Indian Journal of History of Science, 52.1 (2017) 95-101 DOI: 10.16943/ijhs/2017/v52i1/41305

Scientific Explorations and Commercial Sales of the Straw Mushroom *Volvariella volvacea* (Bull.) Singer in Republican China: A Brief Review

Ruixia Wang*, Hui Cao*, Jingsong Zhang* and Qi Tan**

(Received 17 December 2015)

Abstract

This review describes the research status and commercial sales of *Volvariella volvacea* (Bull.) Singer during the Republican period (1912-1949) on the basis of precious data from National library of China, Shanghai library, Nanjing agriculture university library, Chongqing library, Shanghai acdemy of agricultural sciences library. This paper aims to lay the foundation for further studies with emphasis on other periods in Chinese history.

Key words: Cultivation, History of science, Inoculation, Republican period, *Volvariella volvacea* (Bull.) Singer

1. Introduction

The straw mushroom (*Volvariella volvacea*) is a highly nutritious popular delicacy in East and Southeast Asia, whose production in China reached approximately 6,000,000 tons in 2003 (Buswell and Chen 2005; Sun 2008). Initially well known as Nanhua Gu (the mushroom from Nanhua), the straw mushroom was probably cultivated in paddy straw by the Buddhist monks of the Nanhua Temple (located in Shaoguan city, Guangdong province, China) before the 18th century. And no later than the Tongzhi (1862-1874) period, as is shown by another name for this mushroom, i.e. Gonggu (tributary mushroom), it had already become tribute to the royalty in consideration of a relatively long process in which a local product turned into a royal tribute (Chang 1977). The native cultivation skill marked a breakthrough in the production and commercialization of this mushroom, which, though, remained rare in late Qing (1840-1911).

With the introduction of western science and technology in China new theories were localized, and innovations were developed in combination with traditional knowledge. Meanwhile, the straw mushroom as a healthy food, largely strange to science of that time and beneficial to peasants' economic life, also became one of the focuses of attention in the field of agriculture, especially the science and cultivation of edible fungi. This article aims to fill the present gap in the scientific history of edible fungi in Republican China (1912-1949), and contribute to the world transmission and regional development of science in modern history.

* Institute of Edible Fungi, Shanghai Academy of Agricultural Sciences; National Engineering Research Center of Edible Fungi; Shanghai 201403, China;

**Corresponding Author: Shanghai Academy of Agricultural Sciences, No.1000 Jinqi Road, Shanghai 201403, China; Email: wangruixia2893@163.com

Fig. 1. Straw Mushroom *Volvariella volvacea* (Bull.) Singer

2. Publication of Related Studies

We examined the Republican publications kept in the National Library of China, Shanghai Library, Nanjing Agriculture University Library, Chongqing Library and Shanghai Academy of Agricultural Sciences Library, and found two monographs and sixteen articles on the straw mushroom, and three books containing relevant parts devoted to the straw mushroom. In 1920s the researchers placed emphasis on the investigation of production situation, while in 1930s they began to apply some new techniques and in 1940s to conduct introduction tests. This process also accords with the course of human recognition and technical development.

3. Cultivation and Post-harvest Preservation Techniques

Cultivation fields should be exposed to the south, away from northern wind and easy to be irrigated. It would be better if there was natural and clean spring water, a key factor believed to be helpful in enhancing the delicious taste of *V. volvacea*, running near the fields. Irrigation after composting could be counted optimal when free water in the fields was controlled as just visible (Zeng 1921; Qiu 1935).

With respect to inoculation methods, Qiu (1935) reported that a straw bed (1 m in length)

Fig. 2. Section of *V. Volvacea*

consisted of 6 or 7 tiers, while a tier was composed of a straw bundle and an inoculated straw, and inoculums size, inoculated straw/ straw bundle was about 5%-10%. To control and detect the water content, Zeng (1921) introduced a simple but practical method: Crushed the straw tier underfoot, and then twisted straw bundles; if some water trickled out, that meant the water content was optimal. This method is still in use today.

