BIO-INNOVATION AND TECHNOLOGICAL DIGITIZATION OF MUSHROOM CULTIVATION AND MARKETING FOR RURAL DEVELOPMENT

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ABSTRACT

Mushrooms, which were originally picked from forests but are now more often produced, have recently emerged as the products of the world's largest agricultural sector. It is believed that more than 25 million farmers in China are actively engaged in the collecting, cultivation, processing, and sale of mushrooms, according to government statistics. The raw materials have extended from a few hardwoods to a range of woods, with the proportion of agricultural residues and wastes growing as time go on. The average yearly growth rate has been more than 10% in China during the previous 30 years, according to official statistics. This report describes the fast expansion of mushroom production, as well as its contribution to food security and rural development through sustainable practices. Aspects such as bio-innovation, technical digitalization, and marketing are also considered in this study. Mushrooms have the potential to play a significant role in future food supply as well as in the development of new dimensions of sustainable agriculture and forestry.

Keywords: Digitization, Bio-Innovation, Rural Development, China, Mushroom Marketing.

INTRODUCTION

Mushrooms have long been used as food, and they are frequently considered to be delicious and healthful. For example, the Pharaohs regarded mushrooms as a delicacy food as well as a rich source of medicinal ingredients and materials. A wide variety of minerals and other natural phytochemicals are found in mushrooms, and these compounds are associated with a wide range of nutritional and health advantages (Cheung, 2010). Their medical benefits include the ability to heal wounds, boost immunity, and slow the growth of tumors. In recent years, medicinal mushroom experiments done for HIV/AIDS patients in Africa have raised the profile of the mushrooms to incredible heights. The findings of these trials have been overwhelmingly positive (Chang, 2006). A mushroom is the fleshy, spore-bearing fruiting body of a fungus that is normally grown above ground on soil or on its feeding supply, with the majority of mushroom production occurring in forest environments. I believe it is the most well-known and recorded edible forest product on the planet. For various individuals in different nations, the word "*mushroom*" can mean a variety of distinct things (Chang e al., 1992). Mushrooms have piqued the interest of humans since antiquity when they were referred to as "*food of the gods*" by the Romans. Their importance to the Greeks was that they provided strength to warriors during battle. Mushrooms are mystical, cultural, traditional, and legendary, and they have a long history.

Edible mushrooms were previously taken only from the wild, and they were difficult to domesticate and culture in the laboratory. World-wide, and particularly in southern Asia and other developing countries, collection from wild forests is still significant (Adusumalli, 2016). Despite the

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fact that some species have been cultivated for a long time, the scale of cultivation was frequently restricted and limited to a few ideal climates, locations, and seasons. The shiitake mushroom Lentinula edodes is said to be one of the first species to be domesticated. Chinese growers taught Japanese farmers how to cultivate the shiitake mushroom, which they called after the Chinese growers that brought it to them and were ultimately responsible for its expansion eastward (Royse, 2009). In recent decades, the cultivation of saprotrophic species such as oyster mushrooms and shiitake mushrooms has increased dramatically (Arora & Shepard, 2008).

Cultivated mushrooms would not only give food security, but they would also help to create more sustainable and healthy meals because of the diminishing amount of wild mushrooms due to both deteriorated environments and natural resources, as well as more expensive labor. The mushroom industry's quick growth and market extension in China is a remarkable example of rural development fueled by bio-innovation and technical diffusion, and it should be studied further. As well, it is a remarkable example of rural economic development and poverty alleviation, as well as a typical recycle-economy, sustainable agriculture, and forestry, among other things (Madding et al., 2020).

The focus of this article will be on mushrooms that have been grown in captivity. The purpose of this study is to discuss the rapid rise of the mushroom economy in China, as well as the factors that have contributed to this growth, and to disseminate important information about technology innovation and dissemination for rural development throughout the world. Presented in chronological order, the mushroom economy, bio-innovation, and technological diffusion are discussed. Conclusions include a discussion of several difficult issues that must be addressed (Fadziso et al., 2018). The content in this paper is primarily based on existing literature and data, mainly from reports from the mushroom professional association, and the approach employed is more of a review and synthesis in nature, rather than a comprehensive analysis. The authors hope that this review will lead to a more in-depth examination of this emerging business.

Mushroom Cultivation Economy

Prior to the late 1970s, the Commune System handled all main economic operations such as rice and wheat cultivation and sales. The government, however, regarded mushroom growing as a small farm activity. Few policies, laws, and controls were deemed motivating. Households were allowed to produce as a small side business. However, poor cultivation techniques resulted in meager yields (Pasupuleti & Adusumalli, 2018). In the past, just a few species (such straw mushrooms and shiitake) were cultivated.

