AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Research Situation and Development Trend of Resource Recycling Technology for Agricultural Wastes

DU Yan-yan *, **ZHAO Yun-hua**

Institute of Scientific and Technical Information of China, Beijing 100038, China

Abstract Rational utilization of agricultural waste resources is of great significance to reducing environmental pollution, improving rural ecological environment, and developing agricultural circular economy. Besides, in the context of global energy crisis, the research of resource utilization technology for agricultural wastes will exert considerable influence on survival and living of human beings. We firstly discuss about general situations of agricultural waste resources in China, research and application situations of agricultural waste recycling technology both at home and abroad. On the basis of development trend of agricultural waste recycling, we put forward countermeasures for agricultural waste recycling in China.

Key words Agricultural wastes, Resource recycling, Development trend, Countermeasures

Deterioration of ecological environment and high resource consumption mode of production have become shackles of sustainable socio-economic development of China. Especially, the intensive and large-scale development of modern agriculture breaks the waste recycling link in traditional agriculture, leading to massive accumulation of agricultural waste, and consequently leading to increasingly serious environmental problem and waste of resources. Practice at home and abroad shows that recycling and harmless treatment of agricultural wastes are effective approaches to controlling agricultural environmental pollution, improving rural environment, developing circular economy, and realizing sustainable development of agriculture[1]. This article mainly discusses agricultural waste recycling technologies and development trend both at home and abroad.

1 General situation of agricultural waste resources in China

1.1 Plant type Plant type wastes come from residues generated from agricultural and forestry production and mainly refer to crop straws. In 2009, the amount of collectable crop straws was about 687 million tons, accounting for 83.8% of theoretical resource amount. Among various crop straws, rice straw was 205 million tons, wheat straw was 150 million tons, corn straw reached 265 million tons, cotton straw was 25.84 million tons, oil crop (mainly rape and peanut) straw was 37.37 million tons, bean straw was 27.26 million tons and tuber crop straw reached 22.43 million tons, accounting for 25%, 18.3%, 32.3%, 3.2%, 4.6%, 3.3%, and 2.7% respectively. Survey results indicate that the unused resource amount of straw is about 215 million tons, reflecting huge potential of straw resource in China[2].

1.2 Animal type Animal type wastes come from residues generated from animal husbandry and fishery production and mainly refer to cattle, sheep, and chicken reared in pens. In 2007, fecal wastes and developable resources of cattle, pig and chicken are listed in Table 1. The top 6 provinces that have richest fecal waste resources are Henan, Shandong, Hebei, Sichuan, Hunan and Yunnan[3]. By 2020, the total livestock and poultry fecal waste in China will reach 4 billion tons[4].

1.3 Processing type Processing type waste resources come from residues generated from agricultural, forestry, animal husbandry and fishery processing. During the Eleventh Five-year Plan period, residues from wood processing and harvesting reached 80.56 million tons (equivalent to 45.92 million tons of standard coal), and firewood obtained from wood raising and branch pruning during culture of various economic forests was up to 48.13 million tons (equivalent to 27.43 million tons of standard coal). In total, the physical amount reached 128.69 million tons, equivalent to 73.35 million tons of standard coal[5]. Wastes generated from primary processing of agricultural products mainly include rice husk, corncob, peanut shell, and bagasse, *etc.* With growth of grain yield, these wastes will also increase. It is estimated that it will reach 200 million tons in 2020[4].

2 Research progress of agricultural waste resource recycling technologies both at home and abroad

In line with characteristics of agricultural wastes, we introduce the research progress of agricultural waste resource recycling technologies both at home and abroad from collection and storage equipment technology, microorganism enhanced compost technology, dry anaerobic fermentation and cellulose etha-

Received: May 22, 2012 Accepted: June 12, 2012

Supported by Special Project for Basic Work of Ministry of Science and Technology (2009FY240100).

* Corresponding author. E-mail: duyanyan@istic.ac.cn

nol production technology.