Two kinds of methods used to keep spawn were also developed in the Republican period. The first method was related to dryness preservation. Combined fungal mycelium and growth substrate were kept dry for inoculation in early winter, while the remaining available was kept as fertilizer (Zeng 1921). The second method appeared later, relating to wetness preservation. Mycelium with growth substrate (straw) situated in furrows could also be served as spawn (Qiu 1935). After collecting the fruiting bodies of the straw mushroom within 3 days, mycelium with growth substrate (straw) needed to be thickened to 6 or 7 inches with straw to make it unable to grow again. Of course, it was not pure spawn despite that the

concept of spawn had already emerged in the Republican period. But it was still a significant breakthrough in the transition from traditional natural wild spore inoculation to spawn-kept and artificial inoculation.

Like spawn preservation, there was also diversity in the cultivation methods of the straw mushroom. According to Qu (1936) who formulated the bundle cultivation method, paddy straw needed to be first weaved into curtains (6 or 7 feet in length, 3 feet in width), then tightly rolled (a foot and a half in diameter) and soaked in water round the clock. Afterwards, drained off water, and laid the straw curtains flat on the ground to be inoculated.Another cultivation method, widely employed in Guilin, Guangxi, involved the use of straw bricks. First, put selected and thoroughly watered paddy straw into a model which was a foot and two inches in length, six inches in width, and one foot in depth (accommodating 3 kg of straw) beside the mushroom bed. Then, crushed the paddy straw in the model underfoot, facilitating the watering on the straw. In succession, made the soaked crushed straw into brick shape, which were then pulled up with any two angles, flipped flat, and orderly arranged onto the mushroom bed (Qiu 1952). In addition, the third method was called indoor cultivation, using curtains similar to those produced in the bundle cultivation process. Inoculated paddy straw was made into bundles for the growth of fungus, and 4-6 bundles were combined into round shape or four-angular shape. water was not needed during 10 days after spawn due to the fact that indoor cultivation protected straw from exposure to the sun and the wind (Pan 1936). Indoor cultivation, though preliminary, was an effective method for perennial production of the straw mushroom throughout the year.

Different references report different fruiting time of *V. volvacea*. It was February in Xinfeng, Jiangxi (Zeng 1921), March in Guangzhou, Guangdong (Qin 1926), and late February (Qiu 1935). This was mainly caused by different weather and climate in different regions. Relatively, Yang (1943) gave more detailed observations, reporting that high temperature (60-90 degrees Fahrenheit) and humid climate were optimum for the growth of the straw mushroom which was commonly distributed in tropics and subtropics. In respect of biological efficiency, it differed regarding the use of indica rice, japonica rice or glutinous rice. The ingredient content of glutinous rice straw was higher than that of the others. The yields were about 60 kg (higher), 45 kg (medium), 30 kg (lower) respectively in 500 kg [a yan (堰)i.e.10 dan (担)] straw. Accordingly, the biological efficiency was 6%-12%(Qiu 1935). Nevertheless, the biological efficiency of this mushroom remains relatively low even now, usually around 20%. By contrast, it is often between 100% and 150% by reference to some other kinds of mushrooms (Bao 2010).

Cultivation fields were always away from cities, so it was very important to preserve straw mushroom (Qiu 1935). There were two methods. The first was drying method, exposured to the sun for 4 h and then moved into the drying chamber to fire drying. The second was canned method: Fresh ,washed *V. volvacea* fruit bodies were stored in bamboo basket, then immersed immediately 1% boiling salt solution for 3 min, transferred into running cool water , and loaded into the cans, 2% hot salt solution were added, sealed, sterilizated at fahrenheit 120 for 25 min (Yang 1943).

4. Research by using Modern Mycology Knowledge

Although the mycological terms such as spore, mycelium and bud were used in the principal literature introducing the straw mushroom cultivation technology (He 1936; Qu 1936; Bei 1937), modern mycological theories and knowledge was used rarely. This situation changed when the *Cultivation Methods of the Straw Mushroom* was published in 1928, representing a landmark in the assimilation of scientific

theoretical knowledge of fungi in modern China. This book records the development of the fruiting body of *V. volvacea* for the first time, which was divided into 4 phases: kinking period, egg period, elongation period, and mature period. Although some terms were not standard due to limited modern theoretical mycological knowledge, it seemed inevitable during the early transmission of exotic knowledge to modern China. Besides, the 1928 book also mentions the biological characteristics of *V. volvacea*. For example, it points out that the straw mushroom grew best under the high-temperature condition (26-36 ^{o}C), because of which the mushroom was seldom cultivated in spring and autumn due to low temperature. This was the first record introducing the effect of temperature on the growth of *V. volvacea*.