A half-century of mushroom cultivation has seen rapid expansion. From 1969 to 2009, global mushroom production surged tenfold. The FAO reports large growth in China, the US, the Netherlands, India, and Vietnam (Food and Agriculture Organization of the United Nations, 2021). China has grown at a 10% annual rate since the early 1980s. Chinese eat a lot of edible mushrooms. A typical Chinese lunch should consist of three dishes meat, vegetables, and mushrooms.

The China Edible Fungi Commerce Network found that in 2003, edible fungi consumption per capita in Shenzhen, Shanghai, and Beijing reached 6 kg, exceeding the US, Europe, and Japan (Hu, 2005). In 2008, it was over 10 kg per year. Currently, mushroom growing relies on agricultural and wood waste from China. While a lot of wood has been utilized in cultivation, the rising cost of wood has prompted rapid expansion of mushroom-growing materials in a few areas.

Although a few major state-owned, farm-produced mushrooms cultivated as complementary vegetable supply (beginning in Beijing and Shanghai in the early 1980s) for many years. Many rural households have begun cultivating mushrooms (Pasupuleti, 2015a). Mushroom farming, like mushroom eating, is geographically concentrated in a few places, especially in the warm, humid south. Villages have shaped the regional mushroom supply market centers. In the early 1990s, the Chinese Edible Fungi Association estimated that small-scale households produced 95% of all mushrooms.

However, a large-scale integrated production approach is evolving. Some integrated enterprises have begun coordinating with nearby farms to decrease costs, enhance productivity, and market share

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(Pasupuleti et al., 2019). For example, some cultivation tasks are outsourced out to farmers, who are then supplied with substrate bags and technology. The integrated enterprises collect the products. The government has consistently promoted and often subsidized this model because it is easier to execute quality control and safety assurance with larger enterprises than with numerous small farms. This labor-intensive business can generate enormous career prospects (Hossen et al., 2021). Around 25 million people are employed in the mushroom growing and processing industry (Hang et al., 2008). The traditional mushroom growing location was in southeast China, where the environment is warm and humid. Since the 1990s, the production center has moved north, where labor costs are lower, raw materials are cheaper and plentiful, and market access is closer to northern cities like Beijing and Tianjin. Production has recently shifted to north-eastern China, where timber and land are plentiful, and central China, where agricultural leftovers are plentiful.

Quality and safety assurances, as well as easier access to supermarkets, have helped large-scale mushroom producers gain market dominance. Agricultural food wholesale markets (about 10 years ago) to direct procurement from agricultural food supply merchants (in the last 20 years). Farmers can hire counters in some supermarkets to sell their goods. Many large-scale integrated farms supply mushrooms directly to stores.

The mushroom industry has a large and widespread impact on livelihoods and poverty reduction. Mushroom cultivation is a feasible and pleasant hobby for both rural and peri-urban residents. Mushroom farming does not require a substantial capital investment and may be scaled up or down depending on capital and labor availability. It requires little upkeep and can be grown part-time. Indirectly, mushroom farming can improve small farm sustainability by recycling organic matter, which can be utilized as a growing substrate and subsequently returned to the soil as fertilizer (Pasupuleti, 2015b). We may cultivate together as a family. Women can easily participate in mushroom farming by loading substrates into plastic bags or containers, harvesting, and marketing. Several organizations have helped female empowerment by teaching them farming skills, financial independence, and self-respect (Marshall & Nair, 2009). It's difficult to quantify the amount of employment created because most households run other farms or enterprises. The Chinese Edible Fungi Association (China Mushroom Association, 2009) claimed that there were 15 million rural farmers producing and processing edible fungi in the early 2000s.

Nature of the Bio-Innovation

Using synthetic logs instead of natural logs was a breakthrough for this culture (Azam et al., 2021). Synthetic logs made of sawdust and millet and wheat bran generate three to four times as many mushrooms as real logs in a tenth of the time. Temperature, humidity, light, and log moisture content may all be managed in environmental controlled rooms to maximize harvests (Adusumalli, 2017). The main benefits of growing shiitake on synthetic logs over natural ones are year-round supply, higher yields, and shorter crop cycles (Adusumalli, 2018).