Table 1 Fecal wastes and developable resources of cattle, pig and chicken in China

Item	Cattle	Pig	Meat chicken	Laying hen
Weight//kg	500	50	1.5	1.5
Raising (marketing) period//d	365	150	60	365
Fecal waste in 24 hours//kg/herd (piece)	20	4	0.1	0.1
Fecal waste in a year//t/herd (piece)	7.3	0.6	0.006	0.036 5
Annual raising quantity//10^4 herd (piece)/year	10 595	56 508	726 438	248 046
Fetal waste amount//10^4 t/h/year	77 343	33 905	4 359	9 054
Collection coefficient of fecal waste	0.60	1.00	0.60	0.60
Developable fecal wastes//10^4 t	46 406	33 905	2 615	5 432
a. Dry matter content//%	18	20	80	80
b. Conversion coefficient of standard coal	0.471	0.429	0.643	0.643
c. Standard weight (standard coal)//10^4 t	3 934.2	2 909.0	1 345.3	2 794.2
Total standard weight (standard coal)//10^4 t	1 0982.7			

Note: the conversion coefficient of standard coal is selected from *Reference Coefficient for Conversion of Various Energy Sources into Standard Coal in China Energy Statistical Yearbook.*

2.1 Collection and storage equipment technology Achievements in scientific research are mainly shown in following aspects. (i) Agricultural waste collection technology is highly adapted to agricultural industrial system. For example, standardized operation in American and European developed countries has laid excellent foundation for agricultural waste collection technology and equipment. (ii) Agricultural waste collection technology is well connected with standardization of demand for industrialized utilization of raw materials. In Sweden, Denmark and France, in straw power generation works, standardization of straw material equipment is taken into full consideration and mutual connection is realized. (iii) Agricultural waste collection technology and socio-economic development are mutually promotive. For example, large-scale raising and industrial power generation straw purchasers sign the straw supply contract with farmers. (iv) Agricultural waste collection technology well matches with agricultural equipment. Operation machines of foreign countries are mainly the tractors, mainly considering standards of machines and tools for harvesting, loading, transporting, and storing straws, to form a compete professional supporting system of agricultural equipment. (v) Agricultural waste collection equipment is closely connected with informationization and automation technology. For example, in foreign countries, agricultural waste collection equipment and technology are varied, so it is favorable to raising operation efficiency, stability and reliability[6]. China has made great achievements in agricultural waste collection and storage equipment and technology. However, compared with developed countries, China' agricultural waste collection and storage system is not perfect and still remains at the starting stage, and the standard is not unified. It has become a main bottleneck seriously restraining large-scale, commercialized and industrial utilization of agricultural wastes. China has developed small round binders and small square binders, but there is still a gap in high density big square binders and big round binders at present[7].

2.2 Microorganism enhanced compost technology In foreign countries, the compost fermentation process, technology and equipment are increasingly perfect, and have basically reached large-scale and industrial level. For example, the vertical multi-level rapid compost equipment developed by Japan features low area coverage, rapid fermentation and good quality. The organic fermentation equipment developed by Russia can produce 100 tons of organic fertilizer in one day. American BIOTEC2120 high temperature compost system can treat 1 300 tons of livestock and poultry fecal wastes in 72 hours through microorganism fermentation, and turn the waste into high quality organic fertilizer. South Korea adopts the trough fermentation and spiral stirring technology which belongs to advanced fecal waste fermentation technology. Nevertheless, these compost facilities have not been widely applied in China due to high operation cost[8].

China's microorganism enhanced compost technology mainly includes three types. (i) High temperature decomposition and inoculation technology. The success of compost lies in normal propagation of microorganism. Using proper microorganism inoculation agent can accelerate the compost process of agricultural wastes. Gu Wenjie *et al.* took cow dung and spent mushroom compost at raw materials to conduct aerobic composting process, and researched the influence of inoculating exogenous microbial agent on change of microorganism quantity and enzyme activity[9]. (ii) Functional microorganism inoculation technology. Functional organic fertilizer uses traditional composting principle to make microorganism grow in compost, increasing composting effect, regulating crop growth and enhancing crops' disease resisting ability through adding some functional bacterial strains. Research of Sun Haiying *et al.* shows that, compost with cow dung and rice straws as raw materials added with cellulose decomposition bacteria and nitrogen-fixing bacteria has clear reduction of C/N in composting process, improves fertility and maximally keeps nitrogen nutrition in composting material[10]. (iii) Microorganism deodorization technology. In the course of compost fermentation, agricultural wastes will give out odorous gas, pollute environment and affect compost quality. Odor of agricultural wastes mainly comes from NH_3, H_2S and some small organic molecular compounds. Inhibiting growth of these microorganisms in the course of composting can effectively suppress generation of odorous gas[11]. Research conducted by Yu Hongjiu indicates that, compared with the control group, inoculating deodorant in chicken manure can remove odorous gas in the compost about

10 days ahead of time[12], which effectively reduces generation of odorous substance in the course of composting.

