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Article

Edible Mushroom Cultivation for Food Security and Rural Development in China: Bio-Innovation, Technological Dissemination and Marketing

Yaoqi Zhang [1,2,*], Wei Geng [3,*], Yueqin Shen [4], Yanling Wang [1] and Yu-Cheng Dai [5]

[1] International Center for Ecology, Meteorology, and Environment, School of Applied Meteorology, Nanjing University of Information Science and Technology, Nanjing 210044, China; E-Mail: wangyl2117@hotmail.com

[2] School of Forestry and Wildlife Sciences, Auburn University, AL 36849, USA

[3] School of Economics, Tianjin University of Finance and Economics, Tianjin 300222, China

[4] College of Economics and Management, Zhejiang Agriculture and Forestry University, Hangzhou 311300, China; E-Mail: shenyueqin-zj@163.com

[5] State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China; E-Mail: yuchengd@yahoo.com

* Authors to whom correspondence should be addressed; E-Mails: zhangy3@auburn.edu (Y.Z.); gengwei@tjufe.edu.cn (W.G.); Tel.: +1-334-844-1041 (Y.Z.); Fax: +1-334-844-1084 (Y.Z.); Tel.: +86-22-8818-6265 (W.G.); Fax: +86-22-2837-1969 (W.G.).

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Abstract: Mushrooms traditionally collected from forests and now more cultivated have recently become the products of the fifth-largest agricultural sector in China. It was estimated that more than 25 million farmers in China are currently engaged in the collection, cultivation processing and marketing of mushrooms. The total value of mushroom products amounted to 149 billion RMB Yuan (24 billion USD) in 2011. The raw materials have expanded from a few hardwoods to a variety of woods and increasing more into agricultural residues and wastes. The average annual growth rate has been over 10% over the past 30 years in China. This paper describes the rapid growth of mushroom cultivation and its contribution to food security and rural sustainable development. The roles of bio-innovation, technological dissemination, and marketing are also examined. Mushrooms could potentially be very important in future food supplies and in new dimensions of sustainable agriculture and forestry.

Keywords: edible fungi; rural economy; diets; poverty reduction; trade; sustainable agriculture

1. Introduction

A mushroom is the fleshy, spore-bearing fruiting body of a fungus, typically produced above the ground on soil or on its food source, mostly in forests. It is perhaps the most well-known and documented edible forest product [1]. The word "mushroom" means different things for different people in different countries [2]. Since ancient times, man has been interested in mushrooms, which were called "food of gods" by the Romans. The Greeks regarded them as providing strength for warriors in battles. Mushrooms are mysterious, cultural, traditional and legendary [3].

Mushrooms have been widely used as foods [4,5], and very often as delicious and nutritious foods [6]. For example, The Pharaohs prized mushrooms as a delicacy food [7], and valuable resources for medicines as well [8]. Mushrooms contain a large array of nutrients and other natural phytochemicals that have wide ranges of nutritional and health benefits [9]. Their medicinal values include wound-healing, immunity-enhancement, and tumor-retarding effects [10,11]. Their value has recently been promoted to tremendous levels with medicinal mushroom trials conducted for HIV/AIDS patients in Africa, which have been generating encouraging results [12].

Edible mushrooms were only traditionally harvested wild and were difficult to domesticate and cultivate. Collection from wild woodlands is still important in the world and particularly in southern Asia [13,14], and other developing countries [15]. Although cultivation of some species has had a long history, the scale was often small scale and only in few favorable climates, regions, and seasons. The shiitake (*Lentinula edodes*) could be one of the earliest species to be cultivated. Chinese growers introduced shiitake cultivation techniques to Japanese farmers, who named the mushroom and were later responsible for its spread eastward [16]. Cultivation of saprotrophic species such as oyster mushrooms and shiitake has grown rapidly in recent decades [3].

As the amount of wild mushrooms shrink from both the degraded environment and nature resources as well as more costly labor, cultivated mushrooms would not only provide food security, but also sustainable and more nutritious diets [6]. The rapid growth and market expansion of the mushroom business in China is a great example of rural development driven by bio-innovation and technological diffusion. It is also an excellent example of rural economic development and poverty alleviation as well as typical recycle-economy and sustainable agriculture and forestry.

