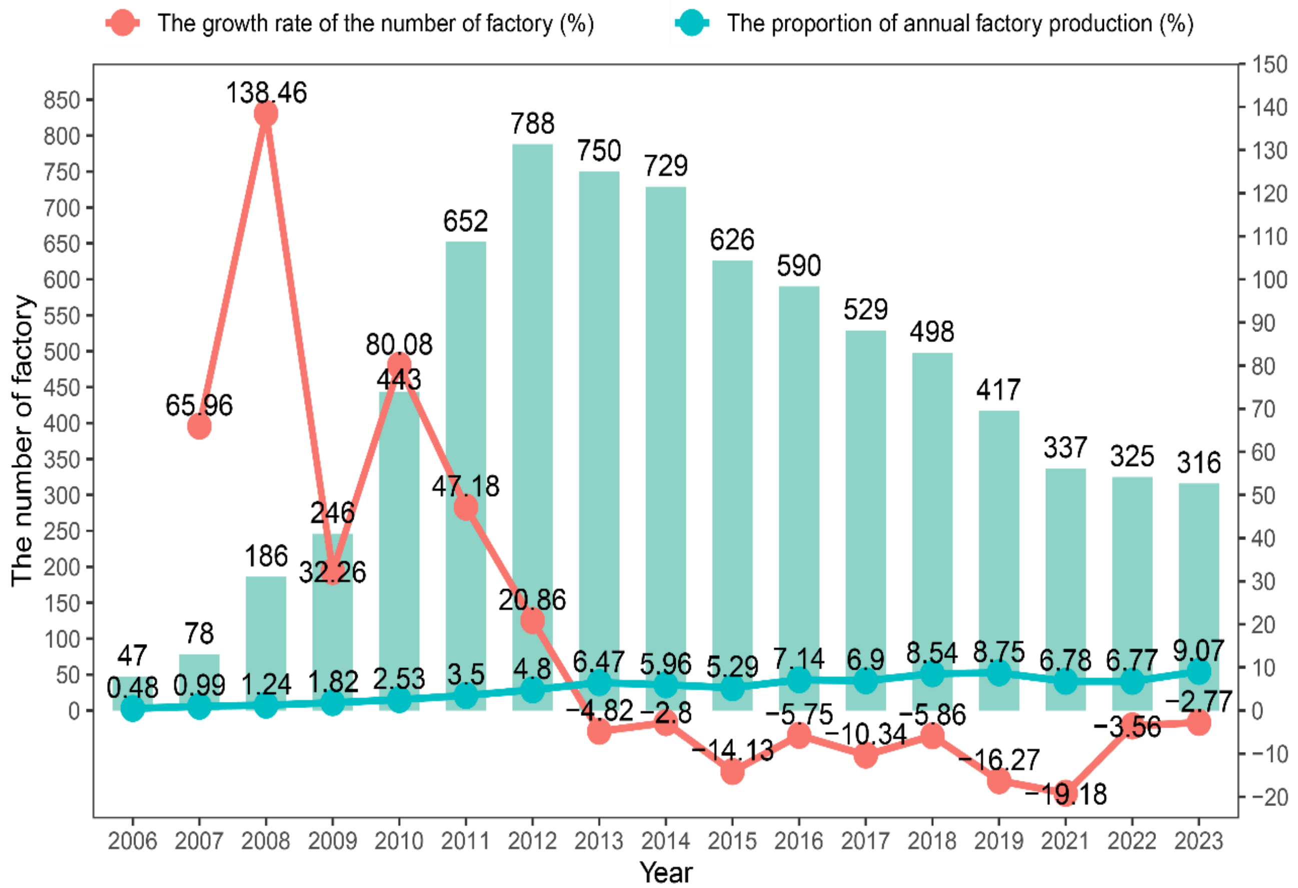

Figure 9 – Factory Cultivation of Edible Fungi in China

The transition from scattered household cultivation to cooperative production involving "Company + Farmer" coupled with the development of park-like, large-scale, and industrialized cultivation, has steered China's edible fungi industry towards cluster development (Tan 2024). From the supply of raw materials, incubation of mushroom spawns, production of mushroom bags, cultivation of mushrooms, to the initial processing, deep processing, transportation, storage, and sales of edible fungi, a full industrial chain system has been established based on the factory production model. Different production or sales entities, including growers, cooperatives, processing plants, and distributors, share the responsibilities of each link in a sophisticated and specialized manner. The distribution of the edible fungi industry in China spans the entire country, with edible fungi being produced in both mountainous and plain areas. According to local climate and resource characteristics, the edible fungi industry in China exhibits a belt-like distribution pattern. For example, the northeastern provinces (Heilongjiang, Jilin, and Liaoning Province), the central province (Henan and Hubei Province), and the coastal areas (Shandong and Zhejiang Province) have formed a *Aur. heimuer* industry belt; the northeast province (Liaoning Province), the northern province (the northeastern part of Hebei Province), the central provinces (Henan and Hubei Province), and the coastal areas (Shandong and Zhejiang Province) have formed a *Len. edodes* industry belt; the southwest provinces (Sichuan, Chongqing, Guizhou, and Yunnan Province), the central provinces (Hubei and Henan Province), and the northern provinces (Shandong and Hebei Province) have formed a *Morchella* spp. cultivation industry belt.

Figure 10 – Factory cultivation of edible fungi in China. **a-b** Edible fungi production factory. **c** Spawn incubation. **d** Mushroom formation. **e** Mushroom packaging. (Image sources: **a:** http://.yuguanchina.com/about.asp?bid=21&sid=64; **b:** http://.tszxjy.cn/Home/Mainbusiness).

Diversity in cultivation methods of edible fungi in China

China cultivates a wide variety of edible fungi, employing a diverse range of cultivation methods. Edible fungi cultivation requires a comprehensive consideration of factors, such as local cultivation history, sources of cultivation substrates, climatic conditions, labor availability and composition, local consumption habits, and the distance between cultivation sites and markets. The main steps of edible fungi cultivation include selecting species and cultivars that are suitable for the region, preparing high-quality spawn, using appropriate cultivation substrates and production techniques, preparing suitable production sites, creating favorable growth conditions, harvesting timely, and providing storage, transportation, and fresh-keeping processing conditions (Fig. 11) (Tan 2024).

Edible fungi can be divided into saprobic, parasitic, and symbiotic based on their nutritional methods, with saprobic fungi being the most prevalent in production. These can be further classified into straw-rotting fungi, which use crop straw as their main substrate and include *Aga. bisporus*, *Cop. comatus*, *Phallus* spp., *Str. rugosoannulata* and *V. volvacea*, and wood-rotting fungi, which primarily use wood as substrates and include species such as *Auricularia* spp., *Ganoderma* spp., *Len. edodes*, *Pleurotus* spp.

Figure 11 – The main steps of edible fungi cultivation in China.

Preparation of spawn

The edible fungi industry is developing rapidly, and mushroom spawn, considered the "chip" of the industry, plays an increasingly important role in mushroom production (Sun et al. 2023). Spawns are fundamental to the cultivation of edible fungi, with their quality directly impacting yield and quality, potentially determining the success or failure of production (Huang 2006, Chen et al. 2013, Yue et al. 2020). There is a three-level spawn subculture system in Chinese edible fungi production, classifying spawn into mother culture (the first generation, G1), stock culture (the second generation, G2), and spawn (the third generation, G3) based on their sources, generations, and production purpose. This system not only increases the quantity of strain to meet production needs but also enhances adaptability to cultivation substrates (Li & Kang 2017, Bian 2020). This system can effectively control strain quality and purity, reduce contamination and strain degeneration, and ensure the well development of the edible fungi industry.

Preparation of mother culture. Mother cultures can be obtained by tissue isolation or spore isolation from the mushroom fruit body. They exhibit strong genetic stability, predominantly using potato dextrose agar medium to facilitate the observation of growth and the detection of pests or mildew infestations. Mother cultures can be prepared in slant or Petri plates.

Preparation of stock culture. Based on the physical state of the medium, stock culture can be classified into solid culture, liquid culture, and reductive liquid culture (Li & Kang 2017, Bian 2020).

Preparation of solid culture. Solid culture is prepared on solid medium, commonly using wheat grain, wood chips, sawdust, or cottonseed hulls in production. The choice of medium depends on the edible fungi species. Wood-rotting species with strong lignin decomposition abilities typically use a medium of wheat grain, wooden chips, and sawdust, while those adept at decomposing cellulose often use a medium of cottonseed hulls. Straw-rotting species generally utilize wheat grain medium (Li & Kang 2017, Bian 2020).

Wheat grain medium is suitable for producing stock cultures of various edible fungi, especially *Aga. bisporus* cultivation. In this medium, the mycelia grow quickly, and any unused nutrients can continue to nourish the mycelia in cultivated substrates, thereby shortening the cultivation cycle. To prepare wheat grain medium, firstly good quality wheat grains free from pest or mildew are selected, secondly wheat grains are boiled in clean water for 20–30 minutes until the wheat grains lack white cores, thirdly the wheat grains are spread out to dry the surface moisture, fourthly $CaCO_3$, $CaSO_4$ and other additives are added to the wheat grains and mix well, next wheat grains are placed in clean polypropylene bags or bottles, finally they are sterilized in wheat grain bags or bottles autoclaved at 121℃ for 2.5–3 hours. After the wheat grain bags or bottles are cooled, they are transferred to an inoculation chamber to inoculate the mother culture. Wheat grain spawn should be used as soon as the mycelia have fully grown to avoid strain degeneration (Wu et al. 2018a, Xu et al. 2023).

Wood chip medium is suitable for cultivating various species and cultivars of wood-rotting fungi, offering advantages such as high inoculum efficiency, rapid mycelial growth, and low contamination rates. Mycelia from wooden chip medium spread radially in cultivation bags, resulting in short germination times and synchronized fruiting. However, it may not be suitable for fungi species with vigorous aerial mycelia, as wooden chips can stick together, which can affect inoculation speed. To prepare the wooden chip medium, first, broadleaf trees with straight grain and loose texture, or disposable chopsticks or popsicle sticks, can be selected as wooden chips. These are typically 3–10 mm in diameter and 12–15 cm long, depending on the wood type and bag size. Secondly, wooden chips should be soaked in lime water for at least 24 hours to achieve about 60% moisture, then boiled in 1% sugar water for 30 minutes. Thirdly, additives should be mixed well to support mycelial growth. Fourthly, the bottom of the bags should be shaped into squares. Additives are added to the bottom, approximately 0.5–1 cm thick. Wooden chips are placed in the bags vertically, and additives are used to fill the gap and the top of each bag. The bags are then autoclaved. After 7–10 days, when the mycelia have fully grown and are abundant and vigorous, they are ideal for production (Zheng & Yao 2012, Duan et al. 2013, Meng 2019).

Sawdust medium is suitable for wood-rotting fungi but requires longer cultivation and yields less mycelia, making it cumbersome for industrial use (Huang 2014). For sawdust medium preparation, first, soluble additives like gypsum should be dissolved in water. Then, the mixture is mixed well with sawdust. Next, the mixture is piled for about 2 hours, until the water seeps but does not drip when squeezed. For cottonseed hull medium preparation, firstly, cottonseed hull and additives are mixed well, and the moisture is adjusted to 70%–75%; then the piles are turned at 70°C every 3–4 days, fermenting for 15–18 days until actinomycetes appear. When sawdust medium or cottonseed hull medium fills the bags or bottles, a 1.5–2 cm stick is inserted for inoculation. Finally, the medium is sterilized with autoclave steam for 1.5 to 2 hours.

Preparation of liquid culture. Liquid culture has distinct advantages in industrial production, offering rapid mycelial germination and shorter production cycles after inoculation, thereby overcoming the asynchronous germination issues associated with solid culture. Liquid culture can be inoculated by machines, which significantly boosts production efficiency. However, it requires higher initial investments and involves more complex operational techniques, presenting greater risks in production.

Liquid culture includes shake flask and fermenter inoculum. For shake flask inoculum, a liquid medium is prepared according to an optimized formula. Then, 200 mL of the liquid medium and glass beads are dispensed into 500 mL Erlenmeyer flasks, and the medium is autoclaved for 30 minutes. Mother cultures are aseptically inoculated into the liquid medium, and then the medium is shaken for a week until a large number of mycelia pellets are suspended in it. The medium is clear and emits a mushroom aroma (Li 2003).

For fermenter culture, fermenters should be cleaned and sterilized before use, then liquid medium and antifoaming agents are added to the fermenters, and the fermenters are autoclaved for 45 minutes. Liquid culture should be inoculated in a sterile environment, with the temperature maintained by circulating water, and synchronized mycelia pellet growth ensured through moderate stirring. Regular sampling ensures the quality of the fermentation in the liquid culture during culturing. Most edible fungi species reach optimal mycelial activity after 7 days of suitable cultivation. Once contamination-free, we should transfer the fermenters to the inoculation chamber and connect them to the sterilized equipment for further inoculation (Li 2024).

Preparation of reverting liquid culture. The reverting liquid culture combines the advantages of solid culture and liquid culture. It is produced by specialized companies through liquid-submerged fermentation to obtain mycelia, which are then filtered, crushed, and solidified into concentrated mycelia blocks. In production, these mycelia blocks are crushed and diluted with sterile water to revert to liquid culture for inoculation. This method provides highly active and stable mycelia, overcoming the transportation and storage challenges associated with traditional liquid culture. Additionally, the reverting liquid culture contains minimal nutrients, which greatly reduces contamination, and has been effectively used in *F. filiformis, Ple. eryngii,* and *Aga. bisporus* with excellent results (Xu et al. 2016, Li et al. 2021).

Reverting liquid culture, 40 g can be inoculated into 10,000 cultivation bottles. When inoculating, the mycelia blocks are aseptically weighed according to the actual production plan, then placed in a blender, and sterile water is added to crush the mycelia. Then the mixture is added to a large tank filled with sterile water to dilute the mycelia, and the liquid culture can be connected to sterilized equipment for inoculation (Xu et al. 2016).

Preparation of spawn. When the actual production scale is large, it is necessary to prepare spawn, which is used in significant quantities and is not suitable for long-term storage. Production planning must consider the season and scale to determine the timing and quantity of spawn. Spawn is produced by inoculating the stock culture into the same or a similar medium for expanded cultivation. The medium formula can be exactly the same as the stock culture, or adjusted by increasing the main substrates and reducing the additives. Spawn can only be used for inoculating cultivation bags, bottles, or mushroom beds, and cannot be reused for expanding spawn cultivation (Li & Kang 2017, Bian 2020). Common media used in spawn cultivation include wooden chips, wheat grain, cottonseed hull, sawdust, and liquid media.

Cultivation techniques of edible fungi

Cultivation techniques of straw-rotting fungi

The cultivation techniques for different species of fungi that rot straw are similar. They primarily involve substrate preparation, sowing, and mycelial growth management, casing and soil layer management, fruiting body management, harvesting, and control of pest or mildew infestations.