2.3 Dry anaerobic fermentation technology As an effective approach to recycling organic solid wastes, the dry anaerobic fermentation technology has gradually become a hot spot of research on agricultural solid waste recycling technology in the world. Currently, the research progress mainly includes: (i) Main factors of dry anaerobic fermentation process are substrate composition, substrate pretreatment, total solid (TS) content, innocuous substance, pH, temperature and stirring. Many researches show that mixed fermentation using many kinds of substrate can raise higher gas generation efficiency, and bring convenience for subsequent treatment and utilization of biogas residues. Lehtom *et al.* adopted 30% straws to mix with fecal waste, increasing marsh gas generation for 16% to 85%, compared with fermentation of single fecal waste[13]. Teihm *et al.* adopted ultrasonic wave to treat material for 20 to 120 minutes, finally increasing marsh gas generation about 2.2 times[14]. Zhang *et al.* found that the higher the pretreatment temperature, the higher reduction of solid substance, and the higher marsh gas generation[15]. Research carried out by Shrivastava *et al.* indicated wheat straw fermentation through white rot fungi can effectively increase protein content and raise digestion rate of organic matter[16]. The above researches indicate that mixed anaerobic fermentation combined with optimum raw material will be an important development direction. (ii) Organic solid waste dry anaerobic digestion treatment process includes continuous and batch reactors. (iii) Research of biological monitoring and environmental effect of dry anaerobic fermentation includes influence of dry fermentation process on pathogenic bacteria and on atmospheric environment. For example, Salminen *et al.* believe that anaerobic digestion can kill pathogenic bacteria[17]. Research of Schauss *et al.* indicates that after dry fermentation, the emission of nitrogen oxide (calculated as N) is about 458 $g/hm^2 \cdot a$, which is 770$g/hm^2 \cdot a$ lower than the control group, and the emission of methane decreases about 22%[18]. Thus, selecting high efficient anaerobic fermentation strain adapted to low temperature is a major approach to raising anaerobic fermentation efficiency and reducing cost for gas generation[15].

2.4 Cellulose ethanol production technology The second generation biological fuels take agricultural wastes, such as wheat straw, grass and wood, as major raw materials, and adopt the cellulose conversion technology to produce ethanol fuel. To achieve this, it requires solving three key technological problems. Firstly, it should overcome resistance of lingo-cellulose molecules against biological conversion, namely, turn polysaccharose to fermentable sugar. Secondly, through research on microbial metabolic engineering and genetic engineering, it is able to utilize fermentable sugar (biological conversion) rapidly, at a high speed and high yield. Thirdly, it has simple and high-efficient downward process, namely, product separation. Among these steps, the first step is the greatest obstacle. In the global range, it is expected to make breakthrough in following technical directions.

2.4.1 Cellulose ethanol production technology based on enzyme preparation. At present, methods for cellulose hydrolysis mainly include chemical method and enzymatic hydrolysis method. The enzymatic hydrolysis method can react under moderate condition, but the production cost remains high. In 2009, the largest industrial enzyme preparation and industrial microorganism preparation producer, Danish Novozymes Company introduced the cellulase Cellic® I. In the next year, cellulase Cellic® II, the cellulose ethanol complex enzyme, came out. Technical breakthrough of cellulose creates new opportunity for bio-ethanol industry. The Research and Development Center of Novozymes Company mainly conducted works in following two aspects. Firstly, it looks for new enzyme with the aid of biological diversity of China, and applies the enzyme in development of global products. Secondly, it researches what kinds of enzyme are needed in China from local market demand. Another bottleneck of cellulose ethanol production is the pretreatment technology. Since most of the cost data obtained from demonstration facility is idealized, it is difficult to reproduce in large-scale production[19].

2.4.2 The Combined Biological Processing (CBP). Traditional cellulose ethanol production process has following three ways: Separate Hydrolysis and Fermentation (SHF), Simultaneous Saccharification and Fermentation (SSF), and Simultaneous Saccharification and Cofermentation (SSCF). On this basis, Lynd *et al.* put forward the Combined Biological Processing (CBP) proposal and proved its feasibility[20]. CBP does not include production and separation of cellulose, but combines saccharification and fermentation into a reaction system mediated by microorganism. Therefore, compared with other processes, the consumption of substrate and raw material is relatively low, while the integration degree is high[21]. In the long run, CBP process is no doubt a perfect process. Nevertheless, it is impossible to achieve industrial application in short period. Deputy Director of the Institute of Nuclear and New Energy Technology (INET) of Tsinghua University, Li Shizhong believes that the cellulose ethanol production process is very complex, so the reduction of cost is limited. Commercialization of cellulose ethanol production possibly needs reform of production process. In Microorganism Screening and Building Technology Special for High-efficient Degradation of Biomass, Li Shizhong *et al.* realized increase of key technical indicators for 10%, yield rate of pentose ethanol fermentation up to 80%, and optical purity of L lactic acid higher than 99%[22].