This article is going to focus on cultivated mushrooms. The objectives of this paper are to describe the fast growth of the mushroom economy and its drivers in China and to provide useful knowledge of the technological innovation and dissemination for rural development to the rest of the world. The mushroom economy, bio-innovation, and technical diffusion are presented in order. Some challenging issues are also discussed in the conclusions. The information used in this paper is more based on the existing literature and data available, particularly from the reports from the mushroom professional organization, and the methodology used is more a review and synthesis. We wish this review will provide more in-depth investigation on this emerging industry.

2. Mushroom Cultivation Economy in China

Prior to the late 1970s, all major economic activities, such as rice and wheat cultivation and sales, were controlled by the Commune System in China. Ironically, the mushroom cultivation was viewed as a minor of farm activities, and received less attention by the government. Few policies, regulations and controls were considered to provide incentives. Households were allowed to engage in the production as a second business, on a very small scale. However, the productivity was very low due to poor cultivation techniques. Only two to four species (such as straw mushrooms, shiitake, and white jelly fungus) were cultivated.

The past half-century has witnessed rapid growth in cultivated mushroom production. From 1969 to 2009, the world mushroom production has increased about ten times. The most notable increases occurred in China, the US, the Netherlands, India and Vietnam, according to the FAO [17]. Since the early 1980s, China has maintained a growth rate of 10% per year for three decades. The total mushroom production has increased from 60,000 tons with less than 100 million Yuan of value (15 million USD) in 1978 to 25.7 million tons with over 87 billion Yuan (13 billion USD) in 2008 [18], and 149 billion Yuan (24 billion USD) in 2011[19]. China's share of global mushroom production has increased from 5.7% in 1978 to 80% in 2008 (see Table 1).

The mushroom industry is currently ranked the fifth among the agricultural products of China (after grain vegetable oil, fruits, and vegetables) [20]. The exports amounted to 1.7 billion USD in 2008 [18]. Although China's export of mushrooms accounts for only about 40% of the total world mushroom export in recent years, the majority (95% of the total production) has been domestic consumption.

Table 1. China's production of edible mushrooms.

Year	Production		Values
	Production in China (1000 tons)	Share of World products (%)	(in billion Yuan)
1978	60	6	
1986	586	27	
1994	2641	54	
2000	6636	64	23
2001	7818	66	32
2002	8764	71	41
2003	10,387	73	48
2004	11,600	68	46
2005	13,340	70	48
2006	14,000	70	64
2007	16,820	75	80
2008	17,300	80	82
2009	20,203	80	110
2010	22,012	80	141
2011	25,717	80	149

Sources: The edible Fungi association of China [18] and Wu *et al.* [19].

Edible mushrooms have become an important food source for the Chinese. It is recommended by nutritionists to have three dishes (meat(s), vegetables, and mushrooms) for a standard meal in China.

According to the survey by the China Edible Fungi Commerce Network, the average annual per capita edible fungi consumption in Shenzhen, Shanghai, Beijing, and other large cities in 2003 was 6 kg, which exceeds the US, Europe, and Japan [21]. The level has increased to more than 10 kg per year in 2008. Current mushroom cultivation primarily uses the residuals or waste of agriculture and wood production and China. Although a great amount of wood has been used for the cultivation, the increased price of woods has also created incentive for fast growth of forest producing mushroom-growing materials in a few provinces.

Over the past three decades edible mushroom cultivation has been a large portion of household economies for many farmers although a few large state-owned, farm-produced mushrooms cultivated as complimentary vegetable supplies (starting in Beijing and Shanghai in the early 1980s) for many years. Mushroom cultivation has been primarily carried out by numerous rural households. Due to its special demand for climate, mushroom cultivation was geographically concentrated in a few places—particularly, in the warm, humid south—and, thus, so is the culture of mushroom consumption. Numerous small-scale rural households have also shaped the regional mushroom supply market centers. The Chinese Edible Fungi Association estimated that about 95% of mushroom production was grown by small-scale households in the early 1990s.