Preparation of substrates. The substrates primarily consist of crop straw, livestock and poultry manure, organic and inorganic nitrogen sources, and mineral fertilizers mixed at a specific carbon-to-nitrogen ratio (C/N ratio). Usable crop straw includes rice straw, wheat straw, corn straw, oat straw, rapeseed stalk, peanut vine, corn cob, and bagasse. These ingredients must be dry and free from mildew; cut and crushed straw can aid in water absorption, fermentation, and enhance the substrate's physical properties (Zhang et al. 2014). Livestock and poultry manure, such as horse, cow, and chicken manure, should be collected in advance, dried, crushed, and stored properly (Zhang et al. 2014). Organic nitrogen sources, such as soybean meal, peanut meal, cottonseed meal powder, rapeseed meal, brewery waste, and wheat bran, should all be dried and free from mildew before use (Zhang et al. 2014). Inorganic nitrogen sources and mineral fertilizers, such as urea, ammonium sulfate, ammonium bicarbonate, superphosphate, gypsum, calcium carbonate, and slaked lime (also known as lime), should be stored in cool, well-ventilated, and dry conditions (Zhang et al. 2014).

The substrate preparation process begins with pre-wetting the ingredients. Crop straw can be soaked in water with 1% lime for 1–2 hours, then drained to achieve a moisture content of 60%–65% (Zhang et al. 2014). Livestock and poultry manure should be sprayed with a 0.5% dichlorvos solution, covered for 24 hours to remove pests and mites, and then adjusted to a moisture content of approximately 55% with clean water (Zhang et al. 2014). Then, the pre-wetted straw, livestock and poultry manure, and organic nitrogen additives should be mixed well for fermentation or high-temperature sterilization. Fermentation can be conducted using tunnel secondary fermentation or pile fermentation methods to produce compost. For the tunnel secondary fermentation, which is used for *Aga. bisporus*, the processes involve fermenting at 50–75°C for 13 days; turning the pile when the temperature reaches 75°C, repeating 3–4 times; then pasteurizing with hot air at 56.5°C for 10 hours; and finally fermenting at 48–52°C for 7 days until the compost turns brown or coffee-colored (Liang et al. 2024). For the pile fermentation, the processes involve choosing a high, flat site; disinfecting the area with lime powder or 3%–5% lime water before piling; building a pile with 1.8 m wide and 1.5 m high; fermenting for 14–18 days with pile temperatures reaching 70°C–75°C, usually turning the pile 4–5 times, adjusting temperature, moisture, and pH as needed. After successful fermentation, the compost will be dark brown with a large amount of white actinomycetes produced. *Stropharia rugosoannulata* and *V. volvacea*, which have strong lignocellulose decomposition capabilities, can be cultivated directly using high-temperature sterile substrates. The mixed substrate is packed into polypropylene bags, which are then stacked in a sterilization device for high-temperature sterilization, usually using atmospheric pressure to quickly raise the temperature to 100°C and maintain it for 12 hours; if using high-pressure steam sterilization, maintain it for 4–6 hours (Huang et al. 2024).

Inoculation and mycelia growth management. In fermented substrate cultivation, initially, fermented substrates should be spread evenly over the surface in indoor bed-frame or outdoor irrigation bays/furrows, with a layer thickness of 20–25 cm; then the stock culture or spawn is evenly distributed through broadcasting or a combination of hole seeding and broadcasting; after sowing, the surface should be covered with a layer of disinfected plastic film to maintain temperature and moisture. In mature substrate cultivation, the stock culture or spawn is directly inoculated into the cultivation bags.

During the mycelia growth phase, the indoor relative humidity should be maintained at 70%–80% and the moisture content of the substrate should be maintained at 65%–70%. When the mycelia grow to 2/3 of the substrate layer or approach the bottom, the surface should be covered with soil.

Casing soil and management of mycelia growth in the soil layer. The properties of the soil directly affect mushroom fruiting and yield. Peat soil, known for its strong water retention, remaining loose and non-cohesive when moist, is the ideal casing material in mushroom production. Before casing soil, the pH of the soil should be adjusted to 7–7.6 using calcium carbonate. The soil can then be sterilized using methods such as sun exposure, pasteurization, or formaldehyde disinfection. When casing soil, the thickness of the soil is 2–3 cm and is evenly distributed. Under conditions of appropriate humidity, temperature, and ventilation, the mycelia gradually grow towards the soil surface. When the mycelia approach the soil surface, due to nutritional gradients and temperature differences, they transition from vegetative growth to reproductive growth (Tan 2024), marking the beginning of the mushroom primordia formation and fruiting body development period.

Fruiting management. In the fruiting management stage, it is crucial to focus on regulating moisture, ensuring adequate ventilation, controlling temperature, and adjusting light levels. For *Aga. bisporus*, this stage also involves scratching the mycelia and reducing the temperature to stimulate fruit body formation. Primordia form when white structures, about the size of millet grains, appear on the mycelia branches. Initially, these primordia resemble white soybean-sized grains, and young fruiting bodies often have nipple-like protrusions, growing in clusters or groups, with a few solitary ones. The fruit body stage requires a lot of oxygen and moisture, so the air relative humidity should be kept at 90%–95%. However, it is necessary to avoid spraying water directly on young mushrooms; instead, spraying upwards into the space and pouring water on the floor to help cool the environment.

Harvesting. As the mushroom grows, it is crucial to strictly control the harvesting time; it is best to harvest the mushroom before the cap opens. Once the fruit body opens or the gills turn black, it loses commercial value. The harvested mushrooms should have the dirt and sand removed from their stems, and should be promptly sold on the market or stored in cold rooms for fresh sale.

Pest or mildew infestation control. Pest and mildew prevention should be prioritized, and strict adherence to operational requirements is required during the production process. Raw materials must be kept dry, free from mildew, and pest-free. Cultivation substrates must be thoroughly sterilized, and the facilities must be clean and disinfected using bleaching powder. During inoculation, strict aseptic techniques or inoculation box procedures must be followed, and any unqualified spawn should be promptly discarded. If contamination by pest or mildew is detected during the mycelia growth or fruiting period, the contaminated cultivation bags must be promptly removed from the cultivation area.

Cultivation techniques of wood-rotting fungi

Cultivation of wood-rotting fungi typically employs log cultivation and substitute cultivation methods. Log cultivation utilizes broadleaf trees, such as oak, beech, and chestnut, to grow edible fungi. The main processes involved include log preparation, drilling and inoculation, mycelial growth management, fruiting management, and harvesting. This method leverages the natural environment, requiring minimal facility investment, and produces products of high quality, ensuring natural-like quality. However, it is prone to contamination by other fungi, with uncertain harvesting times, yields, and quality, leading to low cultivation efficiency.

Substitute cultivation utilizes agricultural by-products, such as sawdust, cottonseed hulls, and corncobs, as primary materials, supplemented by wheat bran, rice bran, and gypsum, to produce a cultivation substrate that replaces wood. The main processes include substrate preparation (mixing, pre-wetting, and sterilization), inoculation, mycelial growth management, fruiting body management, and harvesting. This technology has transformed the production of traditional wood-rotting fungi by utilizing machinery and industrial methods to create cultivation bags, replacing logs with agricultural byproducts. This method has significantly reduced wood consumption, offering cost savings, labor and time efficiency, simplicity in operation, stable production, and high efficiency.

Log cultivation. Preparation of logs: Firstly, it is crucial to select suitable broadleaf tree species for the specific edible fungi species. Then, the broadleaf tree should be felled, lopped, cut, and dried. The logs are typically 8–12 cm in diameter and about 1 meter long. They are ready for inoculation when dried to a moisture content of 37%–40%.

Drilling and inoculation: Inoculation holes in the logs are created using electric drills, typically spaced 8–10 cm apart in rows 6–8 cm apart. Each hole has a diameter of 1–1.2 cm and a depth of 1.5–2 cm. Inoculation should be done at around 20°C in the spring to facilitate mycelia growth. During inoculation, the spawn is quickly filled into the inoculation holes, compacted slightly, and the holes are covered with either bark or a mix of paraffin, rosin, and lard. The process involves simultaneous drilling and inoculation, followed by immediate stacking to promote mycelia growth.

Mycelia growth management: The inoculated logs are stacked to a height of 1.2–1.5 meters, then covered with straw or plastic film to maintain air humidity at 65%–70% and a temperature of 27–28°C, until the mycelia spread from the inoculation holes and the wood tissue turns a yellow-brown color.

Fruiting management and harvesting: Fully fermented logs should be relocated to a higher and cooler area, such as a greenhouse or forestland, and placed on the ground or buried in soil. They should be kept away from direct sunlight and rain. With significant stimulation of temperature variations, mechanical and light, and along with sufficient moisture, the mycelia shift from vegetative growth to reproductive growth, forming primordia. Fruiting bodies should be harvested once they appear. Following winter management, a second batch of fruiting bodies may appear the following year under suitable conditions.

Substitute Cultivation. Preparation of substitute substrates: The suitable agricultural by-products are selected based on the growth characteristics of edible fungi species. Agricultural by-products, such as mixed sawdust, cottonseed hulls, and corncobs which are primary substrates, and additives are added in appropriate ratios. After the ingredients are mixed well, the moisture content is adjusted to 55%–65% using clean water, and the mixture is then packed into plastic containers (either bottles or bags). Different species usually use different containers in production, for instance, *F. filiformis* and *Hyp. marmoreus* use bottles, while *Len. edodes*, *Auricularia* spp., and *Pleurotus* spp. use bags. The substitute substrates are then sterilized using either high-pressure or atmospheric steam.

Inoculation: After the substitute substrate has cooled, the spawns are inoculated, and then the cultivated containers are transferred to a sterilized culture chamber for mycelial growth.

Mycelia growth management: The mycelia are grown between 25°C and 29°C, and a relative humidity of approximately 70%. The culture chamber should have some scattered light, avoiding direct sunlight that is too strong. Proper ventilation is essential during the late stages of mycelial growth. Under these conditions, the mycelia generally colonize the entire cultivation substrates in about 20–25 days, with some even beginning to form primordia on the surface.

Fruiting management and harvesting: When primordia appear or the cultivation substrates are fully colonized by mycelia, the containers can be opened and moved to a suitable fruiting environment. The cultivated bottles can be laid horizontally or placed upright on the ground or on racks for fruiting. Cultivated bags can be placed horizontally on racks for fruiting at both ends, vertically on racks, or stacked into a wall-type for fruiting at both ends. Different edible fungi species require different cultivation methods, such as ground cultivation and shelf cultivation for *Len. edodes*, outdoor cultivation and hanging bag cultivation for *Auricularia* spp., wall-type cultivation and grid rack cultivation for *Pleurotus* spp., and casing soil cultivation for *Ganoderma* spp., *Gri. frondosa* and *Hym. raphanipes* (Tan 2024). During the fruiting body growth stage, it is crucial to control temperature, humidity, air circulation, and light, and to harvest the fruiting bodies promptly once they are mature.

Twenty-four rapidly expanding species produced in China in the past ten years

China cultivates a wide variety of edible fungi, employing a diverse range of cultivation methods. Depending on the nutritional needs of edible fungi, the primary cultivation methods are log cultivation, substitute cultivation, and compost cultivation. Substitute cultivation utilizes straw or wood chips, nutrients, and growth promoters to cultivate edible fungi, employing specific culture formulations tailored to each species. Substitute cultivation technology has revolutionized traditional production, utilizing modern machinery and industrial techniques to produce mushroom bags (sticks), replacing log cultivation and significantly reducing wood consumption. This approach provides energy efficiency, labor savings, time efficiency, simple operation, and stable high yields. Compost cultivation uses the fermentation of straw, animal manure, and soil to grow

Aga. bisporus, *Aga. subrufescens*, *V. volvacea*, and more. According to the cultivation environment, it can be categorized into indoor cultivation (greenhouse, factory), outdoor cultivation, and understory cultivation. A concise overview of the development status and main cultivation methods of edible fungi in China is introduced as follows.

Auricularia spp.

As a medicinal and edible fungus, *Auricularia* spp. have been developed and utilized in China for over 1,000 years. There are approximately 37 species of the genus *Auricularia* worldwide, with 14 species identified in China (Wu et al. 2021). The two main cultivated species in China are *Aur. heimuer* and *Aur. cornea*, and Jilin Agricultural University in China has bred a white variant of *Aur. cornea*, named “White Wood Ear” (Fig. 12) (Wu and Dai 2015, Dai and Yang 2018, Tian et al. 2024b). Early artificial cultivation of *Auricularia* spp. mainly involved log cultivation. Nowadays, they are mainly cultivated using substitute materials during natural seasons, with the main methods being outdoor and greenhouse cultivation (Fig. 12). The yield and quality of *Auricularia* spp. using substrate cultivation can be improved through substrate optimization; it is reported that the yield of *Aur. heimuer* using substitute cultivation is 8 - 14 times higher than that of log cultivation (Nie et al. 2007), and the content of various nutrients of *Auricularia* spp. by substitute cultivation is usually higher than that of log cultivation (Li et al. 2018, Ye et al. 2023, Li et al. 2025). *Auricularia* spp. had a production exceeding 9.97 million tons in China in 2023. The production of *Aur. heimuer* in China accounts for over 90% of the world’s total, with main production areas in Heilongjiang and Jilin provinces. *Auricularia cornea* is mainly distributed in Sichuan and Hebei provinces in China and is a major edible fungus in tropical and subtropical areas. Currently, *Aur. cornea* “White Wood Ear” has achieved large-scale production standards in Liaoning and Jilin provinces, due to large of studies about breeding of excellent strains (Ren et al. 2018, Khan et al. 2020, Khan et al. 2023), advances pertaining to cultivation technologies such as substrate composition, hanging bag production, cultivation management and pest control (Tan et al. 2018, Han 2023). Also, research on nutritional components has shown that *Aur. cornea* “White Wood Ear” is rich in protein and various vitamins; its nutritional value and taste are far superior to those of *Aur. cornea* (Yao et al. 2018, Tian et al. 2024b).

Coprinus comatus

Since the 1960s, Europe has successfully domesticated wild *Cop. comatus* using fermented compost, leading to large-scale commercial cultivation. *Coprinus comatus* was artificially cultivated in China since the 1980s, typically using compost and casing soil, which can be done in a greenhouse or understory (Fig. 13). The fruitbodies of *Cop. comatus* mature quickly and are prone to self-dissolution; they are difficult to preserve at room temperature (Jia & Liu 2006). Research has shown that cap autolysis is triggered by enzymatic reactions after the fruit bodies mature, and this process is regulated by the temperature and humidity during postharvest preservation (Guo et al. 2022). In 2023, the annual production of *Cop. comatus* was 61,398 tons in China, with the main production areas in Fujian, Shandong, and Sichuan provinces.