2.4.3 Bio-fuels from microalgae. In a lot of non-grain biomass, the research on bio-fuels from microalgae is still in the ascendant. The Department of Energy of the United States has carried out relevant researches for over two decades and made significant progress. Japan, Germany and India also conducted relevant researches. Numerous scientific research institutions, bio-fuel companies and investment companies invest huge fund in this field. Large petroleum companies, such as Shell and Chevron, are also carrying out cooperative study with relevant institutions or companies. At present, the technology for bio-fuels from microalgae in China is still in the transition period from laboratory to industrial application. Chinese Academy of Sciences and SINOPEC are jointly developing microalgae bio-fuel technology. In 2015, it will realize outdoor pilot experimental device, and in the distant future, it will be able to build 10 000

– ton level industrial demonstration plant[23]. Although microalgae bio-fuel technology has made considerable progress, to make it become feasible alternative energy, we should solve many problems, including screening and cultivation of microalgae that can effectively fix carbon dioxide, exploration in mechanism for microalgae fixing carbon dioxide, cultivation condition of microalgae, *etc*[24].

3 Development trend of agricultural waste recycling

In the context of market economy and industrialization operation, developing biological materials, biochemical products, and alternative petrochemical products with agricultural wastes has drawn wider and wider attention, which greatly expands recycling field of agricultural wastes. In general, the development trend of agricultural waste recycling is mainly shown in following aspects.

3.1 Research objectives are comprehensive At the same time of raising agricultural waste recycling efficiency, attention is also being increasingly focused on substantial contribution of solving issues concerning agriculture, farmers and countryside, and also focused on the impact on sustainable development of regional ecological environment.

3.2 Research and development means is multiple From the focus on research on natural science and technology, it is gradually turned to organic combination of natural science and technology with natural science and social science. For example, ecological technology and engineering improve or develop new ecological technology for agricultural wastes on the principle of ecology and ecological engineering.

3.3 Research and development way tends towards technology upgrading and system integration Through developing single type technology, it has become difficult to accomplish the objective of comprehensive recycling of agricultural waste. In this situation, the importance of using new and high technology to upgrading and transforming traditional technology and product becomes increasingly prominent.

3.4 Research and development technology becomes more and more mechanized, large-scale, and specialized It is favorable to mechanized, large-scale and specialized development of waste treatment and recycling when the environmental engineering focuses on upgrading of technology and equipment for fecal waste and agricultural straw treatment in large and middle plants. The research of high-efficient modern agricultural waste recycling technology is cooperating with research of key technologies from the concept of " precise, high-efficient, low consumption and environmental protection". It adopts new and high technology to upgrade and transform traditional technology and product, and strengthens the organic and close connection of various agricultural waste recycling technologies and methods.

4 Countermeasures for agricultural waste recycling in China

(i) Strengthening propaganda. It is required to raise the development and utilization of agricultural waste recycling to the height of protecting ecological environment and promoting sustainable development of agriculture and energy. Besides, it is required to propagate widely the significance of agricultural waste recycling industry and propagate typical cases and successful experience, to build up favorable social atmosphere that the whole society cares about and supports agricultural waste recycling development and utilization.

(ii) Establishing monitoring system of agricultural waste resources. This system is established for collecting, transmitting and managing agricultural waste resource and relevant information in real time, and conducting real-time monitoring, optimal distribution and scientific scheduling.

(iii) Providing policy and financial support. Government should provide fund guarantee for agricultural waste recycling technology and provide favorable policy environment. In addition, it should encourage capital market to make direct investment and to actively expand financing channels of agricultural waste resource development and utilization.

(iv) Enhancing scientific and technological support. Technological support system of agricultural waste recycling should include recycling technology, harmless technology, and new and high technologies with high-added value and less pollution and emission.