The spatial distribution among the provinces is presented in Figure 1. In the 1980s, Fujian and Zhejiang were dominant in the production, but in the late 1990s and early 2000s, Henan in the northern China, and Hubei, Hunan and Sichun in the central south were producing a lot as well. Recently, Jilin and Heilongjiang in the northeastern China have the fastest increase and are catching up since they have the most abundant raw materials and land. There were 18 provinces producing values exceeding 2 billion RMB Yuan in 2008.

Figure 1. Mushroom output values (million Yuan) by provinces (2000, 2004, 2008).

As labor-intensive agriculture, the mushroom industry can create significant job opportunities. It was estimated that around 25 million people work in the mushroom cultivation and processing industry [22]. The traditional mushroom production region was located in southeast China where the climate is warm and humid and favorable for mushroom growth. Since the 1990s, the production center has been moving toward the north where the labor costs are lower, raw materials particular residuals of agriculture are cheaper and abundant, and market access is closer to more populated northern cities like Beijing and Tianjin. More recently the production has been moving to north-eastern China where woods and land are more abundant and central China where the agricultural residues are more available (see Figure 1).

The impacts of the mushroom business on livelihoods and poverty reduction are significant and wide-spread. Mushroom cultivation does not require a lot of land and is a viable and attractive activity for both rural farmers and peri-urban dwellers. Mushroom growing does not require significant capital investment and the scale of cultivation can be large or small based on the capital and labor availability. It can be cultivated on a part-time basis with little maintenance. Indirectly, mushroom cultivation also provides opportunities for improving the sustainability of small farming systems through the recycling of organic matter, which can be used as a growing substrate and then returned to the land as fertilizer. Women, elders, and children can actively engage in the cultivation. A large amount of work in mushroom cultivation, such as filling substrates into plastic bags or containers, harvesting, and marketing, is ideally suited for women's participation. Several programs have enhanced female empowerment through mushroom production by giving them the opportunity to gain farming skills, financial independence, and self-respect [23].

While household cultivation is still important, a large-scale integrated production model has been emerging. In order to reduce costs, increase productivity, and expand market share, some integrated firms have begun to coordinate with farmers in surrounding areas. For example, some portions of the cultivation are contracted out to farmers who, in return, are provided with bags of substrate as well as instructions with appropriate technology. The products are collected by the integrated firms. Such a model has been strongly encouraged and often financially supported by the government as it is much easier to implement quality control and safety assurance with larger and fewer firms than with the numerous small farmers.

The advantages of quality and safety assurance, together with better access to supermarkets, have helped large-scale mushroom growers take their shares in the marketplace. Along with emerging supermarkets in the past 20 years, the procurement system has changed from procurement at the agricultural food wholesale markets (around 10 years ago) to the current method of direct procurement from agricultural food supply merchants. Some supermarkets also rent counters to agricultural food suppliers who sell their products. Many large-scale integrated farms or enterprises supply mushrooms to supermarkets directly.

As most households also conduct other farming activities and other off-farm businesses, an accurate estimate on the number of jobs created is difficult. The Chinese Edible Fungi Association [18] estimated that there were 15 million rural farmers in the early 2000s and around 25 million farmers are currently engaged in the production and processing. It was also estimated that the total value of mushroom output was 87 billion Yuan in 2008. Therefore, each farmer, on average, would generate about 3500 Yuan in 2008. The variation must be huge. Several provinces (e.g., Fujian, Hebei, Jiangsu, and Sichuan)

produced more than 1 million tons. Edible mushroom production has become a major agricultural activity over 500 counties and the output value is over 100 million Yuan in more than 100 counties.

Two counties, Qinyuan in Zhejiang Province and Gutian in Fujian Province, should be specially mentioned. In Qinyuan, the total output value of the mushroom industry in 2008 reached 1.1 billion Yuan, of which the output value of the processing sector was 0.18 billion Yuan and that of supporting sectors (mushroom stock, plastics, other materials and machines, *etc.*) was 0.18 billion Yuan. It was estimated that about 70,000 people (more than half of the farmers) are actively engaged in mushroom-related business. In Gutian alone, more than half of the farmers are actively engaged in mushroom growth. The total output value in 2010 was 2.4 billion Yuan. It was estimated that the supporting services and marketing also generated output values between 0.2 and 0.4 billion Yuan. Ninety percent of the nation's white jelly fungus (*Tremella fuciformis* Berk) comes from Gutian alone.