Cordyceps militaris

Cordyceps militaris is a fungus that parasitizes the pupae of certain insects, using the insect tissues as nutrients and spreading throughout the entire insect body. The mycelium of *Cor. militaris* can also secrete toxins that eventually cause the insect to become rigid and die. When environmental conditions are favorable, the mycelium inside the insect will emerge from the insect's openings or soft parts, growing into rod-shaped stroma and sexual fruiting bodies. These structures appear like grass growing from the pupa but are actually a complex of *Cor. militaris* and the insect pupa. Some active ingredients and pharmacological effects of *Cor. militaris* are similar to or even surpass those of *Cor. militaris*. It can be used as a substitute for *Cor. militaris* and has significant development and utilization value. *Cordyceps militaris* was domesticated in China since the 1980s, and achieved artificial cultivation in the 1990s (Dong et al. 2024). China is the first country to commercialize the cultivation and production of *Cor. militaris*. Currently, there are two main cultivation methods: The first method is a semi-artificial cultivation mode using silkworm pupae as the culture medium. In this mode, liquid *Cor. militaris* strains are injected or sprayed onto live silkworm pupae, and fruiting bodies are obtained through artificial cultivation. The second cultivation method is artificial substitute cultivation, where the strains are inoculated onto a solid culture substrate (with raw materials such as rice, wheat, and silkworm pupa powder) and cultivated under suitable light and temperature-humidity conditions to obtain the fruiting bodies of *Cor. militaris*. This method can utilize containers such as plastic pots and canning jars for factory production (Fig. 14). The production of *Cor. militaris* in China reached 94,756 tons in 2023, with the main production areas currently being Inner Mongolia, Liaoning, and Guangdong provinces.

Figure 12 – *Auricularia* spp. cultivation. **a** Outdoor log cultivation of *Aur. heimuer*. **b** Outdoor substitute cultivation of *Aur. heimuer*. **c-d** Substitute cultivation of *Aur. cornea* "White Wood Ear" in the greenhouse.

Figure 13 – *Coprinus comatus* cultivation. **a-b** Compost cultivation with casing soil in a greenhouse. **c** Understory cultivation.

***Cyclocybe cylindracea* complex**

The Tea Tree Mushroom is known as cha shu gu in China and yanagi matsutake in Japan, and is primarily grown in temperate and subtropical regions, including the temperate areas of Asia, Europe, and the southeastern United States. The Tea Tree Mushroom was first successfully domesticated and cultivated in Europe in the 1950s, and substitute cultivated in China in the early 1980s (Dong et al. 2024). In taxonomy, the Tea Tree Mushroom forms a *Cyc. cylindracea* complex, comprising four species: *Cyclocybe aegerita* (V. Brig.) Vizzini, *Cyc. cylindracea*, *Cyclocybe salicaceicola* (Zhu L. Yang, M. Zang & X.X. Liu) Vizzini, and *Cyclocybe chaxingu* (N.L. Huang) Q.M. Liu, Yang Gao & D.M. Hu (= *Agrocybe chaxingu* N.L. Huang), and the main species cultivated in China is *Cyc. chaxingu* currently (Liu et al. 2021a). The production method for Tea Tree Mushroom predominantly involves seasonal substitute cultivation by farmers, with cultivation methods including indoor bag cultivation (Fig. 15) and outdoor bag removal with soil covering. In 2023, China's annual production of Tea Tree Mushrooms was 820,608 tons, with Jiangxi and Fujian provinces being the primary production areas.

***Ganoderma* spp.**

Wild resources of *Ganoderma* spp. are widely distributed in the tropical and subtropical regions of the world, with *Ganoderma lucidum* (Curtis) P. Karst. as the type. *Ganoderma* spp. have been used in Asia for over 2,000 years due to their medicinal, edible, and ornamental value. Currently, there are 137 confirmed species of the *Ganoderma* genus worldwide, with 124 species in China (Wang et al. 2024a). Many species of *Ganoderma* are cultivated in China, with *Ganoderma lingzhi* Sheng H. Wu, Y. Cao & Y.C. Dai (= *Ganoderma sichuanense* J.D. Zhao & X.Q. Zhang) being the main species (Cao et al. 2012, Du et al. 2023). Other species mainly include *Ganoderma atrum* J.D. Zhao, L.W. Hsu & X.Q. Zhang, *Ganoderma leucocontextum* T.H. Li, W.Q. Deng, Sheng H. Wu et al. *Ganoderma sinense* J.D. Zhao, L.W. Hsu & X.Q. Zhang, *Ganoderma tsugae*

Murrill (Cao et al. 2012). Among these, *Gan. lingzhi* and *Gan. sinense* are included in the 2020 edition of "the Chinese Pharmacopoeia" as the two officially recognized medicinal species. In 1969, the Institute of Microbiology of the Chinese Academy of Sciences successfully cultivated *Ganoderma* spp. artificially for the first time (Wang et al. 2024a). Currently, *Ganoderma* spp. are cultivated artificially worldwide, with diverse cultivation techniques including log cultivation, substitute cultivation, greenhouse cultivation and understory wild-simulated cultivation (Fig. 16). The substitute cultivation in greenhouse has stable and high yield, and short cycle, while fluctuant nutritional quality due to the substrate ratio, and there will be a certain degree of accumulation of heavy metals (Xing et al. 2019). Log cultivation has the best quality of fruiting bodies (high content of polysaccharides and triterpenoids), low content of heavy metals, and strong export competitiveness; however, it relies on forest resources and has low sustainability (Guo et al. 2018, Xing et al. 2019, Ma et al. 2023). The understory wild-simulated cultivation produces products with similar quality to wild *Ganoderma* spp., and therefore has become a new development trend with broad development space; however, its yield is restricted by natural conditions (Xing et al. 2019). In 2023, the annual production of *Ganoderma* spp. in China totaled 159,838 tons, with the main cultivation areas being Fujian, Zhejiang, Shandong, and Jilin provinces.

Figure 14 – *Cordyceps militaris* cultivation in a factory.

Grifola frondosa

Grifola frondosa, also known as Maitake, was first artificially cultivated in Japan, where factory production was successfully achieved. The domestication and cultivation of *Gri. frondosa* was began in the 1980s in China, primarily using seasonal cultivation methods. Large-scale cultivation was quickly achieved in Qingyuan County, Zhejiang Province, and Qianxi County, Hebei Province. In recent years, efforts have been made to explore factory production of *Gri. frondosa*, achieving small-scale year-round factory production, mainly using substitute cultivation in a greenhouse (Fig. 17). The factory cultivation of *Gri. frondosa* started relatively late in China but has developed rapidly. Currently, companies such as Jiangsu Hualv Bio-Technology Co., Ltd. and Shanghai Fengke Bio-Technology Co., Ltd. are engaged in factory cultivation of *Gri. frondosa*. In 2023, the annual production of *Gri. frondosa* was 32,856 tons in China, with the main cultivation areas being Hebei, Hunan, and Zhejiang provinces.

Figure 15 – *Cyclocybe cylindracea* complex cultivation in a greenhouse.

***Hericium* spp.**

Hericium spp. are widely distributed across China and primarily grow in deep mountain forests, offering a delicious and nutritious option. In 1959, China successfully isolated pure strains of *Hericium erinaceus* (Bull.) Pers. and achieved artificial domestication. *Hericium erinaceus* has a significant therapeutic effect on gastrointestinal diseases; *Her. erinaceus* polysaccharides and polypeptides can repair gastric mucosal damage and assist in the treatment of gastric ulcers, and have a good effect in regulating gastrointestinal function and improving gastrointestinal protection, such as indigestion (Yang et al. 2022, Gravina et al. 2023). Now the two cultivated species of *Hericium* in China are *Her. erinaceus* and *Hericium coralloides* (Scop.) Pers. The substitute cultivation of *Hericium* spp. use wood chips, corncobs, and other similar substrates, and this process can be conducted using bottles or bags on shelves in a greenhouse (Fig. 18). In 2023, annual production of *Hericium* spp. was 106,983 tons in China, with the main production areas being Heilongjiang and Fujian provinces.

Hymenopellis raphanipes

Wild *Hym. raphanipes* [= *Oudemansiella raphanipes* (Berk.) Pegler & T.W.K. Young] is found in tropical, subtropical, and temperate regions, growing singly or in groups in broadleaf forests during summer and autumn. Its pseudoroots attach to underground decaying wood or humus layers; it is a wood-decay fungus that can adapt to medium to high temperatures (Xiao et al. 2022). In the early 1980s, artificial cultivation of *Hym. raphanipes* was successfully achieved in China, utilizing wood chips, cotton hulls, and other materials (Xiao et al. 2022). Substitute cultivation methods include using bags on shelves in greenhouses, understory wild-simulated cultivation, bag removal, and soil casing cultivation in greenhouses or factories, as well as tea garden intercropping (Xiao et al. 2022). Currently, *Hym. raphanipes* cultivation primarily employs bag removal and soil casing methods, while continuous cropping obstacles limit industry development, and no-soil-cover cultivation faces lower yield issues (Fig. 19) (Xiao et al. 2022). In 2023, the annual production of *Hym. raphanipes* reached 89,162 tons in China, with the main production areas being Shandong, Henan, Zhejiang, and Fujian provinces.

Figure 16 – *Ganoderma* spp. cultivation. **a** Outdoor log cultivation. **b** Understory wild-simulated cultivation. **c** Spore collection in greenhouse. **d** Bag removal and soil covering in greenhouse.
e-f Substitute cultivation in a greenhouse.

Figure 17 – *Grifola frondosa* wild-simulated cultivation in a greenhouse.

Lentinula edodes

Lentinula edodes thrives in tropical and subtropical environments, and is primarily found in East Asia and Southeast Asia (Khaund & Joshi 2016, Xiang et al. 2016, Cao et al. 2024). *Lentinula edodes* was first produced and consumed in China, and China is also the major producer, consumer, and exporter of *Len. edodes* globally (Cao et al. 2024, Wang et al. 2024b). Annual production of *Len. edodes* was 13.04 million tons in China in 2023, accounting for around 98% of the global total; the annual per capita consumption of *Len. edodes* was 8.9 kg in China (Cao et al. 2024). Since the late 1990s, China has exported *Len. edodes* logs overseas, adopting a "domestic substitute-bags production + overseas mushrooming" model. According to incomplete statistics, in 2022, *Len. edodes* were cultivated in 60 countries (regions) globally (Cao et al. 2024). *Lentinula edodes* cultivation techniques have gone through three stages: the "flower cutting" method, log cultivation, and substitute cultivation. The "flower cutting" method is the oldest cultivation technique for *Len. edodes*, which grows completely in the wild and have extremely high quality, while also have the lowest output and biological conversion rate, the cycle of this method is as long as five years, the labor cost is high and it relies on the deep mountain environment; the log cultivation has shorter cycle than that of the "flower cutting" method, and the biological conversion rate is slightly increased; substitute cultivation is a mainstream modern technology, which uses agricultural and forestry wastes such as sawdust and cottonseed hulls to replace logs, its raw materials are widely available, the cycle is short (4 to 6 months), and the yield is high, which is suitable for factory cultivation and has the highest biological efficiency (Xia et al. 2022). Currently, the main production method for *Len. edodes* is substitute cultivation in greenhouses in China (Fig. 20). The main producing regions are Henan, Hebei, Fujian, and Hubei provinces.

Figure 18 – *Hericium* spp. cultivation in a greenhouse. **a**-**c** Substitute cultivation of *Hericium coralloides*. **d-e** Substitute cultivation of *Hericium erinaceus*.

Lyophyllum decastes

Wild *Lyo. decastes* is mainly distributed in the temperate regions of the Northern Hemisphere, and is a saprophytic fungus (Cheng et al. 2008, Wei et al. 2024). In 1973, Zhaotong City in Yunnan Province, China, was the first to cultivate *Lyo. decastes*. The factory production of *Lyo. decastes* began in Japan in 1998. In 2004, Japan achieved indoor cultivation of *Lyo. decastes* without soil casing. In 2006, Shanghai Fengke Company in China first achieved facility-based year-round cultivation of *Lyo. decastes* (Kong et al. 2024). After 2019, substitute cultivation using bags emerged. Currently, the factory-based and large-scale cultivation of *Lyo. decastes* is mainly concentrated in Shanghai, Guangdong, Shandong, and Jiangsu provinces (Fig. 21). The mycelium of *Lyo. decastes* grows relatively slowly and is prone to contamination by harmful fungi during the growth process. Generally, the mycelium incubation of *Lyo. decastes* takes about 70 days, and the mushroom fruiting stage takes about 25 days. *Lyophyllum decastes* cannot form fruiting bodies under dark conditions, and needs continuous light or 12-hour light-dark cycles to induce fruiting bodies formation. This entire cultivation cycle has high technical requirements, but it also indicates the unique value and preciousness of *Lyo. decastes*. In 2023, the annual production of *Lyo. decastes* reached 193,131 tons in China, with the main production areas being Shanghai, Guangdong, Shandong, and Jiangsu provinces.

***Morchella* spp.**

The domestication and cultivation of *Morchella* spp. began in the 1880s, with the first successful indoor domestication in the United States in the 1980s. However, the large-scale production of *Morchella* spp. truly began in China after 2012. In recent years, the cultivation of *Morchella* spp. in China has made significant progress, but it is still in its early stages. Currently, the main species of *Morchella* artificially cultivated in China are *Morchella septimelata* Morchella Kuo, *Morchella importuna* Morchella Kuo, O'Donnell & T.J. Volk, and *Morchella sextelata* Morchella Kuo, research on high-yield and stable production techniques still needs to be further strengthened (Liu et al. 2022c). A special requirement for the artificial cultivation of *Morchella* spp. is placed specially formulated substrates called “exogenous nutrient bags” on the soil surface, when after the mycelium produces white “mycelial frost” in the soil casing layer. Exogenous nutrient bags play a crucial role in the formation of fruiting bodies and serve as the primary carbon source for *Morchella* spp. (Fig. 22). The innovative use of exogenous nutrient bags is one of the key factors for achieving commercial cultivation in China (Tan 2019). Currently, the cultivation modes for *Morchella* spp. in China include field, greenhouse, and understory cultivation. Field cultivation is currently the primary cultivation method in China, used to cultivate *Morchella* spp. during the winter idle period in paddy fields, the straw left after rice harvest can be used as a substrate for *Morchella* spp. cultivation. The tree species used in the understory cultivation of *Morchella* spp. need to have relatively high water tolerance, because high moisture levels are required during the fruiting period of *Morchella* spp. Additionally, the understory provides suitable light conditions for the growth and development of fruiting bodies in *Morchella* spp. The greenhouse cultivation mode is generally similar to the field cultivation mode, but greenhouses provide better heat preservation in winter and allow for temperature control within a certain range. This shows more advantages during the mycelium growth and fruiting management stages, leading to better cultivation results (Fig. 22). Due to price factors, the cultivation scale of *Morchella* spp. has rapidly expanded. In 2023, *Morchella* spp. production reached 283,864 tons in China. The primary production areas are currently located in Sichuan, Yunnan, and Shanxi provinces.

