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# Advances in Utilization of Agricultural Waste Based on Production of Edible Fungi

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**Abstract** Along with the rapid development of edible fungus industry in China, the traditional mode of production giving priority to wood chips will be severely limited, and using agricultural waste distributed widely, having large yield, and containing high content of organic matter to produce edible fungi has good economic and ecological benefit. In this paper, based on the analysis of characteristics of agricultural waste in China, the present situation of application of agricultural waste in the production of edible fungi at home and abroad was introduced, and the main problems existing in production of edible fungi by using agricultural waste in China at the present stage were pointed out. Finally, the development direction of using agricultural waste to cultivate edible fungi was discussed, and some suggestions were put forward, such as improving the theoretical system for using agricultural waste to produce edible fungi, and establishing the standardized technical system for using agricultural waste to produce edible fungi.

**Key words** Edible fungi, Waste, Cultivation materials, Cyclic utilization, Advances

## 1 Introduction

Edible fungi, a kind of big fungi[1], can not only reduce materials but also are the secondary producers that make a contribution to humanity during the process of material cycle[2]. In China, which is the biggest country to produce edible fungi in the world, the output value of edible fungi was next to that of grain, vegetables, fruit and oil in agricultural economy in 2014[3-4]. The yield of shitake mushrooms, oyster mushrooms, enoki mushrooms, button mushrooms, black fungus, white fungus, pholiota nameko, or glossy ganoderma in China ranks firstly in the world[5]. In China, the proportion of yield of edible fungi to their total yield in the world increased from 5.7% in 1978 to more than 80% in 2009[6]. With the deep research of edible fungi in medicinal field, their functions such as immune adjustment, resisting tumors, oxidation and aging, protecting nervous system, reducing blood fat, and protecting liver have been paid more attention to day by day[7-9]. Agricultural waste is the general name of organic substances that are discarded by mankind during the process of agricultural production, including plant waste, animal and livestock manure, waste of processed agricultural and sideline products, and rural domestic waste[10]. With the increase of agricultural products in quantity in China, the quantity of these materials that are misplaced will rise year by year[11]. With the fast increase in the price of cottonseed hulls as the traditional culture matrix of edible fungi as well as the development and application of their new culture matrix, the application of agricultural waste in the cultivation of edible fungi has become increasingly mature in China, which will greatly reduce the present cost of producing edible fungi and can realize the efficient cyclic utilization of agricultural waste. In this paper, based on the characteristics of agricultural waste in China, the application situation of agricultural waste in the production of edible fungi in China will be introduced, and then main problems existing in production of edible fungi by using agricultural waste in China at the present stage are pointed out. Finally, the development direction of using agricultural waste to produce edible fungi is discussed to provide reference for the cyclic utilization of agricultural waste in the production of edible fungi.

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## 2 Characteristics of agricultural waste in China

**2.1 Being distributed widely and having a high yield** China is a big agriculture production country, where the yield of agricultural waste is the highest; crop straw, livestock manure and other waste can be seen anywhere, and most of waste is discarded. According to statistics, there are about 20 types of crop straw in China, and the total annual yield is nearly $7.0 \times 10^8$ t, of which the annual yield of rice straw, corn straw, wheat straw, straw of legumes and rain fed crops, and straw of peanut, potato, and beet is $2.0 \times 10^8$, $2.0 \times 10^8$, $1.0 \times 10^8$, $1.0 \times 10^8$, and $1.0 \times 10^8$ t respectively; the annual yield of livestock manure is around $26.0 \times 10^8$ t, including $10.7 \times 10^8$ t of cow dung, $2.7 \times 10^8$ t of pig manure, $3.4 \times 10^8$ t of sheep manure, $1.8 \times 10^8$ t of poultry manure, and $7.4 \times 10^8$ t of other livestock manure; the annual yield of forestry waste (not including fuelwood forest) is $0.5 \times 10^8$ t; the annual yield of other organic waste is around $0.5 \times 10^8$ t[12]. Moreover, along with the rapid development of society and economy and the increase of population, the total yield of waste will increase at a speed of 5% – 10% every year, and it is estimated that the annual yield of waste in China will exceed $5.0 \times 10^9$ t[13].

**2.2 Being very nutritious and rich in organic matter** Both physical and chemical properties of a variety of agricultural waste from different regions have big differences, and it contains N, P, K, Ca, Mg and S besides major elements C, H and O[11]. Chemical components of crop straw and traditional culture matrix of edible fungi (wood chips and cottonseed hulls) are similar, mainly including cellulose, hemicellulose and lignin. Meanwhile, livestock manure contains a large quantity of undigested protein, minerals, vitamins, crude fat, carbohydrates, and so forth (Table 1). Therefore, agricultural waste can fully meet the demands for the growth of edible fungi, and the quality and quantity of edible fungi produced from agricultural waste are not inferior to that of edible fungi produced from cottonseed hulls[14-16]. If agricultural waste such as corncob, wood chips, cottonseed hulls, bagasse, and straw powder as well as organic nitrogen sources and mineral elements are used to produce oyster mushrooms, the efficiency of biological conversion can reach 100% - 150%.

