Study on three major effects and guarantee system for quality management of edible mushroom products

L Zhou¹, S Guo¹, M Shu², L Liang¹ and Y Li³

¹ Institute of Edible Fungi, Shanxi Academy of Agricultural Sciences, Taiyuan, Shanxi 030031, China
² Shea Labagh Dobberstain, San Francisco CA, California 94111, USA
³ Shanxi Xiu Tong Biotechnology Co., Ltd., Taiyuan, Shanxi 030031, China

E-mail: nkysyj301@126.com; gs0351@sohu.com

Abstract. In order to provide consumers with more safe and edible fungus products and to create a faithful social environment of food quality, the edible fungus products quality safety events, as well as their evoked factors and effects on edible fungus industry were discussed in depth in this paper. The performance of edible fungus products quality management is a comprehensive reflection of technical effect, control effect and implementation effect. Among them, the implementation effect is the most important, which refers to the actual implementation effect of quality and safety rules by practitioners of edible fungus industry. Thus, the initiative implementation effect in quality management will be improved, and a quality assurance system in which practitioners are volunteered to participate and implement initiative the quality standards and regulations so as to provide safe and high-quality products will be established, thereby achieving the best actual implementation effect in quality management.

1. Introduction
Edible fungi (mushroom) are an important class of food consumed by Chinese people, and their safety quality is related to the health of the people and the social stability of China. China is the largest producer, consumer and exporter of edible fungi in the world, and also an emerging power source for the development of the world's edible fungus industry. According to relevant statistics, the annual output of edible fungi in China increased from 58,000 t in 1978 to 31,679,000 t in 2013, accounting for 80% of the world's total production and ranking first in the world [1-2]. China has the largest number of researchers on basic science and applied technology of edible fungi [3]. However, the
quality/safety issues of edible fungus products, such as fluorescent brightener event, formaldehyde event and industrial citric acid event have seriously affected the daily life of consumers [4]. What the status of quality/safety of edible fungus products is, where the quality/safety problems are, and how to deal with the problems are professional and social issues that deserve great attention.

Quality/safety management of edible fungus products is huge and complex system engineering, involved in agriculture, commerce and logistics industry, and related to the community, business and individuals. It has many influencing factors. The effectiveness of safety/quality management of edible fungus products is a combination of technical effect, control effect and implementation effect. Among them, the initiative of implementation effect of quality/safety rules by the practitioners is the most important. In order to study the initiative implementation effect of quality/safety management of edible fungus products and to mobilize the enthusiasm of edible fungus industry practitioners for concerning and implementing the product quality rules, the quality management aspects of edible fungus industry were discussed, and an implementation system was put forward in this paper, thus improving the implementation effect in quality safety management of edible fungus products.

2. Quality/safety issues of edible fungus products and influencing factors
In China, edible fungus industry is initially dominated by self-employment and has now developed into industrialization system with a certain scale, including individual producers, production cooperatives, manufacturing enterprises, product distribution companies, farmers markets, supermarkets and other entities in the product supply chain, as well as administrative departments at all levels, research institutions, tertiary institutions, food hygiene testing departments, consumer associations and other edible fungus products-related practitioners. Due to the high degree of industrialization and the complexity of all aspects of product supply, some problems emerge in the entire edible fungus industry, such as unsatisfactory cooperation and disjointed links. Edible fungus industry in China still has small production scale, low production technology content, low product quality and poor market competitiveness [5]. In addition, there are great hidden dangers in the quality of edible fungus products. For example, abuse and improper application of pesticides lay a hidden danger for the quality safety of products; and sodium sulfite and citric acid added during the processing links of edible fungus products, such as pickling, drying and freezing drying, are prone to exceeding relevant standards [6].