3. Nature of the Bio-Innovation

The rapid development had not begun until a number of bio-innovations were made in the late 1970s and early 1980s. Shiitake and most other mushrooms have been cultivated on various species of hardwood trees. The procedure was to cut down the natural logs in the fall (after leaf fall) and inoculate them with shiitake spawn within 15 to 30 days after felling. Trees that are cut in the fall may also be left intact through the winter and, just before inoculation, cut into lengths of about 1 m. Once the logs are cut to the desired lengths, they are ready for inoculation, or spawning. Spawn is supplied in the form of wooden plugs or sawdust. Growers drill holes in the logs with high-speed drills, the holes corresponding to the diameter and length of the wood-plug spawn. Such techniques were of very low productivity in both wood and labor. No significant improvement to this method had been made for a long time.

One breakthrough for this cultivation was the utilization of synthetic logs instead of natural logs. Composed of sawdust and supplemented with millet and wheat bran, synthetic logs may produce three to four times as many mushrooms as natural logs in one-tenth of the time. Environmentally controlled houses allow for the manipulations of temperature, humidity, light, and the moisture content of the logs to produce the highest possible yields. The major advantages of producing shiitake on synthetic logs rather than natural ones are the consistent market supply through year-round production, increased yields, and decreased time required to complete a crop cycle.

Innovation by farmers was critical to use synthetic logs for all mushroom growth. The white jelly fungus was first cultivated in glass bottles using woody sawdust and then further extended using plastic bags for cultivation by three farmers (Dai Weihao, Yao Shuxian, and Pan Zhaowan) in the county of Gutian. The three farmers were honored as heroes by the local people and were widely reported in the local and national public media. Sawdust is the most popular basal ingredient used in synthetic formulations of substrate for producing shiitake, but other basal ingredients may include straw, corncobs, or both. Regardless of the main ingredient used, starch-based supplements (10 to 60 percent dry weight) such as wheat bran, rice bran, millet, rye, and maize are always added to the mix. These supplements serve as nutrients to create optimum growing mediums. Other supplements, added in lesser quantities, include calcium carbonate ($CaCO_3$), gypsum, and table sugar. These produce a better and more nutritious growing medium for shiitake.

Unlike other technologies, the farmers' innovations played very special roles in the rapid growth of mushroom cultivation and, interestingly, practical cultivation techniques have been largely innovated at the grass-roots level by farmers and individuals poorly equipped and less-educated than the experts. For example, a few major breakthroughs, such as changing from growing on wood logs to glass bottles in the late 1970s (and then in plastic bags in the early 1980s), going from indoor to outdoor farmland, and changing materials from woods to many other wastes and agricultural residues, were primarily developed and tested by farmers and private research institutes.

The farmers' innovations were built upon fundamental research and findings from public institutes. As mushroom farming was a traditional economic activity in southern China, many agricultural institutions, such as the Edible Mushroom Research Institute of the Shanghai Academy of Agriculture and South-Central Agricultural University, established specific teams working on the research who contributed to the progress. In order to improve vegetable supply conditions, the Beijing Municipal Government planned to grow mushrooms to substitute vegetables in the early 1980s.

For new species identification and breeding, the state research institutions, universities, and provincial research institutions have been playing important roles. The local institutes, on the other hand, are complimentary to providing breeds and preserved cultures to large-scale mushroom production farms and some small private institutes, which often undertake multiplications of the stock cultures and produce mushrooms by themselves or sell them to small-scale mushroom-cultivation rural farmers.

The impact of innovation on productivity is enormous. Using the white jelly fungus as an example, the productivity increased by 15–20 times and the duration was cut down from 150 days to 40 days using the synthetic wood log of wood-dust instead of natural wood log. Using cotton residuals can easily double productivity again. Using cotton residuals can produce 75 kg while using wood can only produce 25–35 kg per 1000 synthetic log bags. Many other innovations, such as disease control, also tremendously improved the productivity and success rates. Specialization and labor division, new machine innovations, and the new raw materials utilization improved the productivity.