Growing mushrooms on synthetic logs required farmers to innovate. Three farmers Dai Weihao, Yao Shuxian, and Pan Zhaowan from Gutian County cultivated white jelly fungus in glass bottles with woody sawdust and later in plastic bags. The three farmers were hailed as heroes by the local and national media. Sawdust is the most common base element in shiitake substrate compositions, but additional base ingredients include straw, corncobs, or both. It doesn't matter what the main ingredient is, starch-based supplements (10-60% dry weight) like wheat and rice bran are always added. These nutrients help produce ideal growth conditions. Other minor supplements are calcium carbonate ($CaCO_3$), gypsum, and table sugar. These produce a more nutritious shiitake growing medium.

Several bio-innovations in the late 1970s and early 1980s triggered the rapid development. Shiitake and most other mushrooms are grown on hardwood trees. The natural logs were cut down in the fall (after leaf fall) and inoculated with shiitake spawn 15-30 days later. Fall-cut trees can be left unbroken through the winter and then chopped into 1 m lengths right before inoculation. After the logs are chopped to length, they are ready for inoculation (Pasupuleti, 2015). Spawn is provided as wooden

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plugs or sawdust. Growers use high-speed drills to make holes in logs that match the spawn's diameter and length. These methods were low in both wood and labor productivity. This approach had not been significantly improved in a long time.

It's interesting to note that practical farming techniques were mostly invented at the grass-roots level by farmers and individuals less prepared and educated than professionals (Adusumalli & Pasupuleti, 2017). Growing on glass bottles (later plastic bags) in the late 1970s (and early 1980s) was invented and tested mostly by farmers and private research organizations, as was moving from indoor to outdoor farms and from woodlands to many other wastes and agricultural residues.

Innovation has a huge impact on productivity. Using synthetic wood logs of wood dust instead of natural wood logs enhanced production by 15–20 times and decreased duration by 150 days. Cotton residuals can easily double output. Per 1000 synthetic log bags, cotton residuals can yield 75 kg while wood only produces 25–35 kg. Other advancements, such disease prevention, increased production and success rates. Specialization and labor division, new machine and raw material use boosted productivity.

The farmers' initiatives drew on basic research from governmental institutions. Because mushroom cultivation was a traditional economic activity in southern China, numerous agricultural institutions, such as the Shanghai Academy of Agriculture's Edible Mushroom Research Institute and South-Central Agricultural University, established research teams. In the early 1980s, the Beijing Municipal Government sought to grow mushrooms to replace vegetables.

State, university, and provincial research institutions have been crucial in new species identification and breeding. Local institutes, on the other hand, provide breeds and conserved cultures to large-scale mushroom farms and certain small private institutions that manufacture mushrooms or sell them to small-scale rural mushroom farmers.

Technological Digitization and Marketing Dissemination

The media also played a role. Since the early 1980s, the media has actively promoted rural development. “Getting rich is glorious,” the government told farmers. Major media extensively reported on villages, counties, corporations, and people who made money from farming. Before the late 1980s, mushroom cultivation was a viable way to make quick cash. Some successful farmers and villages acquired widespread notoriety, drawing ambitious and bright farmers from other locations to learn the technology. Sometimes, expert growers were asked as instructors or technicians to a new location to help local farmers with good salary, decent positions, land, and other benefits. This mechanism was significant for promoting long-distance technical distribution in the late 1980s and early 1990s.

Unlike many affluent countries where extension is heavily reliant on public extension systems or private extension-type service organizations (Mayett, et al. 2009), China has used numerous routes for mushroom growth methods that have proven effective. Unlike other industries, mushroom growing is basic and straightforward to master. Initially, the government has a minor involvement. When asked by relatives or neighbors, farmers usually reveal their cultivation secrets. This social network channel was arguably the most crucial at the beginning of technical transmission, concentrating mushroom growing in a few regions and then steadily extending over space.

Due to rising labor and material expenses in southern China, where mushroom cultivation began, several competent and business-minded farmers began to relocate to other locations to cultivate mushrooms. The technological diffusion was significant and far-reaching, given the large number of migrant farmers scattered over the country. After learning how to grow mushrooms, some ended up working on mushroom farms instead of obtaining wage employment (Pasupuleti, 2016). Since the mid-2000s, several hundred households from neighboring provinces have rented land and established farms in Gutian. Some of them returned home to grow mushrooms. This technical distribution method has recently gained importance.

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Experiments between public research institutes and farmers have also helped spread new technologies, particularly new species and early farming methods (Adusumalli, 2017). Local governments usually provide certain incentives and public support. Succeeding farmers would not lose money. This prevents widespread loss if crucial areas fail. The demonstration places are open to the public. This appears to be a very effective technique, as farmers can see for themselves and ask questions. As the government invests more, it appears that such partnership is becoming increasingly widespread (Pasupuleti, 2016).