**Table 1 Main characters of agricultural waste in China[13,17-18]**

| Agricultural waste | Annual yield//$10^8$ t | N content//$10^4$ t | P content//$10^4$ t | K content//$10^4$ t |
|---|---|---|---|---|
| Crop straw | 7.0 | 430.0 | 57.0 | 651.0 |
| Livestock manure | 26.1 | 2063.0 | 413.0 | 1556.0 |
| Forestry waste | 0.5 | 34.0 | 55.5 | 500.0 |
| Other agricultural waste | 0.5 | 56.6 | 11.5 | 67.9 |

## 3 Application of agricultural waste in the production of edible fungi at home and abroad

Production of edible fungi, an important part of modern agriculture, plays carrying and transmission roles in agricultural production and can realize the cycle and transformation of materials and energy. Products of edible fungi can not only supply enough protein to people but also are major sources of medical and health products and functional foods. Moreover, they can promote the improvement of people's dietary structure and enhancement of immune function. At the same time, there are qualitative changes in the material structure of culture medium, and the content of cellulose and lignin in the raw material can decrease by 50% and 30% respectively, while the content of crude protein and crude fat can increase by 6% - 7% and about one time respectively. Moreover, these decomposition products can be used to produce large amounts of available mycoprotein (fruiting bodies)[19]. The scale and benefit level of using agricultural waste to produce edible fungi in China lag far behind that of developed countries such as the United States and Europe. The production of *Agaricus bisporus* is always an environmental protection industry in the United States and Europe, and its yield and quality are at the leading level. In recent years, a great deal of work has been done to study the application of agricultural waste in production of edible fungi, of which the culture media have been studied based on cultivation test, and the formula for using a variety of agricultural waste to culture edible fungi has been developed, while a series of technical equipment related to the cultivation has been studied and developed.

**3.1 Application of agricultural waste in the production of edible fungi in China** China is a country where the artificial domestication and cultivation of edible fungi is the earliest, and there are more than 40 varieties of edible fungi produced by artificial domestication and cultivation. With the expanding of edible fungus industry and scientific and technological development, new types of culture media of edible fungi have been developed constantly, and using agricultural and forestry waste to make culture materials of edible fungi has become a hot spot. For instance, Fan Lingyun *et al.*[20] conducted a greenhouse cultivation test of mushrooms by using rice straw and introduced the cultivation process; the results show that the cultivation effect is very obvious. Yuan Jiansheng[21] cultivated *Agaricus blazei* in the fermented mixture of corn straw, wheat straw, pig, cattle and sheep feces and summarized a new technique to cultivate A. blazei in agricultural waste; the technique has been approved by farmers. Qi Zhiguang *et al.*[22] used corn straw to cultivate straw mushrooms; the results reveal that the test scheme is feasible, and using corn straw to cultivate straw mushrooms can reduce production cost. Xia Min *et al.*[23] used cotton stalk, corn straw, corncob, and pure oak bits to cultivate shitake mushrooms; the results show that the protein of fruiting bodies of shitake mushrooms growing in crop straw and pure oak bits is very nourishing, and there is no significant difference between them. Zhao Xiufang *et al.*[24] used garlic stalk to cultivate shitake mushrooms; the results show that the rate of biological transformation could reach 98%, and mixed fungi pollution could be reduced during the process of production, while the yield of shitake mushrooms could increase. Kong Xianghui *et al.*[25] added 30% corncob, 50% corncob or 30% legume straw to wood chips to cultivate black fungus and studied the growth of hyphae and the yield of black fungus. Miao Renyun *et al.*[26] used peanut shells, wood chips, corncob, rape straw, soybean stalk, kiwi fruit branches, and sorghum husks to replace cottonseed hulls to cultivate needle mushrooms; the results show that the yield of needle mushrooms cultivated in 30% peanut shells is 33.11% higher than that of needle mushrooms cultivated in cottonseed hulls, and the cost of raw materials could be reduced significantly. During the process of using new types of matrices to cultivate edible fungi, some scholars detected the content of crude protein and crude fiber in corn skin, peanut shells, vine branches, dual-purpose rice straw and prickl-yash seeds; the results reveal that the biological transformation rate of agricultural waste is higher than that of traditional cultivation materials[27-30].