Many quality/safety issues occurred in the edible fungus industry in China, so that consumers have a great distrust for edible fungus products. On December 2, 2009, the Trade and Industry Bureau of Yangzhou City found poisonous fungi that had been coated with phosphorus in the sudden inspection in farmers market; in July 2010, Zhang Hao, a primary school student from Beijing, found fluorescent brightener spots on the surface of 12 edible fungus samples under the guidance of Gao Ruifang, a doctoral student at China Agricultural University; in September 2010, the business sector of Zhengzhou City investigated and dealt with an edible fungus wholesale point, and about 20,000 kg of poisonous mushrooms in a total of 1,500 barrels were confiscated; in June 2011, 22 companies in Jixian, Tianjin were ordered to suspend production for rectification; and in April 2012, formaldehyde-soaked mushrooms were found in Qingdao [4]. Ping et al. [7] found the over-limit rates of pesticides, sulfur dioxide and heavy metals in shiitake mushroom and black fungus sampled from the circulation link were higher than those sampled from the production process. According to the
information of Zhejiang Entry-Exit Inspection and Quarantine Bureau [8], more than 80 cases of quality/safety violations were notified in the edible fungus products exported to Japan, the United States and the EU from April 2008 to November 2011, greatly influencing the export trade of China. The main causes of these edible fungus product quality safety incidents lie in outdated technology, imperfect management system and unsatisfactory implementation of quality and safety standards.

From a technical point of view, exceeding relevant standards of heavy metals and pesticide residues is mainly caused by improper operation of mushroom production. According to the report of China Network (news.china.com.cn), the Ministry of Agriculture conducted a two-consecutive-year monitoring on the environment of the major wheat-, corn-, rice- and soybean-producing areas (non-mining areas) in 13 provinces during 2003-2004. It was found that 6.4% of the investigated arable land (2,530,000 hm²) was contaminated by heavy metals, and this phenomenon was more serious in paddy fields, of which the over-standard rate was up to 14% [9]. The main cultivation substrate of edible fungi is agricultural and forestry product scraps. Heavy metals in the soil will be enriched in crops during their growth process, resulting in higher heavy metal residues in the cultivation substrate for edible fungi. Even worse, edible fungi are not sensitive to heavy metals. Therefore, the contents of heavy metals in mushrooms usually exceed relevant standards [10-11]. Pesticide residues exceeding standards have a great impact on the export trade of edible fungus products in China [12-13]. In general, pesticide residue exceeding standard is caused by improper chemical control of diseases and pests in edible fungi, which often occurs in the production management process. In China, the pesticides allowed to be applied to edible fungi are strictly controlled. But in actual production, the phenomenon of indiscriminate use or abuse of pesticides in edible fungus production is more common [13], which is one of the important factors affecting the quality and safety of mushrooms. Chemical pollution is mainly from the practical technology and operation in the processing, storage and transportation links of edible fungi. Microbial contamination refers to the contamination of edible fungus products caused by harmful microorganisms which can occur during all processes of production and marketing of edible mushrooms, leading to the deterioration of the sensory traits and decline of nutritional value and even spoilage. Disqualification of edible fungus products exported from China, such as brine mushrooms, black fungus stripes, freeze-dried mushrooms, mushroom, boiled shiitake mushroom, dried mushroom and ganoderma powder is mainly caused by that all or part of the edible fungus products contain grimed, decaying and decomposed substances or have other problems that are not suitable for consumption [14], which are mainly caused by disqualified packaging labels and improper management procedures.

From the viewpoint of quality control, there are 33 national technical standards and 72 industrial technical standards in China on edible fungi, but they are still imperfect and are lagged behind compared with those in developing countries [2, 4, 14]. For example, some of the pesticides of which the residues in edible fungi are considered excessive by importing counties have no residual hygiene standards, such as chlorpyrifos, fenpropathrin and bifenthrin [15].

In terms of practical implementation, although the administrative departments at various levels in China have formulated various quality management standards for edible fungi, there are still many problems in the overall implementation, such as inadequate awareness (producers, sellers and consumers of edible fungi do not understand relevant standards [16-17]), inactive implementation (as
Producers and sellers of edible fungi do not understand relevant standards, they have no intention for implementation at all, inadequate implementation strength (none of the raw materials quality inspection, production process management and products quality testing is implemented effectively) and weak quality assurance awareness (although the quality of edible fungi can be tracked, the guarantee and compensation measures are absent, so some of the producers and sellers evade regulation, resulting in quality management chaos).