Naematelia aurantialba complex

Naematelia aurantialba (Bandoni & M. Zang) Millanes & Wedin (= *Tremella aurantialba* Bandoni & M. Zang) is a parasitic fungus that parasitizes *Stereum hirsutum* (Willd.). Pers., relying on it for nutrients to grow (Cao et al. 2022, Yang & Dong 2024). Wild *N. aurantialba* and its allies are widely distributed in China, primarily found in Yunnan, Tibet, Sichuan, and Gansu provinces. Although their yield is limited, they are usually referred to as Jiner (Tang & Yang 2024). Jiner is a rare edible mushroom with high nutritional and medicinal value (Wang et al. 2025). In the 1980s, China successfully developed both log cultivation and substitute cultivation for Jiner (Fig. 23) (Tang et al. 2018). In taxonomy, Jiner is from the *N. aurantialba* complex, including four species: *N. aurantialba*, *Naematelia sinensis* Zhu L. Yang & J.Y. Tang (the commonly cultivated species), *Naematelia nodulosa* Zhu L. Yang & J.Y. Tang, *Naematelia pedicellata* Zhu L. Yang & J.Y. Tang (Tang & Yang 2024). Yunnan Junshijie Biotechnology Co., Ltd. first achieved year-round industrial cultivation of *N. aurantialba* complex in 2020. The company currently has a daily production capacity of 10 tons of fresh *N. aurantialba* complex, with a high market share. All products are sold as fresh mushrooms, yielding good profit and driving the development of the fresh *N. aurantialba* complex market and changes in cultivation methods (Dong et al. 2024). The total production of *N. aurantialba* complex in China was nearly 1,000 tons in 2022, with Yunnan province being the main production region (https://society.yunnan.cn/system/2024/02/02/032932607.shtml).

Figure 19 – *Hymenopellis raphanipes* cultivation. **a-b** Bag removal and soil casing cultivation in a factory. **c-d** Bag removal and soil casing cultivation in a greenhouse. **e-f** Substitute cultivation using bags in greenhouse.

Figure 20 – *Lentinula edodes* cultivation. **a-b** Substitute cultivation on shelves in a greenhouse. **c-d** Substitute cultivation in a greenhouse.

Figure 21 – *Lyophyllum decastes* cultivation in a factory.

Ophiocordyceps sinensis

Ophiocordyceps sinensis [= *Cordyceps sinensis* (Berk.) Sacc.] is mainly distributed in the Qinghai-Tibet Plateau and its surrounding areas. It has harsh growing conditions and a low natural formation rate. Due to its excellent efficacy, wild resources have been plundered, and in 2020, it was listed as a vulnerable species in the IUCN Red List of Threatened Species. Years of research in China have proven that *Hirsutella hepiali* C.T. Chen & N.Y. Shen is the asexual morph of the *O. sinensis*. At present, research on the artificial cultivation of *O. sinensis* has made significant progress. By artificially breeding bat moth larvae and inoculating them with *O. sinensis* to increase the infection rate, the infected larvae are then cultivated in low-altitude indoor environments simulating plateau conditions or in high-altitude *O. sinensis* habitats to grow fruiting bodies and form *O. sinensis*. Currently, several *O. sinensis* research and development institutions in China have achieved artificial breeding of *O. sinensis*. For example, the Chongqing Institute of Chinese Materia Medica has established a research base on the Kangding Plateau in Sichuan and conducted research on the artificial cultivation of *O. sinensis*, successfully harvesting *O. sinensis* indoors. Guangdong Dongyangguang Pharmaceutical Co., Ltd. has established an *O. sinensis* cultivation factory in low-altitude areas (Fig. 24). Currently, it has seven production bases in China and has taken the lead in achieving ecological breeding industrialization of *O. sinensis* worldwide. In 2023, the annual production of *O. sinensis* in China was 119 tons, with the main cultivation areas being Yunnan, Sichuan, and Hubei provinces.

Figure 22 – *Morchella sextelata* cultivation using nutrient bags in a greenhouse in Beijing, China.

Figure 23 – Cultivation of *Naematelia aurantialba* complex in a factory.

***Phallus* spp.**

Phallus (= *Dictyophora*) spp. are saprophytic fungi that require a soil casing for cultivation. There are five main species of *Phallus* that are cultivated on a large scale or are widely consumed in China: (1) *Phallus dongsun* T.H. Li, T. Li, Chun Y. Deng et al., naturally distributed in temperate regions, mainly found in bamboo forests or mixed bamboo-broadleaf forests in Zhejiang, Jiangxi, Hunan, Guizhou, and Sichuan provinces, and widely cultivated in Guizhou province; (2) *Phallus rubrovolvatus* (M. Zang, D.G. Ji & X.X. Liu) Kreisel, naturally distributed in temperate to subtropical regions, widely cultivated in Guizhou and Yunnan provinces; (3) *Phallus echinovolvatus* (M. Zang, D.R. Zheng & Z.X. Hu) Kreisel, naturally distributed in subtropical regions, widely cultivated in Hunan, Guangdong, Fujian, and Yunnan provinces; (4) *Phallus luteus* (Liou & L. Hwang) T. Kasuya, naturally distributed in temperate to subtropical regions, widely consumed in Guangdong province; (5) *Phallus cremeo-ochraceus* T. Li, T.H. Li & W.Q. Deng, naturally distributed in temperate regions, widely cultivated under bamboo forests in Guizhou and Sichuan provinces (Li et al. 2023b). The substitute cultivation of *Phallus* spp. uses agricultural and forestry waste such as straw and sawdust to instead of wood, this method can be applied in various models such as understory cultivation, shelf and basket cultivation in greenhouse, and factory cultivation (Fig. 25). In recent years, the development of *Phallus* spp. is promising, with its taste being favored by consumers and strong market demand. In 2023, *Phallus* spp. production reached 223,970 tons in China. The production areas are distributed in Sichuan, Fujian, Guizhou, Jiangxi, and other provinces.

Figure 24 – *Ophiocordyceps sinensis* cultivation in a factory (Image source: http://food.hec.cn/).

Phlebopus portentosus

Wild *Phl. portentosus* is mainly distributed in tropical and subtropical regions of the world (Cao et al. 2021). *Phlebopus portentosus*, commercially known as black bolete, is the only species among the global boletes that has been successfully domesticated and achieved year-round factory cultivation. Guizhou Hongzhen Fungus Industry Investment Development Co., Ltd. in China has established the first research and production base for factory cultivation of *Phl. portentosus* in the world. The company currently has a daily production capacity of 26 tons. Through hybrid breeding, they have selected a high-yield, stable strain, 'YL1701_2', which holds proprietary intellectual property rights. This strain has eliminated the characteristic earthy taste of wild strains (Ji 2019, Luo et al. 2022), and it is currently the main strain used in factory cultivation. *Phlebopus portentosus* can leave the "host tree" and form mature fruiting bodies independently when provided with suitable nutrients (Li et al. 2024). This is the fundamental reason for its successful domestication. It is worth noting that another non-ectomycorrhizal bolete, *Buchwaldoboletus xylophilus* (Petch) Both & B. Ortiz, has been produced by artificial indoor cultivation (Xie et al. 2021, Yang et al. 2021). However, the relatively weak saprophytic ability of *Phl. portentosus* has led to technical bottlenecks in artificial cultivation, such as low biological conversion rates and the issue that nutrients in a single cultivation bottle can only support the growth and maturation of a single fruiting body (Fig. 26). The artificial cultivation of *Phl. portentosus* includes understory wild-simulated cultivation and factory bottle cultivation. Currently, high-quality and high-yield *Phl. portentosus* has been successfully cultivated under economic forests such as phoenix trees and grapefruit trees. Under factory conditions, *Phl. portentosus* can be cultivated year-round, mainly divided into two stages: asexual mycelial growth and sexual development. Soil casing is still an essential step in the artificial cultivation process to stimulate the transition of mycelium from asexual reproduction to sexual reproduction that produces fruiting bodies (Zhang et al. 2012, Cao et al. 2021). In 2023, *Phl. portentosus* production reached 144,849 tons in China.

Figure 25 – *Phallus* spp. cultivation. **a-b** *Phallus echinovolvatus* understory cultivation. **c-d** *Phallus rubrovolvatus* cultivation in greenhouse.

Figure 26 – *Phlebopus portentosus* cultivation in a factory.

Pholiota microspora

Wild *Pho. microspora* is primarily distributed in Northeast China. Artificial cultivation of *Pho. microspora* began in Japan in the 1950s, where industrial cultivation of *Pho. microspora* is now highly developed. In the 1970s, *Pho. microspora* was introduced and cultivated in China. Currently, *Pho. microspora* is primarily grown in greenhouses using seasonal substrate cultivation. Industrial year-round production of *Pho. microspora* in China is still in the exploratory stage on a small scale (Fig. 27) (Dong et al. 2024). In 2023, the annual production of *Pho. microspora* was 582,379 tons in China, with the main production areas in Liaoning, Heilongjiang, Inner Mongolia, and Hebei provinces.

Figure 27 – *Pholiota microspora* cultivation in a factory.

***Pleurotus* spp.**

Pleurotus mushrooms are also called oyster mushrooms. There are over 50 recognized species in the genus *Pleurotus*, with more than 20 species widely cultivated, including *Ple. citrinopileatus*, *Pleurotus cornucopiae* (Paulet) Quél., *Ple. eryngii*, *Pleurotus floridanus* Singer, *Ple. ostreatu*s, *Ple. pulmonarius* and *Ple. tuoliensis*, and new domesticated species such as *Pleurotus placentodes* (Berk.) Sacc. emerging continually (Wang et al. 2018b). *Pleurotus* spp. are widely distributed globally, from tropical to temperate regions, with a broad temperature adaptation range. *Pleurotus* spp. are wood-decaying fungi with robust lignin and cellulose decomposition capabilities, capable of growing on diverse cultivation substrates, including cottonseed hulls, sawdust, various straws, and corncobs, all of which are agricultural waste. The cultivation technologies for *Pleurotus* spp. are simple, primarily involving substitute cultivation (Fig. 28). In 2023, *Pleurotus* spp. production was approximately 8.71 million tons in China.

Sanghuangporus spp.

Sanghuangporus has rich species diversity, and *Sanghuangporus* spp. are widely distributed in China and different regions of the Northern Hemisphere. As a precious medicinal fungus, *Sanghuangporus* spp. is known as "forest gold." Since the 1990s, China has begun artificial domestication of *Sanghuangporus* spp. The main species used in the industry are *Sanghuangporus baumii* (Pilát) L.W. Zhou & Y.C. Dai, *Sanghuangporus sanghuang* (Sheng H. Wu, T. Hatt. & Y.C. Dai) Sheng H. Wu, L.W. Zhou & Y.C. Dai, *Sanghuangporus vaninii* (Ljub.) L.W. Zhou & Y.C. Dai and *Inonotus hispidus* (Bull.) P. Karst., the industry scale is expanding yearly, forming a health industry with broad development potential and generating high economic value and social benefits (Yang et al. 2023). *Sanghuangporus* spp. can grow on various broadleaf trees, both living and fallen. Among them, *San. sanghuang* can only grow on mulberry trees. The current cultivation methods for *Sanghuangporus* spp. include log cultivation and substitute cultivation. Log cultivation typically requires three years to fully utilize the wood substrate and achieve a high biological conversion rate; substitute cultivation usually takes one year, allowing for 1-2 seasons of cultivation per year (Fig. 29) (Yang et al. 2023). In 2023, the annual production of *Sanghuangporus* spp. in China was 674 tons, with the main production areas located in the northeast of the Country.

Schizophyllum commune

Schizophyllum commune Fr., with high food and medicinal value, has a long history of use in Africa and Asia. The artificial domestication and cultivation of *Sch. commune* in China began in the 1980s, with the first successful domestication and cultivation efforts conducted by the Institute of Edible Fungi, Shanghai Academy of Agricultural Sciences (Chen 1986). In 2000, Luo et al. domesticated the flaky and small flower shape of the wild *Sch. commune* into a chrysanthemum-like petal shape and a larger flower shape, thereby enhancing both the appearance and yield (Ma et al. 2017). In 2006, commercial cultivation of *Sch. commune* was carried out in Gutian County, Fujian Province. In 2017, Ma et al. from Yunnan Fungus Vision Biological Technology Co., Ltd carried out a preliminary exploration of the factory cultivation technology of *Sch. commune* (Ma et al. 2019). Bijie Agricultural Investment Fungi Technology Co., Ltd, in the economic development zone of Dafang County, Guizhou Province, is the first fully automatic *Sch. commune* cultivation factory in China with independent intellectual property rights (Fig. 30). Currently, cultivation of *Sch. commune* is mainly in the traditional cultivation mode of greenhouses and mushroom rooms, which has been commercially cultivated in Guizhou, Fujian, Shandong, and Yunnan Province in China (Ma et al. 2017).

Sparassis latifolia

Currently, only Japan, South Korea, and China can achieve artificial cultivation of *Sparassis* spp. *Sparassis crispa* (Wulfen) Fr. was cultivated in Japan and South Korea, and *Spa. latifolia* was cultivated in China (Dai et al. 2006). Due to the scarcity and unique medicinal properties of

Sparassis spp., it is highly sought after in the international market. *Sparassis latifolia* requires more than 10 hours of light daily and is known as the "sunshine mushroom." In terms of the cultivation season, *Spa. latifolia* cultivation is divided into natural cultivation and factory cultivation. In terms of cultivation containers, it is divided into bottle cultivation and bag cultivation. In terms of cultivation methods, it can be divided into substitute cultivation and log cultivation (Fig. 31). In 2023, *Spa. latifolia* output was 6,971 tons in China, with Fujian Province being the main production area.

Figure 28 – *Pleurotus* spp. cultivation. **a-b** *Pleurotus ostreatus* substitute cultivation in greenhouse. **c-d** *Pleurotus eryngii* substitute cultivation in a factory. **e-f** *Pleurotus citrinopileatus* substitute cultivation in greenhouse (photoed by Shi-Po Yan).

Stropharia rugosoannulata

Stropharia rugosoannulata is a straw-decomposing fungus that primarily uses straw and manure as substrates. It exhibits effective degradation of lignin and strong stress resistance, making it an expert in biologically decomposing agricultural waste. In 1969, East Germany (German

Democratic Republic, DDR) first began the domestication and cultivation of *Str. rugosoannulata*. In 1980, *Str. rugosoannulata* was successfully cultivated in China. Due to its simple cultivation techniques, abundant raw material sources, and good economic benefits, *Str. rugosoannulata* has become a preferred species for understory economic cultivation in recent years (Dong et al. 2024). As a new member of the edible fungi family, the cultivation area of *Str. rugosoannulata* in China is currently limited, but various cultivation methods have emerged. These include understory cultivation, winter fallow field cultivation, and greenhouse cultivation using pots, baskets, or bags (Fig. 32). Greenhouses can be used to cultivate *Str. rugosoannulata* alone or intercropped with other vegetables. This cultivation method can mitigate the adverse effects of winter weather and the impact of spring mushroom production, resulting in easy management, rapid mushroom growth, stable and high yields, and scientifically regulated peak production periods to meet market demand. In 2023, the annual production of *Str. rugosoannulata* production in China was 493,745 tons, with the main production areas located in Hunan, Guizhou, Sichuan, and Henan provinces.