Table 2. Top six species of mushroom productions in China, 2007–2011.

Year	Production (1000 tons)					
	Oyster	**Shiitake**	**Blackfungus**	**Velvet Foot**	**Buttonmushroom**	**HairyJew Ear**
	Pleurotus ostreatus	***Lentinula edodes***	***Auricularia polytricha***	***Flammulina velutipes***	***Agaricus Bisporus***	***Auricularia polytricha***
2007	4146	2885	1113	1178	2507	1441
2008	4340	3090	1000	1360	1910	630
2009	4429	3435	2697	1568	2181	890
2010	5599	4276	2896	1848	2206	1258
2011	5633	5018	3461	2493	2462	1435

Sources: Wu *et al.* [19].

The Chinese have identified 966 edible mushrooms and 576 medicinal species [11], of which, around 70 species can be cultivated and 18 species can be cultivated commercially. China tops the world in growing straw mushrooms (*Volvariella volvacea* (Bull.) Singer), tuckahoe (*Wolfiporia cocos* (F.A. Wolf) Ryvarden and Gilb), shiitake (*Lentinula edodes* (Berk.) Pegler), agaric (*Agaricus bisporus* (J.E. Lange) Imbach), wood ear (*Auricularia auricula-judae* (Bull.) Quél.), black fungus (*Auricularia polytricha*

(Mont.) Sacc.), white jelly fungus (*Tremella fuciformis* Berk.), eniki mushroom (*Flammulina velutipes* (Curtis) Singer), oyster mushroom (*Pleurotus ostreatus* (Jacq.) Quél.), King trumpet mushroom (*Pleurotus eryngii* (DC.) Quél.), and hedgehog fungus (*Hericium erinaceus* (Bull.) Pers.). Table 2 presents the top 6 species of mushroom production in China from 2007 to 2011 [19].

4. The Multiple Channels of Technological Dissemination

Unlike many developed countries where extension has been largely dependent on public extension systems or private extension-type service companies [24], China, where most farmers are often illiterate in science and have no access to scientific information, has been using the multiple channels for mushroom growth technologies have proven effective.

Compared with other industries, mushroom cultivation is simple and easy to learn after some trial practices. The government plays a very small role at the beginning. Usually, the farmers would not keep the secrets of their cultivation techniques when asked by relatives and fellow villagers. This channel of social networks probably played the most important role at the early stage of technical dissemination, leading mushroom cultivation to be concentrated in a few places and then slowly spreading across space.

The public media also played an important role. The public media had been working hard to promote rural development since the early 1980s. The government slogan for farmers was "getting rich is glorious." Major newspapers widely reported news covering villages, counties, businesses, and individuals who got rich from all kinds of farming activities. Mushroom cultivation was once a worthy approach for making quick income prior to manufacturing taking place in the late 1980s. Some successful farmers and villages received quite a wide amount of publicity and were noticed by farmers in other places, attracting ambitious and talented farmers from other areas to come to learn the technology. It was also often that some skilled growers were invited as tutors or technicians to a new place for cultivation and to aid the local farmers with good pay or some favorable policies such as good positions, land, and other support. It was mixed with successful and failed cases, but this mechanism was important to promote long-distance technological dissemination in the late 1980s and early 1990s.

During the late 1980s, the increasing costs of labor and raw materials in southern China, where mushroom growth was initiated and developed, made some talented and business-oriented farmers start to migrate to other places to cultivate mushrooms by taking advantage of lower labor and material costs. The technical dissemination was significant and had far-reaching effects since the number of migrated farmers was huge and almost distributed all over the country. According to our survey, almost one third of the farmers in Gutian and Fujian had short-term or long-term mushroom cultivation activities in other provinces, firstly in Guangdong Province in the early 1990s, then in northern China, such as Henan, Beijing, Liaoning, in the later 1990s and early 2000s.