3. Technical effect, control effect and implementation effect of product quality safety management

Based on the analysis of quality and safety incidents of edible fungus products that occurred in China and factors that affect the quality and safety of edible fungi, it is considered that the quality/safety management of edible fungus products is huge and complex system engineering, of which the management effectiveness is a combination of technical effect, control effect and implementation effect. Under the current technical and policy conditions, the most crucial factor in quality/safety management is the actual implementation effect (Figure 1).

The technical effect of quality management mainly refers to the impact of quality safety-related professional technology and quality testing techniques on the quality of products in the entire production process. For example, crop straw is widely used as the main raw material of production substrate for edible fungi which contains a certain amount of heavy metal elements. If these contaminants are not removed from the production process, they may become one of the reasons for exceeding limiting levels of heavy metals in edible fungus products. Therefore, the technology for removing heavy metals in crop straw affects the quality safety of edible fungus products.

Application of pesticides for controlling pests and diseases in edible fungi is a general farming operation, but improper types and doses of pesticides will cause pesticide residue. Therefore, before the product is sold, rapid and simple determination of pesticide residues in edible fungus products is one of the important techniques for edible fungus producers to control pesticide residues and ensure quality safety. Amano et al. [18] quickly determined pesticide residues at the production site using a simple method which makes a rapid determination of pesticide residues possible before shipping and ensures that the pesticide residues in the products are controlled within the allowable ranges.

Control effect of quality management mainly refers to the impact of laws, regulations and standard rules developed by relevant government departments to supervise and guide the commercial activities of practitioners on the quality of products. There are currently 33 national technical standards, 72 industrial technical standards, as well as local standards and procedures and corporate standards on edible fungi in China. In accordance with relevant laws, regulations and technical standards and relevant departments conduct management, supervision and guidance for quality of products. He et al. [19] investigated the residual amounts of thiabendazole, carbendazim and prochloraz in edible fungi of woodland in Beijing. According to GB 2763-2012 (the maximum residue limit of thiabendazole in fresh shiitake mushrooms is 5.0 mg/kg) [20] NY/T 749-2012 (the maximum residue limits of carbendazim and prochloraz in fresh edible fungi are 1.0 and 2.0 mg/kg, respectively) [21], the residual levels of these three kinds of fungicides were in line with the standards for green edible fungi. These standards are developed for mushrooms practitioners and related service personnel, and their
implementation will be supervised and regulated. People who violate laws and regulations will be punished.

The implementation effect of quality management mainly refers to the impact of business activities of the members that engaged in product production, distribution, sales, consumption, business management and technical services on the quality of products. For example, in edible fungus production, excessive use of pesticides, or the use of banned pesticides often occurs to prevent pests and diseases. Producers do not understand the quality management standards on the use of pesticides and types and regulations of banned pesticides, or they do not follow the relevant provisions, resulting in product quality problems. Sellers of edible fungus products usually use some preservatives to maintain the freshness of the products. The improper use of preservatives will also bring problems to product quality.

In this complex quality/safety management system engineering of edible fungi, technology, controlling and implementation are closely linked to each other. Sometimes, they are relatively independent, with their own characteristics. These closely-linked but relatively-independent factors need to be considered comprehensively. Different stakeholders are combined with each other, and the resources are integrated, forming synergy.

In today's edible fungi industry, product quality and safety management often focuses on the management and supervision of production technology and administrative regulations, which is insufficient. We must importance to the initiative effects and the actual effects of practitioners.

![Figure 1](image-url)

**Figure 1.** Influencing factors of quality safety management effectiveness of edible fungus products.

### 4. Passive effects and initiative implementation effect in quality safety management

Edible fungus industry gave great importance to quality safety of products. However, the edible fungus industry and product supply chain are quite different from other agricultural products industries, and its quality safety management has a certain degree of difficulty. As long as it does not violate the laws and regulations, few edible fungus industry practitioners take the initiative to
implement the relevant hygiene standards, naturally forming a passive form. For example, product certification is more difficult from the level of technical expertise, making actual practitioners discouraged; market regulation and consumer complaints cause individual distributors to escape and confront; and production enterprises and self-employed managers are lacking in professional skills and guidance on product quality management. The passive form of product quality management is also manifested by many consumers' lack of understanding on the standards and the problems of the quality of edible fungi. Pan et al. [17] investigated the awareness of some residents in Haidian District, Beijing on edible fungus products. They found that a considerable number of the residents had no knowledge on the standards for safety quality of mushrooms.