Figure 29 – *Sanghuangporus vaninii* substitute cultivation in a greenhouse.

Figure 30 – *Schizophyllum commune* cultivation in a factory.

Tremella fuciformis

Tremella fuciformis is a typical example of a fungus that completes its life cycle in symbiosis with another fungus. During its growth and development, *Tre. fuciformis* requires the presence of *Annulohypoxylon stygium* (Lév.) Y.M. Ju, J.D. Rogers & H.M. Hsieh, promoting each other's substrate degradation and utilization. Artificial cultivation of *Tre. fuciformis* in China began in the latter half of the 19th century, but it remained in a semi-wild, semi-artificial state for a long time. *Tremella fuciformis* production in China primarily relies on traditional farming methods, mainly including log cultivation and substitute material cultivation (Fig. 33). Log-cultivated *Tre. fuciformis* are best known from Tongjiang in Sichuan Province, and substitute material-cultivated *Tre. fuciformis* are most famous from Gutian in Fujian Province. Log-cultivated *Tre. fuciformis* are of high quality and considered premium, but their biological efficiency is relatively low. Currently, *Tre. fuciformis* cultivation is mainly based on substitute material cultivation, using agricultural waste such as cottonseed hulls, bran, and corncobs as raw materials. This method has a shorter cycle and higher yield. China is the world's leading producer of *Tre. fuciformis*, with an annual production of 578,186 tons in 2023. Fujian Province is the top-producing region in China, contributing over 90% of the national total production.

Volvariella volvacea

Volvariella volvacea mainly grows in the tropical and subtropical regions of Asia, characterized by high temperatures and heavy rainfall. China is the leading producer of *V. volvacea*, which is also among the earliest edible mushrooms to be artificially cultivated in the country, with domestication efforts dating back to the 18th century in Guangdong Province. In the 1960s, China began commercial-scale production of *V. volvacea*, initially using raw or compost as a substrate for greenhouse cultivation. Currently, composts are used for factory cultivation (Fig. 34). Due to the short production cycle and minimal investment required for facility cultivation, *V. volvacea* can still yield good economic benefits despite its relatively low output (He et al. 2020). As a typical high-temperature edible mushroom, *V. volvacea* is extremely sensitive to temperature; it autolyzes at low temperatures and easily opens its caps at normal or higher temperatures, which somewhat limits its development (Qiu et al. 2022). In 2023, the annual production of *V. volvacea* in China reached 191,229 tons, with the main production areas located in the southern provinces of Guangdong, Fujian, Jiangsu, Hunan, and Jiangxi.

Figure 31 – *Sparassis latifolia* substitute cultivation in a greenhouse.

Wolfiporia hoelen

Wolfiporia hoelen is one of the most commonly used traditional medicines in China, which was once considered to be the same species as *Wolfiporia cocos* (F.A. Wolf) Ryvarden & Gilb. (= *Poria cocos* F.A. Wolf) in American (Wu et al. 2020, Stalpers et al. 2021). *Wolfiporia hoelen* is an ingredient in many Chinese patent medicines; the 2015 edition of "The Pharmacopoeia of the People's Republic of China" includes over 200 kinds of Chinese patent medicines that contain *W. hoelen* (Li et al. 2019). The large-scale cultivation of *W. hoelen* in China originated in the mid-

Ming Dynasty. In the 1970s, extensive cultivation began in southern China. Currently, *W. hoelen* is mainly cultivated using pine logs, with substitute material cultivation serving as a secondary method (Fig. 35). In 2023, China's annual production of *W. hoelen* was 306,429 tons, with the main production areas located in Hunan and Hubei provinces.

Figure 32 – *Stropharia rugosoannulata* understory cultivation.

Figure 33 – *Tremella fuciformis* cultivation. **a-c** Substitute cultivation of *Tremella fuciformis* on shelves in a greenhouse. **d** Log cultivation of *Tremella fuciformis* in the field.

Diversity of processed products from edible fungi

Foods

In the realm of edible fungi-processed products, basic processing techniques and products remain predominant (Wu et al. 2024). In the market, more than 90% of processed mushroom products are dried or canned (Wu et al. 2024). The same trend is observed in exported mushroom products, with dried *Len. edodes*, dried *Auricularia* spp., and canned *Aga. bisporus* is the main product. Edible fungi contain a large number of fresh and flavorful substances, including soluble sugars, free amino acids, flavorful nucleotides, organic acids, and so on (Yu et al. 2023). Mushroom-based seasoning products, such as mushroom soy sauce, mushroom essence condiments, concentrated mushroom juice, and mushroom sauces, are developed by utilizing the delicious flavor and rich amino acids and nucleotides present in mushrooms (Fig. 36a-c). Mushroom powders are also added to traditional flour-based products, creating a series of mushroom-based staple foods, including mushroom noodles, mushroom bread, truffle cookies, and mushroom meal replacement powders (Fig. 36d-f). Mushroom chips, produced through vacuum low-temperature crisping technology, offer a convenient and tasty snack option, with variations such as *Len. edodes* chips, *Ple. eryngii* chips, *Ple. pulmonarius* chips, and *Hyp. marmoreus* chips (Fig. 36g-l).

Figure 34 – *Volvariella volvacea* cultivation. **a-c** *Volvariella volvacea* cultivation in a factory. **d** *Volvariella volvacea* cultivation in greenhouse.

Health products

Edible fungi are rich in various nutrients and bioactive substances, such as polysaccharides, active proteins and peptides, phenols, ketones, terpenes, and steroidal compounds. Numerous studies have demonstrated their diverse biological activities, including immunomodulation, anti-fatigue effects, hypoxia tolerance, lipid-lowering properties, and tumor inhibition, highlighting their significant medicinal and health value. Currently, there are over 1,600 registered health products in China derived from edible fungi, with a predominant share held by *Ganoderma*-related products (1,224 types, including 1,212 domestic and 12 imported) (Fig. 37). Additionally, there are 140 health products related to *W. hoelen*. (Source: China National Market Supervision Administration Special Food Information Query Platform - http://ypzsx.gsxt.gov.cn/specialfood/#/food)

Figure 35 – *Wolfiporia hoelen* cultivation. **a** Inoculation of *Wolfiporia hoelen*. **b** The fruitbody of *Wolfiporia hoelen*. **c-d** Cutting and airing of *Wolfiporia hoelen*.

Ganoderma is a traditional, precious medicinal herb in China, containing over 400 bioactive substances, including *Ganoderma* polysaccharides, triterpenes, sterols, and alkaloids. Eleven health benefits of registered *Ganoderma* products have been identified, including enhancing immune function, protecting against chemical liver damage, alleviating fatigue, improving sleep quality, and exhibiting antioxidant properties (Guan et al. 2023). The popular *Ganoderma* products are *Ganoderma* breaking spores, which with polysaccharides and triterpenes having absorption rates of over 90% in the human body (Xu & Li 2019), *Ganoderma* water-soluble polysaccharides and lipid-soluble triterpenes possessing essential biological functions such as immunomodulation, blood sugar reduction, anti-ulcer, antioxidant, anti-aging, and anti-tumor activities (Zhang et al. 2023, Zhao et al. 2023), *Ganoderma* acids, the major triterpenes in *Ganoderma*, exhibit various pharmacological activities, including anti-tumor, anti-HIV-1, anti-hypertension, immunomodulation, anti-androgen, anti-hepatitis B, antioxidant, and antibacterial activities (Liang et al. 2019, Huang et al. 2012). *Wolfiporia hoelen* is a classic medicinal and edible herb in traditional medicine in China, and its main effective components include polysaccharides and triterpenes, which have various functions, such as anti-cancer, immune enhancement, antioxidant, anti-apoptosis, anti-nephritis, and diuretic effects (Jia et al. 2016, Wang et al. 2023).

Figure 36 – Processed products of edible fungi (Image source: Internet).
a-c Mushroom-based seasoning products. **d-f** Mushroom-based staple foods.
g-l Mushroom chips. (Image sources: **a, b:** http://.cnylxjl.cn/;
c: https://.totole.com.cn/index.php?r=node%2Fdetail&id=1207&mode=pc&lang=1;
e: http://.jlswtzb.cn/ztzl/kjcgzs/yljk/202110/t20211027_8260635.html; **g-l:** https://www.jd.com/)

In China, nearly 600 medicines are developed primarily using edible fungi as raw materials. The major species include *Ganoderma* (172 types), *Trametes versicolor* (L.) Lloyd (155 types), *Hericium* spp. (57 types), *Cor. militaris* (43 types), *Len. edodes* (38 types), *Desarmillaria tabescens* (Scop.) R.A. Koch & Aime [= *Armillariella tabescens* (Scop.) Singer] (31 types), *W. hoelen* (31 types), *Tre. fuciformis* (19 types), *Auricularia* (7 types), and *O. sinensis* (5 types). These findings are based on data from the China National Medical Products Administration (https://www.nmpa.gov.cn/datasearch/#category=yp). Regarding usage, oral medications account for over 90%, while injections and external-use medicines constitute only a small portion (Wu et al. 2020b). In terms of primary therapeutic functions, they primarily involve immunomodulation, treatment of cardiovascular disease, gastrointestinal disease, and tumors, as well as calming, kidney tonification, blood circulation promotion, anti-inflammatory, and phlegm-dissolving effects (Wu et al. 2020b). In terms of composition, one category involves traditional medicine formulated using edible fungi as raw materials, while the other includes biochemical drugs made from extracts of specific fungi, which represents a new direction and key field in the development of edible fungi drugs. Biochemical drugs primarily consisting of edible fungi polysaccharides have been developed, with notable examples being *Len. edodes* and *Ganoderma* polysaccharide products, such as injectable *Len. edodes* polysaccharides, *Len. edodes* polysaccharide tablets and *Ganoderma* spore polysaccharide injections (Fig. 38).

Cosmetics

As polysaccharides, nucleosides, peptides, amino acids, polyphenols, and triterpenes, the bioactive components in edible fungi are gradually being confirmed to have anti-inflammatory, antibacterial, anti-wrinkle, anti-aging, skin whitening, and moisturizing effects. Consequently, the application of bioactive components from edible fungi in commodities and skincare products has gained increasing attention. Representative examples include *Tre. fuciformis* gel for moisturizing skincare, and *Ganoderma* skincare and haircare cosmetics (Fig. 39). As a natural skin-whitening agent in edible fungi, kojic acid can be added to creams and whitening essences as cosmetic products for treating age spots and pigment deposition (Bentley 2006). Triterpene components in edible fungi exhibit immunomodulatory and anti-inflammatory activities, and are often added to skincare products for treating skin infections and allergies (Jeong et al. 2008).

SCIENTIFIC AND TECHNOLOGICAL DEVELOPING TRENDS OF EDIBLE FUNGI IN CHINA

Research papers related to the study of edible fungi primarily focus on four areas: genetic breeding, cultivation, wild resources, and active ingredients and their processing. Statistics on the number of research papers in each of the above four research directions in the world and in China. Among these directions, the research papers on the active ingredients and processing of edible fungi are the most numerous, followed by cultivation and genetic breeding. Wild resources have the fewest research papers, as shown in Fig. 40. From 2014 to 2023, there has been a progressive increase in the number of papers published in each of these research directions, both globally and in China, indicating a heightened interest in the fundamental research of edible fungi.

Over the past decade (2014 to 2023), the ratio of the number of research papers in all directions related to edible fungi in China to the total number in the world showed an increasing trend (Fig. 41). Among the diverse research directions, genetic breeding of edible fungi in China has seen the most substantial increase, representing 41.23% of the global research output in 2014 and surging to 67.98% in 2023, marking a remarkable 26.75% increase. Although research on edible fungi's active ingredients and processing in China initially had the lowest proportion, it surpassed 44% in 2023. It is anticipated that China will emerge as a global innovation hub for edible fungi industry research within the next five years.

Figure 37 – *Ganoderma* health products (Image source: Internet). **a-c** *Ganoderma* spore products. **d-e** *Ganoderma* slice. **f-k** Products adding bioactive components of *Ganoderma*. (Image sources: https://.xianzhilou.com/)

Wild edible fungi resources

China is one of the richest countries in the world in terms of wild mushroom resources. Continuous investigations by Chinese mycologists into the wild germplasm resources in recent years have led to the discovery and documentation of numerous new edible fungi species. Examples include the description of a new species, *Hygrophorus parvirussula* H.Y. Huang & L.P. Tang in Southwest China by Huang et al. (Huang et al. 2018), *Phlebopus roseus* Mei Yang, C.Y. Liu & Yun Wang in the same region by Mei et al. (Mei et al. 2021), *Gomphus matijun* J.W. Liu &

F.Q. Yu by Liu et al. (Liu et al. 2022a), and the cultivation success of a highly nutritious new species, *Agrocybe striatipes* R.L. Zhao & J.X. Li by Li et al. (Li et al. 2023). Wang et al. (2015) reported a semi-subterranean fruiting fungus, *Agaricus sinodeliciosus* Zhuo R. Wang & R.L. Zhao, from Xinjiang Province in western China, with potential for domestication and industrial production. Cao et al. (2020) published nine new edible species in the *Agaricus* section *Arvenses*, based on morphological and multigene phylogenetic analyses. Gui et al. (2015) reported three additional new edible species in the *Agaricus* section *Arvenses* group from subtropical southwestern China.

Medicines

Figure 38 – Development of biochemical drugs from edible fungi Internet). **a** Injectable *Lentinula edodes* polysaccharides. **b** *Lentinula edodes* polysaccharide tablets. **c** *Ganoderma* spore polysaccharide injections. (Image sources: **a:** https://.315jiage.cn/mn80301.aspx; **b:** https://.baiji.com.cn/goods-14826.html; **c:** https://.imm.ac.cn/xycz/sscxyw/313570d700ef4f7496b3e23bee236590.htm)

Figure 39 – Edible fungi skincare products (Image sources: https://.jd.com/ and https://huaban.com/pins/5009698526).