It was clear what can be used for spawn. Old and big straw mushroom fruiting bodies were picked up and dried, grinded into powder, stored in bottles, and then sealed. In fact, the powder contains both spore and mycelium. Straw where mushroom and mycelium luxuriant growth were dried and stored indoor in September and October. It could not be used if it had been stored for over one year (Pan 1936). Tao (1937) studied the spore reproduction of the straw mushroom. Spores in the gills of old fruiting bodies were cultured into mycelia, and transferred to manure. The procedure was kind of complex, but had good effects. As for mycelium reproduction, it was simple but only suitable for beginners and small-amount production. It was technological progress.

Qiu (1940) first introduced the scientific name and classification of the straw mushroom. He found that there were two species *Volvaria volvacea* and *V. esculenta* cultivated in Republican China. He told that they belonged to the Agaricaceae family, but now according to contemporary biological classification of fungi we know that *V. volvacea* belongs to Volvariella, Pluteaceac, Agaricales, Holobasidiomycetidae, Hyoenomycetes, Basidiomycatina (Liu *et al*. 2012).

5. Introduction Tests

The introduction of the straw mushroom was the only one tested species among the five cultivated kinds of mushroom (*Lentinula edodes*, *Tremella fuciformis*, *Auricularia auricula*, *Poria cocos*, *V. volvacea*) in Republican China (Jia *et al*. 2015). The reasons were as follows: straw mushroom *V. volvacea* is delicious and with high economic value, cultivation materials and methods are simple and easy to be popularized (Qiu 1940).

Environmental conditions play a crucial role in the decision whether a fruiting body will be formed. The optimal environmental situation for mycelial growth and the subsequent fruiting is usually very distinct- fruiting body development is often induced after drastically altering the environmental circumstances (Fan *et al.* 2008). There is no universal set of the conditions that lead to fructification in all mushrooms. The conditions for growing and producing fruiting bodies of a given species have to be empirically established; but the natural environment of the fungus may give valuable indications as how to proceed in this determination. Once the situation has been optimized for a certain fungus, this might help when establishing the cultural conditions for related species (Scrase and Elliott, 1998).

Qiu (1940) investigated the feasibility of introducing the straw mushroom along the way from Guangxi province to Chengdu city , Sichuan province. The temperature in Guangxi was 23^{0} C in April, 29-30^{0} C in June-July, 25-20^{0} C in October and 10^{0} C in January. The straw mushroom was sown in April. Its fruiting bodies emerged in May, and later gradually came out more and more, indicating that the growth temperature for the straw mushroom was over 20^{0} C, while yields were highest when the temperature was 28^{0} C. the average humidity was relatively high (80%).

Average temperature in Chengdu, Sichuan: May (21-22^{0}C), June (28-29^{0}C), September (22-23^{0}C), the average humidity was 75%-80%. So, It was feasibility introduction test from Guangxi to Chengdu, Sichuan due to the same temperature and humidity.

Cultivation method in Chengdu. Advanced experience in Guangxi was applied according to local (Chengdu)conditions and didn't applied it mechanically. The first stage is to obtain spawn.The used straw was used to inoculate in Guangxi, but it was inconvenient to transport from Guangxi to Chengdu. So , Spore inoculation method was used. Spore was collected from agricultural experiment field in Guangxi by Dr. HUANG XR *et al*. There were three kinds of spore: pure spore, spore mixed plant ash, spore attached to straw mushroom.Straw was made into bundles (1 kg /bundles) soaked in water for 24 h and placed in cube (1 m× 2 m ×1 m), about 120~150 bundles, pure spore (10 g) or spore mixed plant ash(15 g) or spore attached to straw mushroom (35 g) was solved in water, and sprayed evenly over the straw layer, and covered it to avoid evaporation.

Everything was done in early May, fruiting body formation in early August (Qiu 1940). There were no difference between fruiting body from Guangxi and from Chengdu. Introductions test to Nanchang, Jiangxi province by MAO FQ (1941) and to Shaowu, Fujian province by CHEN XB (1942) has been done following the success of introductions test from Guangxi to Chengdu.