Masses of farmers from some interior provinces (e.g., Sichuan Province) migrated to the coastal areas in Fujian and Zhejiang in search of various jobs. Some ended up in mushroom cultivation jobs where they quickly learned how to grow mushrooms; they then preferred to grow mushrooms by themselves instead of taking wage jobs. In Gutian alone, it was estimated there were several hundred households from other provinces renting land and setting up their own farms since the mid-2000s. Some of them returned home to cultivate mushrooms in their hometowns. Such a channel of technical dissemination is becoming more important recently.

Private institutes have played important roles in the technological dissemination. Numerous private institutes were primarily motivated to sell strains and equipment. To do that, they usually have to do some pre-testing and some simple experiments. In order to keep and maintain their reputations, some training and follow-up services are usually provided. This was also an important channel for technological dissemination. More recently, some trainings, workshops, and seminars have been provided and organized by local village committees by inviting successful growers or technicians. These activities are usually very popular and well-received by farmers. The limitations of the private institutes include the knowledge and funding.

Joint experiments between public research institutes and farmers have also been playing important roles in dissemination of new technological improvements, particularly new species and premature cultivation methods. Usually, some incentives and public support are provided by the local governments. In case of failure, the farmers would not suffer the loss. This measure also prevents potential wide-spread loss in case of failure in some key areas. The demonstration sites are open to public access and learning. Apparently, this is a very effective measure as farmers can see for themselves and get clarification on any practical questions. As more investment is provided by the government, it seems that such collaboration is becoming more common.

5. Marketing

China has a very special history of food culture and edible mushrooms have a special place in the diet history. Due to its scarcity and costly harvesting, the Chinese had listed edible fungi as a precious and delicious food, or "mountain treasure", together with other foods from the ocean called "ocean tastes". Therefore, it was only the royal and noble families who had the privilege to enjoy the treasured foods (for an excellent review, see Hu, D. [21]). Some mysterious functions of edible mushrooms were recorded in Chinese literature. Due to the long culture history of using edible mushrooms, many Chinese believe that some edible mushrooms contain great nutritional value. Such a belief kept a few traditional mushrooms (like white jelly fungus and shiitake) at very high prices at first, leading many farmers to engage in both wild collection (called "treasure seeking") and exploration of new ways to cultivate.

New cultivation has led to the dramatic decline in the prices of mushrooms. Using the white jelly fungus as an example, the price was more than 1000 Yuan/kg in the late 1970s when the average annual household income was only 200–300 Yuan at that time. Currently, it is only 80 Yuan/kg, equivalent to about one day's pay. The good price was maintained not just by the strong domestic market, but by overseas Chinese consumers who share the same food and nutrition culture. Prior to the 1970s, a majority of white jelly fungus and shiitake were either used for medical purposes or were exported. The importance of foreign currency promoted the government (particularly, the foreign trade department) to support and establish research institutions engaged in the studies on the survey, classification, and domestication and cultivation technology of mushroom species resources.

The significant drop in price compared to the income is critical to allow ordinary households to access the foods, which were once extremely expensive. For example, the market price of dry shiitake was around 50 Yuan ($7)/kg, which was half of the monthly income in the early 1990s. Currently, it is very much the same (50 Yuan/kg), which is less than one day's pay. The expanding domestic demand in recent years took a larger share of the market and made China itself the chief mushroom consumption

market. More consumers are substituting meat products with mushrooms. In the early 2000s, over 80% of China's mushroom production was consumed domestically and less than 20% was exported. Currently, mushroom export accounts for less than 5% of China's total domestic production. This is in sharp contrast with the 1980s when over 80% of mushroom production in China was exported.

One unique but very important marketing channel that has been developed is the use of seasonal agricultural product expos, usually held in big cities (such as Shanghai, Beijing, Guangzhou, Hangzhou) across the country. The expos serve a number of functions, such as: (1) direct sales from producers in remote areas to consumers in big cities; (2) meetings and negotiations between producers and businessmen; and (3) the promotion of mushroom products as well as other agricultural products that are often not well-known to many consumers through mushroom cuisine demonstrations and cooking information.