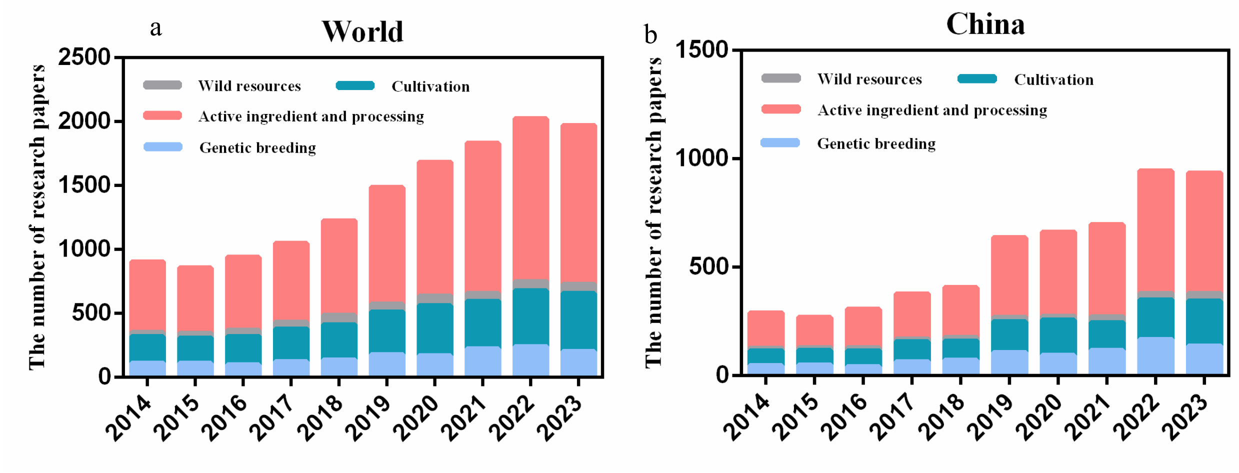

Figure 40 – Statistics on the number of research papers in each direction of edible fungi. **a** Stacked column chart of research papers on edible fungi worldwide in different research directions (2014 to 2023). **b** Stacked column chart of research papers on edible fungi in China in different research directions (2014 to 2023). (Data Source: Web of Science)

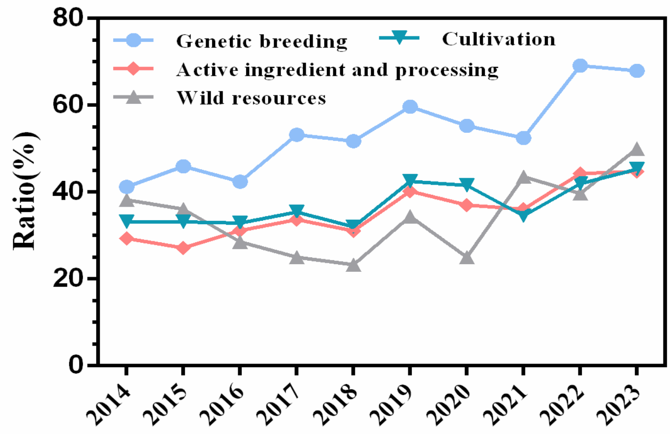

Figure 41 – Proportion of research papers on edible fungi in China compared to worldwide (2014 to 2023)

Edible fungi genetic breeding

Edible fungus genetics is one of the important branches of the subject of edible fungi. At present, the research topics of edible fungi genetics in China mainly include the following 9 aspects: investigation of germplasm resources and local cultivated varieties, molecular localization of agronomic trait control genes and molecular auxiliary breeding technology, genetic regularity of cross-breeding, genetic stability of cultivated strains and variation risk monitoring, molecular mechanism of cultivation substrate decomposition and nutrient storage and transport, molecular mechanism in response to the changes of environmental factors, molecular regulation mechanism of fruiting body development, molecular mechanism of secondary metabolite biosynthesis, and molecular mechanism of metabolic physiology in preservation of fresh products after picking (Bao 2021). Currently, some of these research topics are emerging as research hotspots (Bao 2021).

Studies in this area have primarily focused on the major of edible fungi, delving into breeding, genetic characteristics, gene functions, and environmental adaptability. The evolution and breeding history of *Len. edodes* were studied by using genomic methods. Target agronomic trait candidate genes by genome-wide association analysis (GWAS) to investigate the effects of environmental factors, such as temperature, on the genetic diversity of *Len. edodes* were also investigated (Xiao et al. 2016, Yu et al. 2022, Zhang et al. 2022a), and the genetic basis of heat resistance and chromium resistance was studied (Wang et al. 2018a, Ling et al. 2022, Yu et al. 2022). Research on *F. filiformis* involves the screening of new high-temperature-tolerant varieties (Kang et al. 2013), molecular mechanisms of stipe browning and toughness changes as well as cold-induced fruiting (Wu et al. 2018b, Deng et al. 2023), functional studies on genes related to lysine content, mating-type loci, and related to the growth and development of fruiting body, as well as molecular markers in variety identification (MNP) and genetic diversity analysis (SSR) (Liu et al. 2016, Liu et al. 2017, Liu et al. 2023). Additionally, research on *Morchella* spp. has analyzed the impact of continuous cropping on yield (Liu et al. 2022d), studied mating-type genes, light-regulated fruiting molecular mechanisms(Chai et al. 2017, Liu et al. 2022b, Qiu et al. 2023), and integrated transcriptomics and metabolomics for molecular insights into nutritional growth and storage (Deng et al. 2022, Gao et al. 2022a, Gao et al. 2022b), and a rapid identification method of *Mor. sextelata* based on PCR and an efficient genetic transformation technique was also developed (Lv et al. 2018, Shen et al. 2020, Zhang et al. 2022b). These achievements provide a scientific basis for genetic improvement, variety cultivation, and enhanced environmental adaptability, contributing to the efficient and sustainable development of the edible fungi industry.

Edible fungi cultivation

The edible fungi industry has become an integral part of China's agricultural production. Cultivation models in China have evolved from log cultivation to sawdust medium cultivation, transitioning towards modern factory cultivation with year-round production. The cultivation process has become more streamlined, mechanized, and automated, with significant advancements in cultivation techniques. Innovations such as the invention of external nutrient conversion bags for *Morchella* cultivation (Tan 2019), the study of the interaction mechanism between *Tre. fuciformis* and companion fungi (Tian et al. 2019), and the development of technologies for *Len. edodes* color transformation (Pang et al. 2016) has marked significant progress. China's cultivation techniques for many rare edible fungi, such as *Phl. portentosus* and *N. aurantialba* complex have gradually surpassed those of other countries (Tang et al. 2018, Cao et al. 2021). Moreover, at present, according to climatic conditions and cultivation materials, China has established a number of edible fungi characteristic production areas that are well-suited to local conditions (Li 2018).

Edible fungi bioactive components and processing

Edible fungi are rich in bioactive components such as polysaccharides, polyphenols, terpenes, sterols, and nucleosides, which have very high health benefits such as immune, anti-cancer, liver protection and stomach strengthening, blood sugar regulation, intestinal flora regulation, anti-ulcer, antioxidant, and anti-aging (Assemie and Abaya 2022, Chen et al. 2024). China has made rapid progress in the study of the molecular mechanisms of the bioactive components of edible fungi, such as exploring the role of the GATA transcription factor AREA in *Ganoderma* triterpene synthesis (Zhu et al. 2019), and factors such as NO and the interaction of NO and calmodulin under heat stress regulate the mechanism of *Ganoderma* triterpene biosynthesis (Liu et al. 2021b).

Research teams in China have developed a scarless CRISPR/Cas9 gene editing system in *Cor. militaris*, which enables efficient scarless editing and precise knockout of single and double genes, laying the foundation for gene editing breeding in *Cor. militaris* (Meng et al. 2022). The optimized cellulase degradation system was introduced into *Cor. militaris* using gene editing technology to transform it into a creature that feeds on agricultural waste, successfully converting agricultural waste into the high-added-value anti-cancer drug Pentostatin; this method is more efficient and environmentally friendly (Zou et al. 2021).

CONCLUSION AND OUTLOOK

Since 2000, China has become the world's largest producer and consumer of edible fungi. Based on comprehensive data on the edible fungi industry in China since 2014, as well as related scientific literature, we present a systematic overview of the edible fungi industry in China and analyze its developing trends. China's edible fungi industry is maintaining steady scale expansion through optimized production methods, emerging cultivated edible fungi species, and increasingly integrated processing chains.

China's edible fungi industry has indicated sustained rapid growth in the past decade, with a CAGR of 3.18% in production, 6.46% in production value, and 2.51% in the number of commercial species. In recent years, rapid developments of cultivation and breeding technologies have driven higher output and quality production of edible fungi. We predict that China's edible fungi production value will increase from 396.56 billion RMB in 2023 to 527.39 billion RMB by 2030.

China has diversified production models in the edible fungi industry. The transition from scattered household cultivation to cooperative production involving "Company + Farmer", coupled with the development of park-like, large-scale, and industrialized cultivation, has steered China's edible fungi industry towards cluster development. An increasing proportion of industrialization is a significant trend in China's edible fungi cultivation. There are also a rich range of cultivation techniques in China which meet the needs of various environmental conditions and mushroom species. In this paper, 24 rapidly expanding species in China since 2014 were reviewed, especially *O. sinensis*, *Lyo. decastes*, *Morchella* spp., *Hym. raphanipes*, and *Ple. citrinopileatus*.

China's edible fungi processing industry exhibits remarkable diversification across various processed foods, healthy products, medicine, and cosmetics, significantly increasing the value of edible fungi. China has made significant progress in scientific research on edible fungi, including genetic breeding, surveys of germplasm resources, optimization of cultivation techniques, biosynthesis mechanisms of secondary metabolites, and processing methods for edible fungi products.

However, persistent challenges include rudimentary facilities, outdated technologies, rising costs and profitability constraints, limited product diversification and value addition, a shortage of professional persons, and an incomplete standardization framework, resulting in inconsistent product quality and suboptimal economic returns that dampen industrial development momentum. While scientific researches advance rapidly, the translation of scientific achievements into practical applications remains insufficient to meet industrial demands.

Challenges and recommendations for high-quality development of China's edible fungi industry include: 1) Weak industrial foundations. Industrial production faces limited adoption of automation/intelligent equipment, as well as overdependence on imported seeds with limited genetic diversity. We should increase investment in fully automated production systems, novel cultivars adapted to industrial cultivation, reliable spawn preservation and production protocols, and other related areas. 2) Rising costs and profitability constraints. We should optimize cultivation techniques and identify optimal economic parameters for investment-return ratios. In the cultivation of wood-rotting fungi, further development of substitute substrates for wood is being pursued to break the traditional boundaries between wood-rotting fungi and straw-rotting fungi, achieving the integration of these two types of fungi, reducing resource waste, and realizing the goal of recycling agricultural waste (Tan 2024). 3) Limited product diversification and value addition. The processing industry faces monolithic product structures and slow full-chain development. We should strengthen processing technologies and develop high-value functional products (e.g., nutraceuticals, pharmaceuticals). 4) Professional persons shortage. We recommend fostering industry-academia-research integration by establishing enterprise-led consortia with universities/research institutes, to standardize production from spawn to raw materials, and conduct demand-driven scientific research and innovation. 5) Incomplete standardization framework. Gaps exist in spawn quality, product standards, and cultivation protocols across the industrial chain. We should accelerate the development of comprehensive standards through unified technical specifications for standardized production, international compatibility alignment, and quality assurance systems for processed products.

In short, China's edible fungi industry has broad prospects for development. Through continuous scientific research and industrial upgrading, it is expected to maintain rapid development, making significant contributions to human health and economic advancement.

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DECLARATION ON CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCE

Assemie A, Abaya G. 2022 – The effect of edible mushroom on health and their biochemistry. International Journal of Microbiology 2022(1), 8744788.

Bao D. 2021 – Development and prospect of genetics of edible mushrooms in China. Mycosystema 40(4), 806–821 (in Chinese).

Bao D, Chen H, Wu Y, Zou G. 2022a – Discussion on the new track of future development of Chinese mushroom industry. Edible and Medicinal Mushrooms 30(05), 333–337 (in

Chinese).
Bao D, Pan Y, Tan Q. 2022b – Understanding and enlightenment of the fundamentals of China's edible mushroom industry development. Journal of Fungal Research 20(03), 160–165 (in Chinese).
Bao D, Tan Q. 2024 – The major scientific and technical issues in the development of Chinese edible mushroom industry. Edible and Medicinal Mushrooms 32(04), 217–225 (in Chinese).
Bao D, Zou G, Pei X, Yang R et al. 2022c – Discussion on the path toward high quality modernization of edible fungi industry in China. Acta Edulis Fungi 29(06), 103–110 (in Chinese).
Bian Y. 2020 – Edible fungi cultivation. Zhongyuan Farmers Publishing House, Henan (in Chinese).
Cao B, He MQ, Ling ZL, Zhang MZ et al. 2020 – A revision of *Agaricus* section *Arvenses* with nine new species from China. Mycologia, 1–21.
Cao B, Zhang Y, Gao B. 2024 – Development history, current situation and trends of global *Lentinula edodes* industry. Acta Edulis Fungi 31(03), 1–20 (in Chinese).
Cao Y, Ji G, Luo S, Gao L et al. 2021 – Domestication and artificially cultivation of *Phlebopus portentosus*: retrospect and prospect. Mycosystema 40(12), 3064–3080 (in Chinese).
Cao Y, Wu SH, Dai YC. 2012 – Species clarification of the prize medicinal *Ganoderma* mushroom "Lingzhi". Fungal Diversity 56, 49–62.
Cao Y, Yang L, Li R, Feng F et al. 2022 – A preliminary study on composition of fungal species and nutrient transportation in *Naematelia aurantialba* culture. Acta Edulis Fungi 29(2), 48–53 (in Chinese).
CEFA. 2021 – Analysis of the results of the 2019 national edible fungi statistical survey. Edible Fungi of China 40(06), 104–110 (in Chinese).
CEFA. 2022 – Analysis of the results of the 2020 national edible fungi statistical survey. Edible Fungi of China 41(01), 85–91 (in Chinese).
CEFA. 2023 – Analysis of the results of the 2021 national edible fungi statistical survey. Edible Fungi of China 42(01), 118–127 (in Chinese).
CEFA. 2024 – Analysis of the results of the 2022 national edible fungi statistical survey. Edible Fungi of China 43(01), 118–126 (in Chinese).
CEFA. 2025 – Analysis of the results of the 2023 national edible fungi statistical survey. Edible Fungi of China 44(01), 120–129 (in Chinese).
Chai H, Chen L, Chen W, Zhao Q et al. 2017 – Characterization of mating-type idiomorphs suggests that *Morchella importuna*, *Mel-20* and *M. sextelata* are heterothallic. Mycological Progress 16(7), 743–752.
Chen GL. 1986 – Domestication and cultivation of *Schizophyllum commune* Fr. edible fungi. Edible Fungi 02, 8 (in Chinese).
Chen H, Zhao C, Yu H, Liu Y et al. 2013 – Research progress of quality evaluation methods for edible fungi. Edible Fungi 35(02), 7–8+11 (in Chinese).
Chen J, Yang Z, Wang Y, Gong Z et al. 2024 – Research progress in nutrient composition, functional activity and processing status of edible fungi. Science and Technology of Food Industry 45(12), 358–366 (in Chinese).
Cheng J, Zheng H, Ben W, Ma S. 2008 – Industrial cultivation of *Lyophyllum decastes*. Acta Edulis Fungi 2, 20–22 (in Chinese).
Dai Y, Yang Z. 2018 – Notes on the nomenclature of five important edible fungi in China.