6. Sales in main Production Areas

There were mainly four provinces in southern China (Guangdong, Guangxi, Jiangxi and Fujian provinces) where the straw mushroom could be cultivated due to hot weather. We can still find from their reports that the annual output of the straw mushroom amounted to 400-500 dan (20000-25000 kg) in Xinfeng, Jiangxi, and 150 dan (7500 kg) in Liujiang, Guangxi (Yang 1943). And in Zhusigang and Taojinkeng, Guangzhou, the straw mushroom was even sold to hotel restaurants and teahouses in Hong Kong (Qin 1926). Previously, people used tile jars and boxes to load the mushroom; but gradually people realized that they were not suitable for transportation. Later, iron drums replaced tile jars and boxes, with their interface soldered by tin. This kind of container has been passed down to date (Qiu 1935). As for profits, the straw mushroom in Xinfeng sold to Guangzhou was in the vicinity of 100,000 Yuan (Zeng 1921). Annual investment per mu (666.7 m^2) was 166 Yuan and total income was 1320 Yuan (best) or 880 Yuan(medium) or 660 Yuan (low) (Qiu 1935). This indicates that mushroom cultivation was relatively still a profitable activity at that time.

The detailed information on the production areas, seasons, and transportation centres for *V.volvacea* was relatively systematically and comprehensively recorded in the 1937 *Zhongguo tongyou difang wuchanzhi*, which is of great significance to the investigation of the historical changes in the economy and resource of edible and medicinal fungi. On the basis of arranging the historical information, it analysed the geographical features of the distribution of edible and medicinal fungi productions, and their major production areas and and discussed relevant issues (Lu 2015).

7. Conclusion

Knowledge of modern fungi theory has been applied in the straw mushroom in Republican China. Spore and mycelium can be used to cultivate. Artificial cultivation method of pure strain has not been used , but already got rid of natural inoculation and was the origin of straw mushroom cultivation new method in China. It was a new transformation from learning from the West and Japan to get science and technology by local people. It was an important contribution to scientific knowledge system.

Acknowledgments

We are grateful to Mr. Shenmao Jia who contributed his time and effort in collecting primary sources.

Bibliography

Bao, D.P.; Zhao, G. P.; Tan, Q.; *et al.*. Draft Sequence of the *Volvariella volvacea* Genome. *Acta Eduis Fungi*, 17.1(2010): 3-5.

Bei, J. Straw mushroom cultivation method. *China New Agriculture*, 1.1 (1937): 113-114.

Chang, S.T. The origin and early development of straw mushroom cultivation. *Economic Botany* 31(1977): 374-376.

Chen, A.W. and Huang, NL. Production of the medicinal mushroom *Tremella fuciformis* Berk. by mixed-culture cultivation on synthetic logs. *International Journal of Medicinal Mushrooms*, 3.2(2001): 130.

Chen, X. B. Cultivation of straw mushroom. *Fukien Agricultural Journal*3.2 (1941): 168-172.

Extension Department of the College of Agriculture, National Sun Yat-Sen University.. Cultivation of straw mushroom (4th). Guangzhou: National Sun Yat-Sen University, (1934):1-5.

Fan, L.; Soccol, C.R.; and Pandey, A.. Mushroom Production. In: *Current Developments in Solid-state Fermentation*. Asiarech Publishers ,New Delhi, (2008) 253-274.

Gan, L. How to cultivate *Volvariella volvacea. Agricultural Sound Monthly*, 168 (1933): 1-3.

He, Y. X. *Volvariella volvacea* cultivation. *Public Rural Sideline Monthly*, 1.5 (1936): 81-85.

He, K. Z. *Experimental cultivation of straw mushroom*. Guilin: Experimental Field of Straw Mushroom Cultivation in Guilin, Guangxi, 1938.

Huang, G. Q. *Volvariella volvacea* cultivation. *Agricultural Sound Monthly*, 3(1923):3-6.

Jia, S. M. and Wang, R. X. The effect of spawn knowledge in western nations on China. *Edible and Medicinal Mushrooms*, 23.1(2015)56-58.