(v) Reinforcing strategic cooperation with production, teaching and research. It is proposed to establish a technical innovation platform with enterprises as main part, colleges and universities as reliance, oriented towards market, with capital as the link, and modern enterprise system as norms. Also, it should encourage enterprises to introduce advanced technologies both at home and abroad, to constantly raise the contribution rate of technological progress to agricultural waste recycling.

(vi) Exploring practical development model. Agricultural waste recycling is a system involving government, processing enterprises, scientific research units and farmers. Therefore, relevant departments should formulate practical support polices and measures from the perspective of environmental protection, combine product processing, base construction and ecological engineering, as well as increase in farmers' income.

References

[1] PENG J. Review and dicussion on utilization of agricultural waste resources in China[J]. Ecology and Environmnet, 2009, 18(2): 794 –798. (in Chinese).

[2] Department of Science and Education. Crops straw resource investigation and evaluation report in China[J]. Agricultural Enigineering Technology, New Energy Industry, 2011(2): 2 –5. (in Chinese).

[3] SHI YC. China's resources of biomass feedstock[J]. Engineering Science, 2011, 13(2): 16 –23. (in Chinese).

[4] The Ministry of Agriculture Department of Development and Planning. Development plan of agriculture biomass industry (2007—2015)[EB/OL]. (2008 –08 –26) [EB/OL]. http://www.agri.gov.cn/jhgb/t20080826_1168529.htm. (in Chinese).

[5] SHI YC. Set of China renewable energy source development strategy research(volume of biomass energy[M]. Beijing: China Electronic Power Press, 2008. (in Chinese).

[6] LI SJ, YANG BN, WANG JY, *et al.* Main crops straw collecting technique development[J]. Farm Machinery, 2008(16): 23 –26. (in Chinese).

[7] LIU YY. On China straw collective technology and operation mode [C]// The First Development Forum of Rural Watses and Renewable Energy Source Development Utilization Technique Equipment, 2010. (in Chinese).
[8] SUN ZJ, SUN YM. Situation and development of agricultural residues as energy resource utilization in rural areas in China[J]. Journal of Agricultural Science and Technology, 2006, 8(1): 6 –13. (in Chinese).
[9] GU WJ, ZHANG FB, XU PZ, *et al*. Inoculum additions during composting: impacts on microbial populations and enzyme activity[J]. Journal of Agro-Environment Science, 2009, 28(8): 1718 – 1722. (in Chinese).
[10] SUN HY, XU XH. Effect of inoculating cellulose – decomposing bacteria and Azotobacter on cow manure compost fermentation [J]. Journal of Northeast Agricultural University, 2009, 40(10): 52 –54. (in Chinese).
[11] WANG Y. Rapid composting treatment of breeding industry solid wastes[M]. Beijing: Chemical Inudstry Press, 2005. (in Chinese).
[12] YU HJ. Study of controlling nitrogen loss from volatilization in poultry composting process[J]. Heilongjiang Agricultural Science, 2009 (6): 61 –62. (in Chinese).
[13] LEHTOM A, HUTTUNEN S, RINTALA JA. Laboratory investigations on Co – digestion of energy crops and crop residues with cow manure for methane production: Effect of crop to manure ratio[J]. Resources Conservation and Recycling, 2007, 51(3): 591 –609.
[14] TEIHM A, NICKWL K, ZELLHORN N, et a1. Ultrasonic waste activated sludge disintegration for improving anaerobic digestion[J]. Water Resource, 2001, 35(8): 2003 –2009.
[15] YE XM, CHANG ZZ. State of arts and perspective of dry anaerobic digestion of organic solid waste[J]. Journal of Ecology and Rural Environment, 2008, 24(2): 76 –79. (in Chinese).
[16] SHRIVASTAVA B, THAKUR S, KHASA YP, *et al*. White-rot fungal conversion of wheat straw to energy rich cattle feed[J]. Biodegration, 2011, 22(4): 823 –831.
[17] SALMINEN E, RINTALA J. Anaerobic digestion of organic solid poultry slaughterhouse waste—a review[J]. Bio-Resource Technology, 2002, 83(1): 13 –26.
[18] SCHAUSS K, RATERING S, SCHNELL S. Impact of fermented organic fertilizer on trace gas emission in organic agriculture[M]. Kassel: Kassel University Press GMBH, 2005: 589 –592.
[19] LI J. The burning fire of the second generation fuel of ethanol[J]. Pioneering With Science and Technology, 2011(4): 65 –67. (in Chinese).
[20] LYND LR, VAN ZYL WH, MCBRIDE JE, *et al*. Consolidated bioprocessing of cellulosic biomass: an update[J]. Biochemical engineering, 2005, 16: 577 –583.
[21] ZHANG YHP, LYND LR. Cellulose utilization by clostridium thermocellum: bioenergetics and hydrolysis product assimilation[J]. Proc Nati Acad Sci USA, 2005, 102: 7321 –7325.
[22] LI SZ, ZHANG LY, QIAO M, *et al*. The development progress of algae fuel[J]. China Science and Technology Achievements, 2009 (13): 16 –17. (in Chinese).
[23] YANG R. Cellulosic ethanol has an infinite prospect and needs technical breakthrough[J]. Green China, 2011(3): 10 –11. (in Chinese).
[24] LI XJ, ZHANG LY, QIAO M, *et al*. Progress in algae biofuel research & development[J]. Sino-global Energy, 2009, 14(4): 23 –26. (in Chinese).
[25] XIAO Q, DING YW, JIN W. Feasibility analysis and practice of resource utilization of waste from planting and breeding industry[J]. Journal of Anhui Agricultural Sciences, 2011,39(3): 1665 –1666, 1690. (in Chinese).

(From page 57)

so as to provide the correct direction of public opinion for consumers' purchase of genetically modified food as soon as possible. Yanbian Prefecture can conduct research on the safety of genetically modified food, by giving play to the intellectual superiority of experts and scholars in the Agricultural College of Yanbian University, Yanbian Academy of Agricultural Sciences and other institutions.

References

[1] DENG PJ. Interpretation of genetically modified food[M]. Beijing: People's Medical Publishing House, 2006: 1 –2, 25 –26. (in Chinese).
[2] DING YL. The attitude of consumers to genetically modified food—investigation in Nanjing[D]. Nanjing: Nanjing Agricultural University, 2004. (in Chinese).
[3] JIA SR. The nature of current debate on biosafety of genetically modified crops[J]. Biotechnology Bulletin, 1999(6): 1 –7. (in Chinese).
[4] FAN LY, WEI W, ZHU ZG. Survey and cognitive situation on consumers towards genetically modified food[J]. Chinese Agricultural Science Bulletin, 2010, 26(20): 80 –85. (in Chinese).
[5] HU H, LIN LY, LIANG LM, *et al*. An analysis of current consumers' knowledge about and purchase desire for gene engineered food [J]. Consumer Economics, 2006, 22(1): 42 –46. (in Chinese).
[6] HUANG JK, QIU HG, BAI JG, *et al*. Awareness, acceptance and willingness to buy genetically modified foods in urban China[J]. China Soft Science, 2006(2): 41 –47. (in Chinese).
[7] LIU LL. Consumer's awareness and response to genetically modified food—using GM rice as an example[J]. Agricultural Outlook, 2010 (8): 40 –44. (in Chinese).
[8] WANG RD, WANG JX, ZHOU W, *et al*. Study on influencing factors of consumer cognition and acceptance of GM foods in Wuhan [J]. Tianjin Agricultural Sciences, 2010, 16(2): 44 –48. (in Chinese).
[9] WANG YQ, XUE DY. Investigation and analysis for consumers' recognition to genetically modified food[J]. Environmental Protection, 2005(3): 46 –48. (in Chinese).
[10] XU LL, GONG QW, TIAN ZH. Reviews of consumer's cognition for genetical modified food and the government regulation[J]. Tianjin Agricultural Sciences, 2010(5): 63 –67. (in Chinese).
[11] XUAN LJ, XIE YT. The safety and safety assessment of genetically modified foods[J]. Journal of Anhui Agricultural Sciences, 2010 (25): 175 –177. (in Chinese).
[12] XUAN YN, ZHOU SD. Investigation into potential consumer's response to GMO products[J]. China Population Resources and Environment, 2002, 12(3): 126 –131. (in Chinese).
[13] YAN GC, QIN XD. Consumer awareness and response to genetically modified foods in Shanghai[J]. Journal of Anhui Agricultural Sciences, 2006(1): 154 –156. (in Chinese).
[14] ZHONG FN, DING YL. Consumer awareness and potential attitudes to genetically modified foods[J]. China Rural Survey, 2004 (1): 22 –27. (in Chinese).
[15] ZHOU W. Research on analytic frame of consumer cognition of genetically modified foods[J]. Tianjin Agricultural Sciences, 2010 (5): 68 –70. (in Chinese).