Playing the initiative of edible fungus industry practitioners, mobilizing the enthusiasm of the administrative, commercial and technical departments related to quality management and integrating consumers to create a proactive safety quality management, is a powerful measure to solve the problems with edible fungus products. Some scholars, both at home and abroad, have proposed to pay attention to the influence of the actual operation behavior of practitioners on the safety quality of products. Nishisato [22] proposed quality assurance in the study of quality management. For producers, distributors and sellers, quality evaluation, quality grading system, quality policies and quality assurance must be considered, that is, in the quality management, practitioners should take the initiative to implement the quality safety rules and quality assurance. Some researchers and enterprises in China have carried out this effort. Many agricultural and mushroom enterprises have taken the initiative to put forward the quality safety assurance and product quality certification and improve product quality and integrity. In order to improve the quality of agricultural products, the Helen Farm in Heilongjiang Province established a traceability system of agricultural product quality and built an information transfer system and established a social integrity of product brand [23]. Yuan et al. [14] proposed that enterprises should establish and improve the industry self-discipline mechanism for food safety, such as responsibility statement of business sector and food business and establish enterprise self-discipline, industrial and commercial supervision and social supervision trinity regulatory model. Jia et al. [15] proposed to raise the level of standardized implementation of mushroom enterprises, and both producers and processing enterprises are the subject of the implementation of the standards for edible fungi and should seriously implement the national and industrial standards for edible fungi. In the construction of the regulatory system for agricultural product quality in Leshan, Sichuan, it was put forward that the awareness of a safety quality of agricultural products has to be improved [24].

Producer-processor, producer-wholesaler and producer-supermarket sellers are the common patterns of combination to determine sale agreement. However, this pure and simple commodity contract does not have stability. When the commodity market changes, it often leads to a large number of default phenomena, exacerbating the risk of product sales of producers and increasing the operational risk and transaction costs of sales enterprises [25]. The cooperation mode of farmer-supermarket, as well as farmer-cooperative-supermarket is a way of selling the agricultural products. With benefit as a fundamental point, farmers (producers) and supermarkets are matched directly. Based on this, the intervention of cooperatives makes sure that the interests of both parties can be guaranteed. On the basis of government subsidies and supermarket grants for agricultural
cooperatives, docking cooperation is easy to set up and the stability of cooperation between cooperatives and farmers is also improved [26].

Yasaka Yasuyoshi et al. [27] investigated the concern of consumers in Tokyo, Japan for food labeling that indicates food safety. They found that the Japanese consumers are very concerned about food safety. In addition, they proposed to strengthen the management of food labeling, supervise the amount and accuracy of the content of food labeling, and strengthen the supervision of the government departments and the functions of the inspection departments so as to enhance the trust of consumers. In order to enhance consumers' concern and awareness of food safety and increase consumers' sense of security and trust, quality tracking and tracing system is developed in agricultural product circulation. To a certain extent, more accurate feedback of product information can be obtained. However, at present, China is lacking inaccurate quality indicators in production, processing, distribution and consumption of agricultural products. In China, sub-regulation is employed, which cannot be collaborated and cannot directly trace back to the issue. Even worse, the design of traceability information has limitations. Thus, all aspects cannot be well butt, making full traceability impossible [28].

In the current agricultural quality traceability system, all practitioners have different interests, including producers, processors, sellers and consumers. They lack of understanding the quality traceability of agricultural products and their understanding are inconsistent. As a result, no obvious price difference has been formed between the agricultural products, with and without traceability system. This situation of high quality but low price requires certain investment. The practitioners that had took part in the traceability system did not receive the corresponding benefits, thus the stakeholders who originally had the willingness to participate also lost their enthusiasm, eventually leading to all stakeholders' losing the willingness [29]. This situation also exists in the circulation of agricultural products abroad. The practitioners, especially producers who spend high costs into the traceability system, could not get the corresponding benefits, so their willingness to implement gradually disappears. As the current agricultural product quality traceability system has not been standardized and it is first promoted among producers, there are still many problems that should be pondered [30].