Mycosystema 37(12), 1572–1577 (in Chinese).
Dai YC, Wang Z, Binder M, Hibbett DS. 2006 – Phylogeny and a new species of *Sparassis* (Polyporales, Basidiomycota): evidence from mitochondrial atp6, nuclear rDNA and rpb2 genes. Mycologia 98(4), 584–592.
Deng B, Zhang B, Xi L, Chang M et al. 2023 – The tissue browning and concomitant toughening of yellow *Flammulina filiformis* stipes is caused by oxidative damage-mediated metabolic disorder and cell wall glycan remodeling. Journal of Agricultural and Food Chemistry.71(44), 16593–16603.
Deng K, Lan X, Chen Y, Wang T et al. 2022 – Integration of transcriptomics and metabolomics for understanding the different vegetative growth in *Morchella sextelata*. Frontiers in Genetics 12.
Dong HR, Yu HL, Zhou F, Chen H et al. 2024 – Development status and trend of rare edible mushrooms industry in China. Edible and Medicinal Mushrooms 32(02), 77–83 (in Chinese).
Du Z, Li Y, Wang X, Wang K et al. 2023 – Re-examination of the holotype of *Ganoderma sichuanense* (Ganodermataceae, Polyporales) and a clarification of the identity of Chinese cultivated Lingzhi. Journal of Fungi 9 (3).
Duan C, Wang X, Zuo L, Yang J et al. 2013 – Study on the branch strains production technology of *Pleurotus eryngii*. Journal of Shanxi Agricultural Sciences 41(03), 230–232 (in Chinese).
Gao F, Xie W, Zhang H, Li S et al. 2022a – Molecular mechanisms of browning process encountered in morels (*Morchella sextelata*) during storage. Food and Bioprocess Technology 15(9), 1997–2008.
Gao F, Xie W, Zhang H, Li Z et al. 2022b – Metabolomic analysis of browning mechanisms of morels (*Morchella sextelata*) during storage. Postharvest Biology and Technology 185, 111801.
Gravina AG, Pellegrino R, Auletta S, Palladino G et al. 2023 – *Hericium erinaceus*, a medicinal fungus with a centuries-old history: Evidence in gastrointestinal diseases. World journal of gastroenterology 29(20), 3048–3065.
Gui Y, Zhu GS, Callac P, Hyde KD et al. 2015 – *Agaricus* section *Arvenses*: three new species in highland subtropical Southwest China. Fungal Biology 119(2), 79–94.
Guo A, Ning H, Qin Z, Tan X et al. 2018 – Effect of different cultivation methods on polysaccharides of *Ganoderma lucidum*. Edible Fungi of China 37(3), 47–51 (in Chinese).
Guo HB, Zhang ZF, Wang JQ, Wang SY et al. 2022 – Transcriptome analysis of genes associated with autolysis of *Coprinus comatus*. Scientific Reports 12 (1):2476.
Han D. 2023 – Hanging bag *Auricularia cornea* cultivation technique. Agricultural Technology & Equipment 5, 166–168 (in Chinese).
He HQ, Xiao ZT, Peng YY, Liu M et al. 2020 – Development history and innovation research progress of straw mushroom cultivation technology. Guangdong Agricultural Sciences 47(12), 53–61 (in Chinese).
Hou D, Yang R, Bao D. 2023 – Checklist of edible and officinal fungi domesticated and cultivated species in China. J Microbiol 43(6), 62–74 (in Chinese).
Huang HY, Yang SD, Zeng NK, Zhang GL et al. 2018 – *Hygrophorus parvirussula* sp. Nov., a new edible mushroom from southwestern China. Phytotaxa 373, 139.
Huang J, Song Y, Zhou Y, Xia H et al. 2024 – Bag cultivation technology of *Volvariella volvacea*. Horticulture & Seed 44(04), 12–14 (in Chinese).

Huang Y. 2014 – Practical mushroom farming. Fujian Science & Technology Publishing House.
Huang ZL. 2006 – Quality detection technology of edible fungi. Edible Fungi of China 25(5), 29–30 (in Chinese).
Ji K. 2019 – Research and development of industrialized cultivation of *Phlebopus portentosus*. Edible and Medicinal Mushrooms 27(01), 9–12 (in Chinese).
Jia R, Liu F. 2006 – Research current situation and developing prospect of *Coprinus comatus*. Food Science and Technology 11, 155–159 (in Chinese).
Jiang N, Dong H, Yu H, Li Q et al. 2025 – Achievements of China agriculture research system of edible fungi "the 14th Five-Year Plan" new varieties, new technologies and new products. Journal of Fungal Research 23(1), 1–20 (in Chinese).
Kang LZ, Han F, Lin JF, Guo LQ et al. 2013 – Breeding of new high-temperature-tolerant strains of *Flammulina velutipes*. Scientia Horticulturae 151, 97–102.
Kapahi M. 2018 – Recent advances in cultivation of edible mushrooms. In: Singh BP, Lallawmsanga, Passari AK (eds) Biology of Macrofungi. Springer International Publishing, Cham, 275–286.
Kew TRBG. 2018 – State of the world's fungi 2018.
Khan AA, Lu LX, Yao FJ, Fang M et al. 2023 – Characterization, antioxidant activity, and mineral profiling of *Auricularia cornea* mushroom strains. Frontiers in Nutrition 10, 1167805.
Khan AA, Yao F, Idrees M, Lu L et al. 2020 – A comparative study of growth, biological efficiency, antioxidant activity and molecular structure in wild and commercially cultivated *Auricularia cornea* strains. Folia Horticulturae 32(2), 255–264.
Khaund P, Joshi SR. 2016 – *Lentinula edodes* based GIS mapping, biometabolites and antiinflamatory activity of wild edible mushrooms from tropical 'sacred grove' forests of Meghalaya, India. Revista de Biología Tropical 64(1), 247–257.
Kong JX, Wei CH, Feng BB, Ren A et al. 2024 – Overview of research on *Lyophyllum decastes*. Edible fungi 46(2), 1–6 (in Chinese).
Li C, Xu S. 2022 – Edible mushroom industry in China: current state and perspectives. Applied microbiology and biotechnology 106(11), 3949–3955.
Li D, Zhang W, Zhang L, Zhang J et al. 2025 – Feasibility of using bamboo sawdust as a substitute for wood sawdust in the cultivation of *Auricularia cornea* and comprehensive quality evaluation. Food and Fermentation Industries, 1–10 (in Chinese).
Li F, Cao Y, Jin Z, Dong C et al. 2024 – Research progress of biological characteristics and cultivation techniques of *Phlebopus portentosus*. Journal of Fungal Research, 1–9 (in Chinese).
Li H, Tian Y, Menolli N, Jr., Ye L et al. 2021a – Reviewing the world's edible mushroom species: a new evidence-based classification system. Comprehensive Reviews in Food Science and Food Safety 20(2), 1982–2014.
Li J, Yang W, Ren J, Cao B et al. 2023a – A New species *Agrocybe striatipes*, also a newly commercially cultivated mushroom with highly nutritional and healthy values. Journal of Fungi 9 (3).
Li R, Wang T, Wang Y, Xia J et al. 2018 – Comparative analysis of nutrients of three kinds of *Auricularia auricula*. Journal of Agriculture 8(03), 48–52 (in Chinese).
Li SJ, Wang Q, Liu QZ, Dong CH. 2019 – Current status and prospects of biological study and sclerotium cultivation of *Wolfiporia cocos*. Mycosystema 38(09), 1395–1406 (in Chinese).
Li T, Li Y, Li T, Deng W. 2023b – A taxonomic revision of commercial *Phallus* species in China.

Acta Edulis Fungi 30(05), 94–102 (in Chinese).
Li Y. 2018 – The status, opportunities and challenges of edible fungi industry in China: develop with Chinese characteristics, realize the dream of powerful mushroom industrial country. Journal of Fungal Research 16(03), 125–131 (in Chinese).
Li Y. 2021 – The sustainable development of edible fungi industry in China in the post epidemic era. Journal of Fungal Research 19(01), 1–5 (in Chinese).
Li Y. 2022 – The role of edible fungi in building the overall situation of food security. Journal of Fungal Research 20(3), 157–159 (in Chinese).
Li Y, Kang Y. 2017 – Edible fungi production in China. Higher Education Press, Beijing (in Chinese).
Li Y, Xu Z, Shang D, Zhang Y et al. 2021b – Optimization of *Agaricus bisporus* liquid culture cultivation by response surface methodology and preparation of reduced liquid culture. Northern Horticulture(14), 134–142 (in Chinese).
Li Z. 2003 – A study on the culturing technique of mushroom species in liquid. Journal of Shandong Education Institute(05), 98–99 (in Chinese).
Li Z. 2024 – Key points of liquid culture and application of edible fungi. World Tropical Agriculture Information(05), 19–21 (in Chinese).
Liang Q, Ding L, Tian L, Wang Y et al. 2024 – Domestication and cultivation of a wild brown strain of *Agaricus bisporus* collected from Qilian Mountains. Mycosystema, 1–15 (in Chinese).
Ling YY, Ling ZL, Zhao RL. 2022 – Construction of a heat-resistant strain of *Lentinus edodes* by fungal Hsp20 protein overexpression and genetic transformation. Frontiers in Microbiology 13.
Liu F, Wang SH, Jia DH, Tan H et al. 2023 – Development of multiple nucleotide polymorphism molecular markers for enoki mushroom (*Flammulina filiformis*) cultivars identification. Journal of Fungi 9(3).
Liu JW, Luangharn T, Wan SP, Wang R et al. 2022a – A new edible species of *Gomphus* (Gomphaceae) from southwestern China. Mycoscience 63(6), 293–297.
Liu Q, Qu S, He G, Wei J et al. 2022b – Mating-type genes play an important role in fruiting body development in *Morchella sextelata*. Journal of Fungi 8 (6).
Liu QM, Song HY, Chen RX, Chen MH et al. 2021a – Species concept of *Cyclocybe chaxingu*, an edible mushroom cultivated in China. Mycosystema 40(05), 981–991 (in Chinese).
Liu R, Zhu T, Yang T, Yang Z et al. 2021b – Nitric oxide regulates ganoderic acid biosynthesis by the S-nitrosylation of aconitase under heat stress in *Ganoderma lucidum*. Environmental Microbiology. 23(2), 682–695.
Liu W, He PX, Shi XF, Xu WJ et al. 2022c – Progress in the cultivation process and related basic research of *Morchella* spp. in China. Edible and medicinal mushrooms 30(04), 261–270 (in Chinese).
Liu WY, Guo HB, Bi KX, Sibirina Lidiya A et al. 2022d – Determining why continuous cropping reduces the production of the morel *Morchella sextelata*. Frontiers in Microbiology 13.
Liu XB, Feng B, Li J, Yan C et al. 2016 – Genetic diversity and breeding history of Winter Mushroom (*Flammulina velutipes*) in China uncovered by genomic SSR markers. Gene 591(1), 227–235.
Liu XB, Li J, Yang ZL. 2017 – Genetic diversity and structure of core collection of winter mushroom (*Flammulina velutipes*) developed by genomic SSR markers. Hereditas 155(1),

3.
Luo S, Ji K, Cao Y, Ji G. 2022 – A new *Phlebopus portentosus* cultivar 'YL1701-2'. Mycosystema 41(07), 1140–1142 (in Chinese).
Lv S, Chen X, Mou C, Dai S et al. 2018 – Agrobacterium-mediated transformation of the ascomycete mushroom *Morchella importuna* using polyubiquitin and glyceraldehyde-3-phosphate dehydrogenase promoter-based binary vectors. World Journal of Microbiology and Biotechnology 34(10), 148.
Ma BP, Liu SC, Li RC, Zhou ZF et al. 2019 – Study on cultivation technique of *Schizophyllum commune*. Journal of lnner Mongolia Agricultural University (Natural Science Edition) 40(01), 11–21 (in Chinese).
Ma BP, Luo XY, Liu SC, Li RC. 2017 – Advances in the research of *Schizophyllum commune* Fr. Edible and Medicinal Mushrooms 25(05), 303–307+322 (in Chinese).
Ma C, Zhang Z, Wu Z, Pan L et al. 2023 – Research progress on eficient cultivation and biological activity of tree-cultivated *Ganoderma lingzhi*. China Fruit & Vegetable 43(5), 55–59 (in Chinese).
Mei Y, Liu CY, Li SH, Guerin-Laguette A et al. 2021 – *Phlebopus roseus*, a new edible bolete from China, is associated with insects and plants. Mycologia 113(1), 33–42.
Meng G, Wang X, Liu M, Wang F et al. 2022 – Efficient CRISPR/Cas9 system based on autonomously replicating plasmid with an AMA1 sequence and precisely targeted gene deletion in the edible fungus, Cordyceps militaris. Microbial Biotechnology 15(10), 2594–2606.
Meng Q. 2019 – Main technical points of wooden chip spawn production of *Pleurotus ostreatus*. Edible Fungi 41(01), 63+68 (in Chinese).
Mori K. 1987 – Cultivated mushrooms in Japan. In: Wuest PJ, Royse DJ, Beelman RB (eds) Developments in Crop Science, vol 10. Elsevier, pp 455–459.
Nie L, Li H, Nie F. 2007 – High-quality circular cultivation of *Auricularia heimuer* by substitute cultivation. Contemporary Eco-Agriculture Z2, 59–116 (in Chinese).
Pang J, Sun GQ, Yu J, Wang HY et al. 2016 – Research progress of mechanism and inflencing factors of *Lentinus edodes* shiitake color-turning. Guizhou Agricultural Sciences 44(03), 99–101 (in Chinese).
Qiu MM, Hu YX, Lin C, Zhang FY et al. 2022 – Research of postharvest preservation methods of edible fungi in the application of *Volvariella volvacea*. Edible Fungi of China 41(02), 1–5+9 (in Chinese).
Qiu Z, Wang S, Zhao J, Cui L et al. 2023 – Synthesis and structural characteristics analysis of melanin pigments induced by blue light in *Morchella sextelata*. Frontiers in Microbiology 14.
Ren C, Wang M, Wu J, Zhou F et al. 2025 – Research status and prospect of edible fungus factory equipment in China. Journal of Chinese Agricultural Mechanization 46(5), 207–213 (in Chinese).
Ren Z, Fang H, Meng X, Zhang K et al. 2018 – Breeding of a new white *Auricularia cornea* Ehrenb. “White Wood Ear”. Molecular Plant Breeding 16(3), 954–959 (in Chinese).
Royse DJ, Baars J, Tan Q. 2017 – Current overview of mushroom production in the world. In: Edible and Medicinal Mushrooms. 5–13 (in Chinese).
Shen Q, Li C, Xie M, Li W et al. 2020 – A novel PCR-based approach for rapid identification of *Morchella sextelata* using species-specific primers. Current Microbiology 77(2), 232–237.

Stalpers JA, Redhead SA, May TW, Rossman AY et al. 2021 – Competing sexual-asexual generic names in Agaricomycotina (Basidiomycota) with recommendations for use. IMA fungus 12(1), 22.

Sun CH, Chen LY, Chen J, Zhao BL et al. 2023 – Status quo of strain seeds of edible fungi and measurement to prevent and control their degeneration. J Microbiol 43(6), 124–128 (in Chinese).