In the producer regions, mushroom festivals are held annually, for example, in Gutian/Fujian, Qingyuan/Zhejiang, Zhangzhou/Fujian, *etc.* The main purpose of the festivals is to promote local products that include not only mushroom products but also equipment and new technologies. The festivals attract businessmen from around the country and even the world. Such festivals usually receive great attention and are largely supported and organized by local governments. In order to get public attraction and media attention, cultural components such as music and art performances, mushroom culture, cuisine demonstrations and competition, and conferences and seminars are held simultaneously. The local governments often take them very seriously. They try to give the world the impression as well as the perception of the best quality of their products. Presently, both Gutian and Qingyuan have mushroom museums built by public finance to promote mushroom culture, history, cultivation information, and, most importantly, local products. The Dashan Group (a production and trade firm based in Qingyuan) has built another privately-owned mushroom museum in Shanghai to promote mushroom culture, history, and technologies as well as the products.

After decades of development, local and small markets of mushrooms in China have developed into integrated, national-level market centers and several national wholesale markets for mushrooms have been formed (e.g., Gutian Mushroom Market, Qingyuan Mushroom Market, Beijing Xinfadi Farm Produce Wholesale Market). The changes have resulted from improved communication and transportation (The National Mushroom Market Information Network) and large wholesalers at national levels as well as increasing technological knowledge and awareness of mushroom products.

6. Conclusion and Discussion

Mushroom production has been described as the most versatile and prolific agriculture and forestry venture all over the world. The production in the United States, Japan, the Netherlands, Germany, and the United Kingdom increased from the 1960s to 1980s. However, it seems stagnant and even in decline in recent years [17]. In contrast, the world production has doubled every decade primarily due to the growth in China. For example, Japan once was very successful in shiitake cultivation, was the leader in its biotechnology, and was dominant in the international market. However, with its high labor cost, Japan could not compete with China and lost to Chinese producers in recent decades. A few other countries like Indonesia, India, and Vietnam have great potential. In general, it is still a labor-intensive industry and developing countries still have advantages in mushroom growth. The FAO has been actively promoting mushroom cultivation for rural development and food security in developing countries [23].

Bio-innovation is very important for mushroom cultivation and so is the technological dissemination [24]. Technological development can largely increase production capabilities and even significantly reduce the costs, but market promotion and nutrition education could be important as well. Mayett, Y. *et al.* [25] found that preferences and perceptions to mushrooms from Mexican consumers depended on the social level, although the variation of mushroom prices was a major factor influencing consumption. The challenge is to recognize opportunities such as increasing consumption capabilities with the increase in world population and to take advantage of this by promoting the consumption of mushrooms [12].

Mushrooms could be an important sector for our future agriculture and forestry as proposed by Qiu, H. *et al.* [26]. Huge quantities of wide varieties of organic waste are generated from agriculture, forestry, and food processing. Mushroom cultivation is an effective bioconversion technology of transforming wastes and woods into potentially valuable resources. Mushroom cultivation could also be an important part of sustainable agriculture and forestry.

Wood waste from thinned material and overstocked small-diameter wood poses a serious threat to forest health and forest fires, which severely damage the ecosystem, threaten life, and are extremely expensive to control. How to effectively use the wastes and residuals from forest and wood production provides useful alternative practices. It was suggested that varieties of woods that can be used to grow mushrooms [27]. At the same time, the demand for woods as raw materials has also promoted alternative development of forest cultivation and management. In China, a special category of forest is planted for mushroom materials in all major mushroom cultivation locations. Accordingly, specific species and silviculture have been investigated and developed [28]. The understories and floors of forests are also good places to grow certain species of mushroom.

Growing evidence shows that mushroom growth has great potential in many other countries, particularly in developing countries. Approximately 14,000 described species of the 1.5 million fungi estimated in the world produce fruiting bodies that are large enough to be considered as mushrooms [12]. Given the many mushroom species that have not yet been studied, new discoveries of the health benefits of mushrooms will continue and promising mushroom treatments and products for human diseases may be found in the future [29].

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Author Contributions

Yaoqi Zhang, Wei Gen and Yu-Cheng Dai jointly initiated the project and conceptualized and structured the paper. Wei Gen led the project. Yaoqi Zhang and Wei Gen analyzed the data, and led the writing. Yueqin Shen made contribution in data collection and discussion of the manuscript. Yanling Wang contributed in the writing and particularly the finalization of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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