Liu, P.H.; Deng, Y.J.; Jiang, Y.J. *et al*.. Analysis of Differentially Expressed Genes between Mycelium and Primordium of Paddy Straw Mushroom (*Volvariella volvacea*). *Genomics and Applied Biology*, 31.2 (2012): 147-153.

Lu, Di. Study on the edible and medicinal fungi and their economy recorded in *Zhongguo Tongyou Difang Wuchanzhi*. *Ancient and Modern Agriculture*, 1(2015):51-66.

Mao, F. Q. Straw mushroom cultivation method. *Agricultural Extension Communication*, 4.5(1942): 14-18.

Mao, F. Q. Straw mushroom cultivation method. *Agricultural Extension Communication*, 4.6(1942): 48-51.

Pan, Z. N. *Cultivation of Mushroom throughout the Year* (2th edition).Sanshan Agricultural Cooperatives, Fuzhou, 1936.

Pan, Z. N. *New Experiments Artificial Cultivation of Mushroom, Questions and Answers* (3rd edition). Sanshan Agricultural Cooperatives, Fuzhou, 1937.

Qin, W. K. Investigation of *Volvariella volvacea. Farming Bimonthly*, 5.2(1926): 55-58.

Qiu, G. S. *Volvariella volvacea* cultivation. *Journal of Modern Production*, 1.8 (1935): 64-68.

Qiu, W. F. Memories segmentsof of my research on edible fungi. *Edible Fungi of China*, 4.1 (1985): 1-2.

Qiu, W. F. Speak again about my research experience on edible fungi. *Edible Fungi*, 12.1 (1991): 2-3.

Qiu, W. F. Preliminary success and prospects of straw mushroom introduction from Guangxi to Chengdu. *Agricultural Newspaper*, 5.31-33(1940):625-628.

Qiu, W. F. *Chinese Edible Fungi and Their Cultivation*. Zhonghua Book Company, Shanghai, 1952.

Qu, C. *Volvariella volvacea* cultivation. *Public Rural Sideline Monthly*, 1.5(1936): 74-80.

Scrase, R. J. and Elliott, T. J. *Biotechnology and Technology of Mushroom Culture in Microbiology of Fermented Foods*. Thompson Science, London, 1998:543-584.

Sun, X. H; Chen, M. J.; Pan, Y. J. Cloning, sequence analysis and putative promoter region of a Glyceraldehyde-3-Phosphate dehydrogenase gene from *Volvariella volvacea*, and expression pattern under cold stress. *Acta Edulis Fungi*, 15.1 (2008): 25-31.

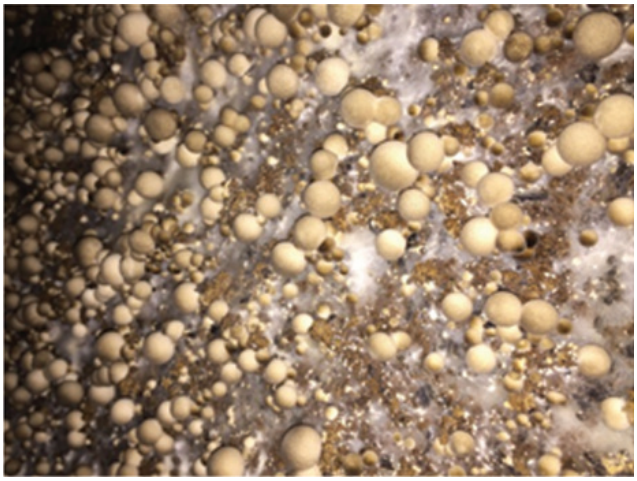
Tao, Z. Y. Indoor cultivation of straw mushroom. *Shanghai Machinery Manufacturing National Product Union Association Journal,* 163: (1937): 7-9.

Yang, Z. C. General situation of the production and marketing of Liujiang straw mushroom.*Industry communications*, 65 (1943):22-25.

Zeng, B. R. *Volvariella volvacea* cultivation in Xinfeng, Jiangxi. *The Journal of the Agricultural Association of China*, 2.4 (1921): 7-10.

Zheng, G. Y. and Liao, H. Q. *Straw Mushroom Production in China*. China Agricultural Publishing House, Beijing, 2000.

Appendix



Early growth of *V. volvacea*

Pileus expansion of *V. volvacea*