In order to solve these problems better, a quality safety assurance system, based on the actual practitioners of the edible fungus industry is advocated to mobilize the enthusiasm of practitioners in production, circulation, sales and service linked to the edible fungus industry. Relying on their own integrity, the national quality standards and regulations should be strictly implemented, and high-quality products with clear responsibility distinction will be provided, thus the practitioners will get higher economic benefits and consumers will get safe and healthy mushrooms.

5. Implementation system for improving implementation effect in quality safety management

Ensuring quality safety of products and building brand integrity with integrity of practitioners who are volunteered to participate

It is urgent to establish a quality safety assurance system based on the actual practitioners of the edible fungus industry to make the practitioners in production, circulation, sales and service links of the edible fungus industry participate voluntarily. Relying on their own integrity, the national quality standards and regulations will be implemented strictly, and high-quality safe products with clear
responsibility distinction will be provided, thus the producers and sellers can get higher economic benefits, consumers can get safe and healthy edible fungus products and brand integrity is built. Figure 2 showed the basic model to improve the implementation effect.

| Producer | Circulation practitioner | Wholesaler | Small seller | Consumer |
|----------|--------------------------|------------|--------------|----------|

**Figure 2.** Implementation effect system of edible fungus product quality.

5.1. **Replacing complaint and punishment system by responsibility system that ensures quality safety**

In the product sales, consumers often do not understand the product. Usually, the quality problems cannot be detected with the ordinary naked eyes. Thus, a blind sense of crisis emerges, causing great social adverse effects. Coupled with the media exposure of some product quality incidents, the majority of consumers have a sense of insecurity. Different from industrial products, unqualified edible fungus products cannot be returned and replaced, which is the special feature of edible mushrooms. Therefore, it is very necessary to establish a system of compensation that protects the interests of consumers. In the advocated safety quality assurance system, consumers must participate. They will monitor the production and marketing aspects and improve the level of product quality. If bad products are found in the market or defective products are purchased, losers can be compensated from this quality safety assurance system. In addition, producers and sellers can be spurred and supervised, the mutual cooperation will be strengthened, and the integrity will be enhanced.

5.2. **Holding edible fungus product quality safety appraisal meeting regularly to make the quality of the products public and to monitor the quality safety of the products relying on the wisdom of the majority of stakeholders**

The laws and regulations and technical knowledge of product quality safety need to be popularized. Product quality situations also need to understand by vast number of consumers. The producer's
production status and product quality needs testing. These can be achieved through regular or irregular control. Thus, the understanding and supervision of consumers on edible fungus product quality is enhanced, the high-quality products, as well as quality safety knowledge and technology are publicized. Eventually, high quality, high benefit, eased consumption and healthy living are achieved. In this way, the edible fungus industry in China can be raised to a whole new level, making the quality of edible fungus products reliable and assured.

