Pharmaceutical Biology

ISSN: 1388-0209 (Print) 1744-5116 (Online) