

## The Current Status and Prospect of Sericultural Byproduct Industry in China

Zhongzheng Gui\*, Xijie Guo, Wu Fuan and Dai Jianyi<sup>1</sup>

Sericultural Research Institute, Chinese Academy of Agricultural Sciences, Zhenjiang-212018, Jiangsu, China.

<sup>1</sup>Sericulture Company of Tongxiang City, Tongxiang-314500, Zhejiang, China.

(Received 11 March 2003; Accepted 1 June 2003)

Sericulture is a traditional agro-industry, which involves mulberry cultivation and silkworm rearing, has made great contributes to the human civilization. With the development of national economy and modern technology, mulberry and silkworm are being used to develop products with functionality besides the traditional cocoon production in China. In this paper, we brief the current developing situation of sericultural byproducts with functionality in the following aspects. (1) Functional products from silkworm larvae: silkworm powder, white muscardine silkworm, isolation and purification of anti-bacterial proteins from the larvae and production of medically valuable substances by *Bombyx mori* nuclear polyhedrosis virus (BmNPV) vector. (2) Utilization of silkworm feces: for pillow and for isolation of chlorophyll etc. (3) Production of valuable Chinese traditional medicine like *Cordyceps sinensis* with pupae, functional utilization of pupa protein and chitin. (4) Silk as additives to cosmetics, silk food and medical materials. (5) Functional utilization of mulberry: cultivation of edible fungus on mulberry shoots as medium, mulberry fruit drinks, mulberry tea, etc. The prospect of sericultural byproduct industry in China is also discussed.

**Key words:** Sericulture, Byproduct industry, China

### Introduction

Sericulture has a long history of more than 5,000 years in China. It has devoted a great deal to the civilization of human beings and the development of Chinese economy during the past thousand years. Up to now, cocoon production in China is about 500,000 tons per year and 70% of the total production in the world. However, a large amount of sericulture byproducts such as pupa, moth, and mulberry leaves, mulberry fruit, mulberry shoots etc have not yet been utilized properly. In recent years, more and more efforts have being made by Chinese government and scientists to non-fiber utilization of silkworm and mulberry for sustainable development of sericulture. A series of functional products such as silkworm powder, *Cordyceps sinensis*, pupal amino acids, mulberry fruit drinks, mulberry tea, silk cosmetics, gene engineering product of silkworm etc have been developed.

### The functional utilization of silkworm larva

The edible and medicine value of silkworm has been recorded in ancient Chinese medicine books. For example, muscardine silkworm larva was used as one of the Chinese medicines from ancient time. The medicine value of silkworm larva has been studied and developed in the following aspects in recent years.

### Lowering blood-glucose for type-2 diabetes mellitus

Since Ryu *et al.* (1995) demonstrated the function of silkworm powder in lowering blood-glucose for type-2 diabetes mellitus, Chinese sericultural scientists have also studied the effect of silkworm powder on type-2 diabetes mellitus for further development of anti-diabetic agent (Gui *et al.*, 2001; Chen *et al.*, 2002). The results showed that silkworm powder lowers blood-glucose of diabetes

\*To whom correspondence should be addressed.

Sericultural Research Institute, Chinese Academy of Agricultural Sciences, Zhenjiang-212018, Jiangsu, P. R. China. Tel: 86-511-5616716; Fax: 86-511-5622507; E-mail: srizzgui@hotmail.com

Present address: College of Natural Resources and Life Science, Dong-A University, Busan 604-714, Korea. Tel: 82-51-200-5672; Fax: 82-51-200-7594; E-mail: srizzgui@hotmail.com

mellitus animals effectively by partially related to the inhibition of  $\alpha$ -maltase glycosidase activity in the small intestine in order to delay of the absorption of glucose by blood or tissues. Silkworm powder has also some effects proved by therapy in immunization stimulation (T-lymphocyte transformation rate was elevated by 35%), lowering blood-lipid, recovering fatigue and improving resistance of insulin, etc (Gui *et al.*, 2001). It is believed that the silkworm powder is one kind of nature and multi-effect anti-diabetic agent without side effect. Meanwhile, IGF-1 (Insulin Growth Factor-1) was successfully expressed in silkworm larvae with the baculovirus expression system and used to lowering blood-glucose for diabetic patients.

#### **Isolation and purification of anti-bacterial substances in silkworm**

Silkworm likes other insects have efficient self-defence mechanisms, such as phagocytosis, encapsulation and humoral responses against bacterial infection. The humoral response mainly involves production of a variety of anti-bacterial substances such as cecropins, attacins, defensins etc. Those anti-bacteria proteins in silkworm can be induced by either infection of some pathogenic substances or stimulation of non-pathogenic physical or chemical factors like ultrasonic wave, rays, physiological saline etc. So far, several anti-substances such as anti-bacteria protein, anti-bacteria peptide, lectin, lysozyme etc have been isolated and purified from silkworm (Dai and Zhang, 1999). Some of them have already been produced by baculovirus vector in silkworm, and used in medical field successfully.

#### **Production of white muscardine silkworm**

White muscardine silkworm, valuable ingredients of traditional Chinese medicine, is dried dead larvae (or pupae) of silkworm infected by fungus *Beauveria bassiana*. It is widely used in traditional Chinese medicine with much advantage in detoxification, lowering cholesterol, and effective to apoplexy, convulsions, parotitis mumps, tonsillitis, diabetes mellitus etc. It also inhibits respiration of cancer cells (Jiang, 1996). It is reported that there are 49 ingredients of traditional Chinese medicine for adult of total 513 is composing of white muscardine silkworm. Now, white muscardine silkworm is produced in some restricted area in large scale every year.

#### **Production of valuable substance (protein) in silkworm by BmNPV vector**

Many medically valuable substances such as human interferon, IGF (Insulin Growth Factor), interleukin-3, HbsAg, phytase, etc have been expressed at high level in silkworm larvae and pupae infected with recombinant *Bombyx mori*

nuclear polyhedrosis virus (BmNPV) carrying corresponding foreign genes in recent years (Yu *et al.*, 2000).

Expression of phytase in silkworm is one of great achievements of the baculovirus expression vector system. The expressed product can be stored at room temperature for a period of 6 months and the recovering ratio of enzyme activity is about 78%.

Many researches indicated that addition of microbial phytase could increase the bio-availability of phosphate in feed significantly, even when the level of phosphate in diet is close to the level of nutrition requirement recommendation. It reduces not only the addition of inorganic phosphate to feed but also the phosphate excretion of in feces and the phosphate pollution to the environment. Phytase can increase the digestibility of amino acid and nitrogen apparently, and promote the animal growth performances.

### **The utilization of silkworm feces**

#### **Silkworm feces pillow**

Silkworm feces pillow is a mixture silkworm feces with other Chinese medicines. The pressure and temperature from head makes the medical activities to release slowly. It functions to blood cycling by respiration or skin permeation and regulates the body conditions (Yang *et al.*, 2002). Now, silkworm feces pillow is being widely used for baby and aged people.

#### **Isolation of chlorophyll from silkworm feces**

Silkworm feces are utilized as the material for extraction of chlorophyll, which is widely used in medical, food and normal industries. It enhances metabolism, activates cells and inhibits bacterial growth in human body, which is helpful for treatment of some diseases such as hepatitis, gastric ulcer, nephritis and others, and also for increases in synthesis of hemoglobin. There are many chlorophyll products in the market in China, such as "Ganbao", "Weiganlu", "Shengxuebao", etc.

### **The functional utilization of pupa**

Silkworm pupa is the one largest part of byproduct in sericulture. About 400,000 tons of fresh pupae are produced in China every year. It is a potential bio-resource with plenty of high quality of proteins.

**Production of valuable medicine like *Cordyceps sinensis***  
*Cordyceps sinensis*, one of the valuable Chinese medicines, is a kind of complex matter with *C. militaris* and pupa. It can be used to inhibit and cure some of human

diseases. Due to damaging of nature resources and over harvest, natural *C. sinensis* is becoming exhausted and could not meet the demand of both national and international market, leading to a sharp increase in the market price. Scientific researches showed that artificial *C. sinensis* produced with the pupae infected by *C. sinensis* is similar to the nature one in chemical compositions (Gong *et al.*, 2002), and also similar in effect, such as clam remaining, fatigued recovering, anti-tumor, inhibition of cancer cells without side-effects (Jiang, 1996). Some of Institutions in China have made great progress at this subject by recombination of genes and made it possible to produce *C. sinensis* by silkworm larvae or pupae in large scale.

#### **The utilization of pupa protein**

Pupa is one kind of potential bio-resource with plenty of high quality protein to be exploited. In China, the pupae protein is mainly for the following propose: to produce pupae cans to be supplied to national and international market, especially to South Asia nations; to produce pupa amino acids for soft drinks; to produce additives for the functional food and medicine.

#### **Chitin of pupa**

Since 1990s, many efforts have been made to study the application of chitin worldwide. Chitin is famed to be one of the six main elements in human body, *i.e.* protein, fat, sugar, cellulose, mineral substances and chitin. The amount of chitin is about 3.7% of total dried pupa. It is demonstrated that chitin is one of the proper materials for surgical line, vector of stationary enzymes, artificial skin etc.

#### **The functional utilization of silk protein**

The waste silk, which is unusable textile material from non-reelable cocoons and reeling processes, amounts about 10% of total cocoon materials. Fibroin, main protein of silk, was decomposed into oligopeptide or amino acids by chemical and biological methods. Due to its excellent physical and chemical properties and fine biocompatibility, fibroin is widely used in cosmetic material, functional food and medical substance etc.

#### **Cosmetic material**

Because its excellent properties in skin affinity, ultraviolet ray blockage, moisture retention, skin adhesion, silk fibroin is used as additives to produce many kinds of cosmetics. Since the 1970s, some companies in sericulture provinces of Jiangsu and Zhejiang have manufactured

cosmetics to supply national and international market. So far, different kind of fibroin cosmetics is available in Chinese market.

#### **Food material**

Silk fibroin powder is also used as materials for health food. It is known to descent in the cholesterol and blood glucose level, facilitation of alcohol metabolism and other functions (Yuan and Zheng, 1991; Gui and Zhuang, 2002). In China, silk fibroin for food material is mainly use to additive food.

#### **Medical substance**

Since the middle of 1980s, the medical utilization of silk fibroin (or silk essence) was developed for wound recovering and facility the absorption of skin by some companies in Zhejiang, Shandong provinces etc. The other functions of silk fibroin *i.e.* silk membrane, medicine vector, biosensor, the substitution of natural skin are also well studied in China (Zhang *et al.*, 1999; Zhu and Xu, 2002).

#### **The utilization of mulberry**

Besides the mulberry leaves are used for rearing silkworms, the root barks, shoots, fruits and extra leaves of mulberry have also a high economical value to be exploited.

#### **Cultivation of edible fungus on mulberry shoots**

Traditionally, mulberry shoots are widely used as fuels by farmers. In the recent decades, mulberry stem and stem powder are found to be good source of medium for mushroom production. In some sericulture area in China, farmers collect mulberry shoots after summer pruning (or cuttings) for cultivation of edible fungus to generate good income for themselves.

#### **Mulberry tea**

Mulberry tea is long known with its medicinal values. It was recorded on the ancient Chinese pharmacological book that mulberry leaves could be boiled in water for daily drinks instead of tea. It can helpful for eyesight and hearing ability of a person. It can also smooth skin and protect liver and stomach. Owing to its good functions to human health, it has been called "leave of immortals" and been widely used by elderly persons.

Modern scientific researches proved that mulberry leaves contain large amount of protein, carbohydrates, and plenty of potassium, calcium, and vitamins. Persistently drinking mulberry tea can lower blood pressure, prevent diabetes, reduce cholesterol in blood vessels, prevent can-

cer and reduce body weight etc. In a word, the mulberry tree is a precious natural resource from which nothing need be wasted. Mulberry tea is one of the main byproducts of sericulture to be developed successfully and widely used for Chinese.

### Mulberry fruit drinks

Mulberry fruit drink is another main byproduct of sericulture in China. Mulberry fruit can be consumed freshly, made into jam or liquor (mulberry drink). It was found that mulberry fruit has an anti-oxidative property (Yao *et al.*, 2002). On average, the sugar content in mulberry fruit is about 12%, but in some varieties it is more than 20% (Su *et al.*, 2002).

There are many good fruit mulberry varieties suitable for drinks with big size, high yield, and good quality and resistant to adverse condition. A great market potential is expected for the mulberry drinks in the future in China.

### Prospect of development in sericultural byproduct with functionality

China as a largest sericultural country preserved most of silkworm races (more than 800) and mulberry varieties (more than 1,900) in the world. Along with the traditional cocoon production, more and more byproducts with functionality will be developed and utilized with new and high technologies, for example, silkworm as bio-reactor to express foreign genes to produce medically valuable substances for human health, development of pupae resource for both food and medicines, multi-utilization of silk protein, medical utilization of mulberry, etc. The sericulture will be the industries of multilevel and multi-utilization in the future and its economical benefit and market competitiveness will be further increased.

### References

- Chen, Z. Y., S. T. Liao and Q. B. Li (2002) Study on multivoltine yellow blood silkworm for edible and medicine utilization. *Acta Sericologica Sinica* **28**, 173-176.
- Dai, Z. Y. and S. Q. Zhang (1999) The research progress on anti-bacterial peptide in insects. *J. Nanjing Nor. Univ.* **22**, 2-15.
- Gong, C., W. Wu, C. Xu, K. Yang and G. Chen (2002) Analysis of chemical compositions of silkworm *Cordyceps militaris*. *Acta Sericologica Sinica* **28**, 168-172.
- Gui, Z. Z., D. H. Zhuang, J. Chen and W. H. Chen (2001) Effect of silkworm powder (SP) lowering blood-glucose levels in mice and its mechanism. *Acta Sericologica Sinica* **27**, 114-118.
- Gui, Z. Z. and D. H. Zhuang (2002) Effect of silk fibroin of the silkworm (*Bombyx mori* L.) on cholesterol metabolism in the rat. *Acta Sericologica Sinica* **28**, 301-303.
- Jiang, S. J. (1996) Effect of white muscardine silkworm on the cancer. *Edible Fungus* **18**, 40.
- Ryu, K. S., H. S. Lee, S. H. Chung and P. D. Kang (1997) An activity of lowering blood-glucose levels according to preparative condition of silkworm powder. *Koeran J. Seric. Sci.* **39**, 79-85.
- Su, C., Q. Chen, L. H. Su and G. Y. Zhu (2002) Breeding of a fruit mulberry variety "Hongguo 1". *Acta Sericologica Sinica* **27**, 59-60.
- Yang, H. X., X. R. Zhu and Z. M. Fang (2002) Research progress on exploiting and utilizing of silkworm feces. *Bull. Seric.* **33**, 9-12.
- Yao, X. Z., S. T. Liao and G. S. Xiao (2002) Discussion on the industrialization of comprehensive development and utilization of silkworm and mulberry resources. *Acta Sericologica Sinica* **27**, 297-302.
- Yuan, G. H. and X. Y. Zheng (1991) Utilization of protein resource of edible insects. *Entomol. Knowledge* **28**, 122-144.
- Yu, L., K. H. Song, Y. Z. Zhang, Y. W. Huang and J. R. Li (2000) Study on the immunogenicity of infectious bursal disease virus VP2 protein expression in silkworm. *J. Zhejiang Univ.* **26**, 9-16.
- Zhang, Y. Z., Z. X. Wang and Y. Ding (1999) Studies on fibroin protein membrane as material of medicine release control. *Acta Sericologica Sinica* **25**, 181-185.
- Zhu, X. R. and J. L. Xu (2002) Studies on immobilization of saccharogenic amylases with silk fibroin. *Acta Sericologica Sinica* **25**, 113-119.