Private institutes have helped spread technology. Many private institutes were motivated by sales of strains and equipment. They frequently undertake pre-testing and simple experiments to achieve this. Training and follow-up services are usually provided to keep their reputations. This was also a major technology dissemination route. Local village committees have recently arranged trainings, workshops, and seminars with successful producers or specialists. These activities are frequently well-liked by farmers. Private institutes have knowledge and financing limits.

Mushroom Marketing

Many Chinese think that some edible mushrooms have high nutritional value due to their long history of use. The high prices of some traditional mushrooms (such white jelly fungus and shiitake) drove many farmers to pursue wild collecting (dubbed "*treasure seeking*") and novel cultivation methods. Mushroom prices have fallen dramatically due to new cultivation. The low pricing was maintained by overseas Chinese consumers who share the same food and nutrition culture. White jelly fungus and shiitake were mostly employed for medicine or exported until the 1970s. The value of foreign currency prompted the government (especially the foreign trade department) to fund and establish research centers studying mushroom species resources.

The considerable decline in price relative to income is crucial to allowing regular households to acquire previously pricey meals. In recent years, growing domestic demand has made China the leading mushroom consumer. More people are choosing mushrooms over beef. In the early 2000s, China consumed almost 80% of its mushroom production and exported less than 20%. Currently, less than 5% of China's total domestic production is exported. In the 1980s, nearly 80% of China's mushroom crop was exported. The usage of seasonal agricultural product expos, mainly held in big cities (such as Shanghai, Beijing, Guangzhou, Hangzhou), has developed into a highly important marketing outlet. (1) Direct sales from rural producers to customers in big cities; (2) meetings and discussions between producers and businesspeople; and (3) promotion of mushroom cuisine demonstrations and cooking knowledge to many consumers (Ragi et al., 2021).

The events promote local products, including mushrooms, equipment, and innovative innovations. It draws businessmen from across the country and beyond. Local governments frequently fund and arrange such celebrations. Concurrently, cultural events such as music and art performances, mushroom culture, cooking demonstrations and competitions, and conferences and seminars are arranged to attract the public and media Mayett et al. (2009). So do municipal governments. They attempt to offer the world the best impression of their items' quality. Both Gutian and Qingyuan now have public-funded mushroom museums to promote mushroom culture, history, farming, and, most significantly, local goods (Hossen et al., 2021).

CONCLUSION AND DISCUSSION

Mushroom farming has been called the world's most adaptable and prolific agriculture and forestry venture. From 1960 to 1980, manufacturing rose in the US, Japan, the Netherlands, Germany, and the UK. However, global production has increased every decade, largely due to China's rise. For example, Japan used to be a leader in biotechnology and a global leader in shiitake farming. However, because to its high labor costs, Japan has recently lost market share to Chinese producers. Indonesia, India, and Vietnam also have considerable promise. On the whole, it's a labor-intensive business, with

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advantages for developing countries. As a result, the FAO has been actively supporting mushroom farming in developing nations.

Bio-innovation and technical diffusion are vital in mushroom growing. Technological advancements can greatly boost production capacity and cut costs, but market promotion and nutrition education can also help discovered that while price volatility was a substantial factor influencing consumption, it was not the only factor. The challenge is to promote mushroom consumption by recognizing and using opportunities such as expanding consumption capacity with increasing global population. Agriculture, forestry, and food processing generate huge amounts of diverse organic waste. It is a good way to turn wastes and woods into potentially profitable resources. Sustainable agriculture and forestry may include mushroom growing.

Forest fires, which cause significant ecosystem damage, risk lives, and are exceedingly expensive to prevent, are caused by thinning and overstocked small-diameter wood waste using wastes and residuals from forest and wood manufacturing is a useful alternative. A variety of woods can be used to cultivate mushrooms. Simultaneously, the demand for wood as a raw commodity has encouraged alternative forest production and management. In all important mushroom growing areas in China, a specific mushroom forest is established. So specialized species and silviculture were studied and created. Some mushrooms thrive on the forest's understory and floor.

Mushroom cultivation has significant promise in many other countries, especially in underdeveloped ones. Around 14,000 of the 1.5 million known fungal species produce fruiting bodies large enough to be called mushrooms. Because there are so many mushroom species yet to be explored, new discoveries of mushroom health benefits and viable mushroom treatments and products for human ailments are possible.

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