**3.2 Application of agricultural waste in the production of edible fungi in foreign countries** In Europe and America, the production and consumption of *A. bisporus* are dominant among edible fungi, and the factory and specialized production of edible fungi is conducted by using crop straw and livestock manure as culture raw materials. In Asia, the production of wood-rotting fungi is dominant among edible fungi, and the factory production technology of wood-rotting fungi in Japan and Korea is in the forefront of the world, while wood chips are mainly used as culture raw materials. In Southeast Asia, edible fungi have developed rapidly in Vietnam, Thailand, Indonesia, India, and Malaysia in recent years; wood-rotting fungi are dominant among edible fungi, and most of production varieties are shitake mushrooms and other common wood-rotting fungi, while wood chips are mainly used as culture raw materials. In recent years, the production of edible fungi has been started in Namibia, Zambia, Tanzania, Kenya and Egypt successively, and a complete set of culture techniques for the factory production of *A. bisporus* are from Europe and America, while *Pleurotus ostreatus* from China is used as cultivation raw materials mostly[4]. At present stage, the industrialized production of *A. bisporus* has been shown, and its specialized, intensive scale, factory, mechanization and automatic production have been formed in Europe and America. Sylvan Company that engages in the production of *A. bisporus* has founded more than ten enterprises in the world. In the Netherlands, Heveco Company that engages in the production of culture materials has built big fermentation tunnels to supply high-quality fermented culture materials to farmers directly; the number of annual cultivation times can reach 6, and the average yield of mushrooms is 26 – 32 kg/m$^2$, while the work efficiency and utilization rate of facilities in mushroom houses are improved.

## 4 Main problems existing in the production of edible fungi by using agricultural waste in China

**4.1 Differences between various types of agricultural waste in terms of properties are not clear** In China, the production of wood-rotting fungi is dominant among edible fungi presently; culture raw materials have transferred towards grass decay, but it is at the experimental stage, and it has not been popularized and applied on a large scale. The main reasons are shown as follows: agricultural waste has the potential as the culture raw material of edible fungi, but its sources are different, and there are big differences between various types of agricultural waste in different regions in terms of physical and chemical properties; there are certain differences between different batches in respect of quality, so there exists empirical character and even uncertainty about agricultural waste as the culture raw material of edible fungi.

**4.2 Lacking safe culture formulation** There is no uniform standard culture formula for various types of agricultural waste, and the adopted culture formula for the cultivation of the same species of edible fungi by using the same type of straw in a region is not uniform, so its extensive popularization and application are not realized presently. Meanwhile, culture raw materials of edible fungi that are mainly composed of agricultural waste contain a large quantity of infectious bacteria and metallic substances, which can lead to the infection of edible fungi with the bacteria and metal aggregation during the process of their growth, thereby bringing big economic risk and adverse impacts to enterprises.

**4.3 Lacking efficient technology and equipment for comprehensive utilization of agricultural waste** As the main culture raw materials of edible fungi, a large amount of agricultural waste is widely distributed in field, and its collection, storage, transportation and processing are finished artificially. Due to the shortage of efficient technology and equipment, the utilization cost of agricultural waste increases presently. At the same time, no complete mature technical system is formed during the process of comprehensive utilization, and production process, technology and equipment are not upgraded, so the cost of using agricultural waste to produce edible fungi will be increasingly high.

## 5 Recommendations

**5.1 Further making both physical and chemical properties of agricultural waste in various regions clear to avoid heavy metal pollution** In order to efficiently promote the application of agricultural waste in the production of edible fungi in China, both physical and chemical properties of agricultural waste in various regions should be made clear further, including the physical, chemical and thermal engineer properties of various types of agricultural waste in different regions, and the distribution and content of heavy metals in agricultural waste should be made explicit. Through regional cultivation tests, it is necessary to make various indicators and parameters clear and establish normalized technical regulations on the production of edible fungi by using agricultural waste.

**5.2 Strengthening the research and application of new formulae for agricultural waste used for the production of edible fungi** Based on scientific formulae and growth properties of edible fungi, by using existing waste culture techniques, it is necessary to upgrade current traditional modes of production and enhance the biological conversion efficiency of agricultural waste in the production of edible fungi. Meanwhile, it is necessary to strengthen the groundwork for cultivation formulae, make the growth mechanism of edible fungi, reveal changes in physical, chemical and biological properties of agricultural waste during the production process of edible fungi, establish, popularize and then apply a set of complete theoretical system.

**5.3 Enhancing the research and development of key technology and equipment during the process of using agricultural waste to produce edible fungi** During the process of using agricultural waste to produce edible fungi, it is necessary to strengthen the research and development of technology and equipment used for the collection, storage, transportation and processing of agricultural waste and preparation of culture materials, build the demonstration base of standardized production of agricultural waste, guide enterprises engaging in the production of edible fungi by using agricultural waste to change towards standardization and specialization, speed up the transformation of agricultural waste during the production process of edible fungi, and then maximize the utilization rate of agricultural waste.

**5.4 Improving the standardized technical system for using agricultural waste to produce edible fungi** In view of the shortage of standardized technical system for using agricultural waste to produce edible fungi, it is necessary to accelerate comprehensive research of using agricultural waste to produce edible fungi (including the optimal ratio, appropriate additive amount, the best transformation efficiency, and changes in properties of microbial population), and establish standardized parameter system of agricultural waste, which is key to the improvement, popularization and application of formulas for culture materials.

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(From page 91)


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