References
[1] Zhang J X, Chen Q, Huang C Y, Gao W and Qu J B 2015. History, current situation and trend of edible mushroom industry development. Mycosystema, 34, 524-40.
[2] Li H, Xu X H and Wang X G 2015. Present situation, problems and countermeasures of technical standards of edible fungi in China. Edible Fungi Chi., 34, 1-6.
[3] Zhang, J X 2014. Powerful supports of scientific research are indispensable to the development of mushroom industry. Mycosystema, 33, 175-82.
[4] Meng X H and Zhang J B 2013. Measures for quality control of edible fungus products. J. Changjiang Vege., 14, 1-5.
[5] Lin G Z 2015. Analysis on the development of Chinese mushroom industry. Northern Horticulture, 3, 163-64.
[6] Li G B 2013. Potential safety problems of edible fungus product quality and preventive measures. Edible Medici. Mushrooms, 21, 337-38.
[7] Ping H, Wang J H, Ma Z H, Li Y, Li B R, Wang B H, and Fu W L. 2016 Investigation and analysis of quality and safety of edible fungi in Beijing and Hebei. J. Food Safety Quality, 7, 478-83.
[8] Xu, L. H., Zhang, Y. Z., Wang, G. J., Wang F, Zhang Y, Wu Y M and Chai Z L 2007. The quality and safety of edible fungi from Zhejiang Province. J. Agro-Envir. Sci. 26, 679-85.
[9] News Center - China Network. Heavy metal pollution enters the high incidence period with annual loss of food for 40 million people. http://www. china. com. cn/news/env/2012-06/13/content_25631940. htm, (2012-06-13) [2016-09-11].
[10] Huang Q, Li W, Guo X, Wang T T and Gui M Y 2014. Research progress on accumulation of heavy metal in edible fungi. Edible Fungi Chi., 33, 4-6.
[11] Yoshiyuki B, Masayuki K and Koichi F 2013. Effect of the concentration of heavy metals in shiitake cultivation medium on the accumulation of heavy metals in fruiting bodies. Forest Appl. Res., 22(2), 25-30
[12] Guan D P and Hu Q X 2008. Maximum pesticide residues limits for edible fungi product quality and safety. Edible Fungi Chi., 27, 3-6.
[13] Xing Z T and Yu Q H 2014. Analysis on the obstruction of export of canned white mushroom in 2012. Edible Fungi, (1), 1-3.
[14] Yuan J P and Xiao Z 2006. Study on institutional factors and countermeasures for food safety. Food Sci., 27, 563-67.
[15] Jia S M and Liu G J 2010. Edible fungus product quality and safety standards and implementation status in China. Zhejiang Shiyongjun, 18, 17-20.
[16] Tao S X and Li L 2016. Regulation effect of agricultural product quality and safety standards on
farmers' production behavior. *Rural Econ.*, 2, 563-67.

[17] Pan Z Q, Xu T, Zhang D J Zheng B, Lan F Y, Li L and Xu Y J 2015. Detection of heavy metals in two kinds of edible fungi available in market and a related KAP survey in Haidian district in Beijing. *J. Food Safety Qual.*, 6, 2361-67.

[18] Akiko A and Naria I 2010. Application and dissemination of simple pesticide residue analysis system at agricultural production site. Journal of the Japanese Pesticide Soc., 35, 516-20.

[19] He M, Luo M M, Wang J H, Ma Z H, Liu Y and Wang S X 2015. Residue and safety evaluation of three fungicides in edible fungi in plantation woodlands of Beijing. *J. Food Sci.*, 36, 213-16.

[20] National Pesticide Residue Criteria Committee. 2012. GB 2763-2012 *Maximum residue limits for pesticides in food*. Beijing: China Standard Press.

[21] Li, Q W, Wang Q P, Liu H C, He L Z, Wang L X and Mei W Q 2012. NY/T 749-2012 *Green food: Edible fungi*. Beijing: China Standard Press.

[22] Nishi T 2005. Quality assurance management system. *J. Okayama Commer. Soci. Res. Instit.*, 26: 45-48.

[23] Li D D 2014. Problems in quality and safety of agricultural products and research on quality tracking and tracing construction. *Farm Econ. Manag.*, 1, 73-74.

[24] Mei C F 2015. Promoting the construction of agricultural products quality and safety system in Leshan. *J. Party School Leshan Munic. Commi. O C. P. C.*, 17, 72-75.

[25] Wang X P and Zhang X F 2013. Agricultural products traceability system behavior of enterprises and farmers under the game theory. *China Busi. Market*, 9, 94-99.

[26] Jin J X 2014. Agricultural products "agricultural super-docking" mode development mechanism and policy research (doctor's thesis). Chongqing: Southwest University.

[27] Kageyama Y, Ishida A, and Yokoyama S, 2007. Consideration on consumer consciousness and its attributes in 10 items of food labeling. *Agr. Market Res.*, 16, 120-27

[28] Huang H B 2016. Current status, problems and countermeasures of agricultural products traceability system construction. *Agri. Tech.*, 36, 179.

[29] Zhang F, Niu J and Gao F 2012. The construction of agricultural product quality tracing system: the situation, the problems and the way-out. *Chin. Agri. Sci.Bull.*, 28, 186-89.

[30] Miyamori M 2006. The marketing effect of traceability. *J. Industry Inform. Sci.*, 2, 11-20.