Svanberg I, Lindh H. 2019 – Mushroom hunting and consumption in twenty-first century post-industrial Sweden. Journal of Ethnobiology and Ethnomedicine 15(1), 42.

Tan FH. 2019 – Analysis of development process of cultivation technique with 'external nutrition bag' of *Morchella* in China. Edible and Medicinal Mushrooms 27(04), 257–263 (in Chinese).

Tan Q. 2024 – The development history of edible fungus cultivation. Acta Edulis Fungi(05), 1–8 (in Chinese).

Tan W, Miao R, Zhou J, Li X et al. 2018 – Advances in cultivation techniques of *Auricularia cornea*. Acta Edulis Fungi 25(1), 1–12 (in Chinese).

Tang J, Yang Z. 2024 – Phylogeny and taxonomy of the *Naematelia aurantialba* complex in southwestern China. Journal of Fungi 10 (12).

Tang SM, He J, Zhang XL, Wang L et al. 2018 – Research advances in artificial cultivation of *Tremella aurantialba*. Edible Fungi of China 37(04), 1–4 (in Chinese).

Tian D, Liu Q, Gao K, Wang Y. 2024a – Research on interprovincial agglomeration and spatial differentiation of China's edible fungi industry. Northern Horticulture 07, 139–146 (in Chinese).

Tian YX, Tong JY, Wang W, Tian X et al. 2019 – Research progress on commensalism of *Tremella*. Edible Fungi 41(04), 1–3 (in Chinese).

Tian Z, Cao L, Wang M, Zhao J et al. 2024b – Research progress on cultivation techniques and active components of *Auricularia cornea*. Edible Fungi 46(1), 6–10 (in Chinese).

Wang GZ, Ma CJ, Luo Y, Zhou SS et al. 2018a – Proteome and transcriptome reveal involvement of heat shock proteins and indoleacetic acid metabolism process in *Lentinula edodes* thermotolerance. Cellular Physiology and Biochemistry 50(5), 1617–1637.

Wang HJ, Li GJ, Zhao RL. 2018b – Artificial cultivation and nutrition analysis of *Pleurotus placentodes* wild strain. Mycosystema 37(5), 606–616 (in Chinese).

Wang M, Zhao R. 2023 – A review on nutritional advantages of edible mushrooms and its industrialization development situation in protein meat analogues. Journal of Future Foods 3(1), 1–7.

Wang N, Tian S, Ma Q, Zhang P et al. 2025 – Research progress on biological characteristics, cultivation techniques and polysaccharide efficacy of *Naematelia aurantialba*. China Cucurbits and Vegetables 38(5), 14–19 (in Chinese).

Wang T, Xu J, Liu X. 2024a – Research progress on *Ganoderma* cultivation. Journal of Fungal Research 22(01), 94–102 (in Chinese).

Wang Z, Tao K, Yuan J, Liu X. 2024b – Design and experiment on mechanized batch harvesting of Shiitake mushrooms. Comput Electron Agric 217, 108593.

Wang ZR, Parra L, Callac P, Zhou JL et al. 2015 – Edible species of *Agaricus* (Agaricaceae) from Xinjiang Province (Western China). Phytotaxa 202, 185–197.

Wei S, Qi B, Zhang X, Peng Z et al. 2024 – Global diversity and biogeography of *Lyophyllum* inferred from amplicon datasets. Frontiers in Ecology and Evolution 12, 01–12.

Wu F, Dai Y. 2015 – Notes on the nomenclature of the *Auricularia auricula-judae* complex. Mycosystema 34(4), 604–611 (in Chinese).

Wu F, Li SJ, Dong CH, Dai YC et al. 2020a – The genus *Pachyma* (Syn. *Wolfiporia*) reinstated and species clarification of the cultivated medicinal mushroom "Fuling" in China. Frontiers in Microbiology 11.

Wu F, Tohtirjap A, Fan LF, Zhou LW et al. 2021 – Global diversity and updated phylogeny of *Auricularia* (Auriculariales, Basidiomycota). Journal of Fungi 7 (11).

Wu JJ, Song WD, Wang MY, Ding TH et al. 2018a – Application of wheat grain spawn in the cultivation of *Agaricus bisporus*. Edible Fungi 40(02), 5–7 (in Chinese).

Wu SR, Yan M, Chen X, Deng YY et al. 2020b – Current status of the development of edible and medicinal fungi medicine in China. Edible fungi of China 39(7), 1–9 (in Chinese).

Wu T, Ye Z, Guo L, Yang X et al. 2018b – De novo transcriptome sequencing of *Flammulina velutipes* uncover candidate genes associated with cold-induced fruiting. Journal of Basic Microbiology 58(8), 698–703.

Wu W, Yu X, Li Q, Jia Z et al. 2024 – The current status and development countermeasures of edible fungi intensive processing. Agricultural Equipment & Vehicle Engineering 62(9), 9–13 (in Chinese).

Xia Y, Shi L, Tang Z, Zhou H et al. 2022 – Iterative upgrading of *Lentinula edodes* cultivation technology and comparison of industrialized and agricultural cultivation modes. Edible and Medicinal Mushrooms 30(5), 338–342 (in Chinese).

Xiang X, Li C, Li L, Bian Y et al. 2016 – Genetic diversity and population structure of Chinese *Lentinula edodes* revealed by InDel and SSR markers. Mycological Progress 15(4), 37.

Xiao Y, Cheng X, Liu J, Li C et al. 2016 – Population genomic analysis uncovers environmental stress-driven selection and adaptation of *Lentinula edodes* population in China. Sci Rep 6(1), 36789.

Xiao Z, He H, Liu M, Peng Y et al. 2022 – Development history and key technical points of *Oudemansiella raphanipes* cultivation. Edible and Medicinal Meshrooms 30(04), 277–282 (in Chinese).

Xie HJ, Zhang CX, He MX, Liang ZQ et al. 2021 – *Buchwaldoboletus xylophilus* and *Phlebopus portentosus*, two non-ectomycorrhizal boletes from tropical China. Phytotaxa 520, 137–154.

Xing Q, An W, Zhang J, Gu C. 2019 – Analysis of nutritional composition and safety of *Ganoderma Lucidum* under different cultivation methods. Shanxi Forestry Science and Technology 48(4), 8–11 (in Chinese).

Xu B, Wu KX, Zheng LX, Ji H. 2016 – The application technology research for the reduced liquid strains of *Pleurotus eryngii*. Food Research and Development 37(01), 195–197 (in Chinese).

Xu H, Hua f, Ji G, Kou F. 2023 – The common problems and countermeasures in the production of wheat grains spawn of *Stropharia rugosoannulata*. New Rural Technology 10, 22–23 (in Chinese).

Yang Y, Chen X, Dai Y, ZHou L et al. 2023 – Sanghuang industry in China: current status, challenges and perspectives: the Qiandao Lake declaration for sanghuang industry development. Mycosystema 42(4), 855–873 (in Chinese).

Yang Y, Dong C. 2024 – Fruiting body heterogeneity, dimorphism and haustorium-like structure of *Naematelia aurantialba* (Jin Er mushroom). Journal of Fungi 10 (8).

Yang Y, Li J, Hong Q, Zhang X et al. 2022 – Polysaccharides from *Hericium erinaceus* fruiting bodies: Structural characterization, immunomodulatory activity and mechanism. Nutrients

14(18).
Yang Z, Mao L, Yang T. 2021 – *Buchwaldoboletus xylophilus* has realized the artificial indoor cultivation. Edible and Medicinal Mushrooms 21(05), 439 (in Chinese).
Yao Q, Chen G, Yan S, Lin X et al. 2018 – Nutritional analysis and evaluation of two varieties of *Auricularia polytricha*. Acta Nutrimenta Sinica, 40(2), 197–199 (in Chinese).
Ye L, Zhang B, Yang X, Li X et al. 2023 – Feasibility of *Auricularia cornea* cultivation with bamboo sawdust instead of wood sawdust and comprehensive evaluation of quality. Acta Agriculturae Zhejiangensis 35(06), 1416–1426 (in Chinese).
Yu F, Guerin-Laguette A, Wang Y. 2020 – Edible mushrooms and their cultural importance in Yunnan, China. In: Pérez-Moreno J, Guerin-Laguette A, Flores Arzú R, Yu F-Q (eds) Mushrooms, Humans and Nature in a Changing World: Perspectives from Ecological, Agricultural and Social Sciences. Cham: Springer International Publishing, 163–204.
Yu H, Zhang L, Shang X, Peng B et al. 2022 – Chromosomal genome and population genetic analyses to reveal genetic architecture, breeding history and genes related to cadmium accumulation in *Lentinula edodes*. BMC Genomics 23(1), 120.
Yu Z, Li N, Gong Z, Wang W et al. 2023 – Research progress on edible fungus flavor substances and their detection technology and application. Science and Technology of Food Industry 45(2), 373–379 (in Chinese).
Yue WS, Hua R, Liu SX, Li XS et al. 2020 – Investigation of factors affecting spawn quality of edible fungus and methods to improve spawn quality. Tillage and Cultivation 40(6), 28–32 (in Chinese).
Zhang CX, He MX, Ji KP, Cao Y et al. 2012 – Studies on ecological characteristics of *Phlebopus portentosus*. Southwest China Journal of Agricultural Sciences 25(02), 614–619 (in Chinese).
Zhang F, Liu Y, Li Q. 2014 – Culture technology of coprophilous straw-rotting fungi. Edible Fungi of China 33(05), 73–76 (in Chinese).
Zhang J, Shen N, Li C, Xiang X et al. 2022a – Population genomics provides insights into the genetic basis of adaptive evolution in the mushroom-forming fungus *Lentinula edodes*. Journal of Advanced Research 38, 91–106.
Zhang JX, Chen Q, Huang CY, Gao W et al. 2015 – History, current situation and trend of edible mushroom industry development. Mycosystema 34(4), 524–540 (in Chinese).
Zhang Q, Shu F, Chen X, Liu W et al. 2022b – Construction of nucleus-directed fluorescent reporter systems and its application to verification of heterokaryon formation in *Morchella importuna*. Frontiers in Microbiology 13.
Zhang Y, Mo M, Yang L, Mi F et al. 2021 – Exploring the species diversity of edible mushrooms in Yunnan, Southwestern China, by DNA barcoding. Journal of Fungi 7 (4).
Zhao RL. 2023 – Edible and medicinal macrofungi. Journal of Fungi 9 (9).
Zheng W, Yao F. 2012 – Key techniques for the production and utilization of wooden chip spawn of *Auricularia heimuer*. Edible and Medicinal Mushrooms 20(03), 164–165 (in Chinese).
Zhu J, Sun Z, Shi D, Song S et al. 2019 – Dual functions of AreA, a GATA transcription factor, on influencing ganoderic acid biosynthesis in *Ganoderma lucidum*. Environmental Microbiology 21(11), 4166–4179.
Zou G, Li B, Wang Y, Yin X et al. 2021 – Efficient conversion of spent mushroom substrate into a high value-added anticancer drug pentostatin with engineered *Cordyceps militaris*. Green Chemistry. 23(24), 10030–10038.

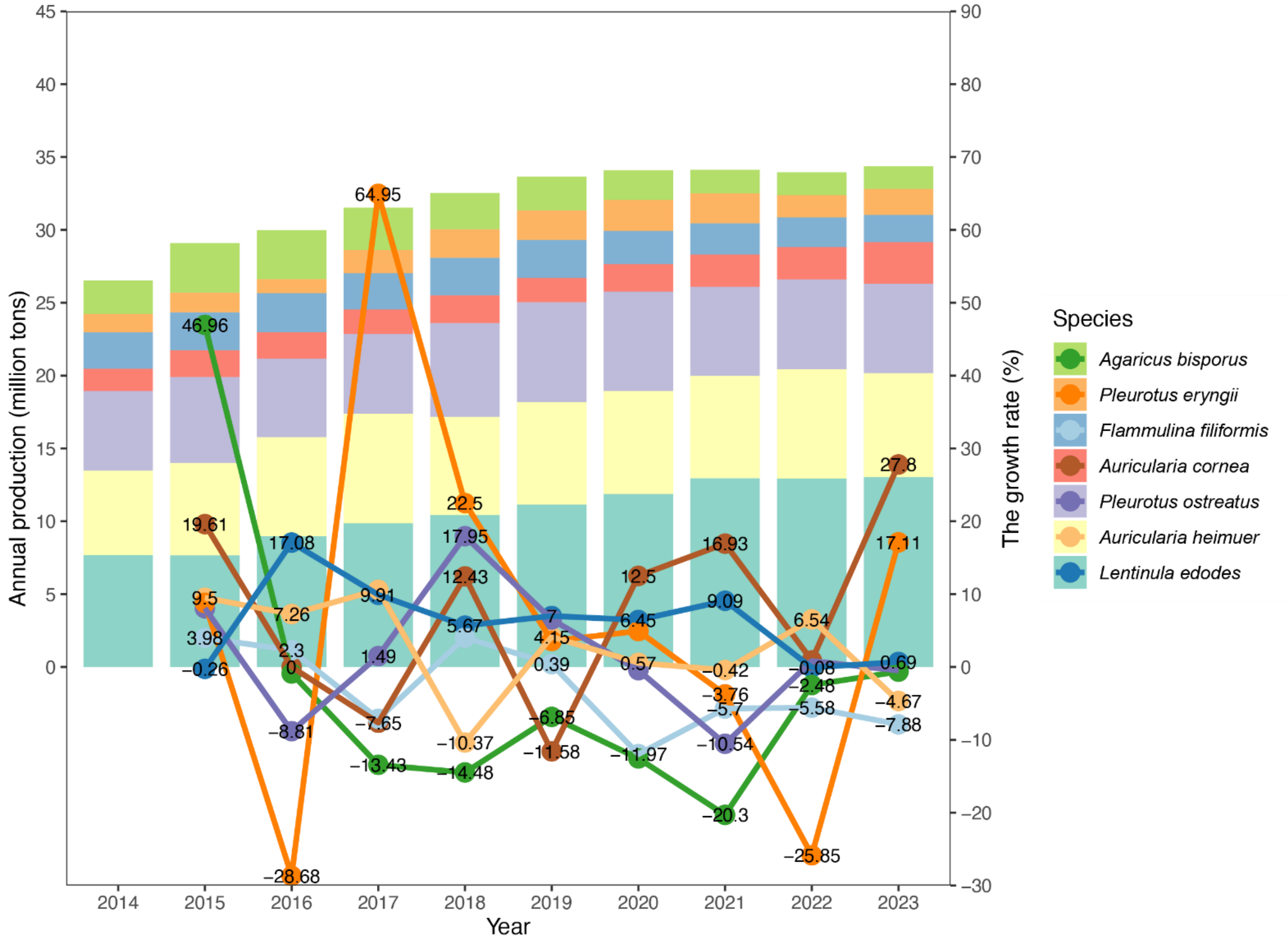

Figure S1 – Production changes in bulk species.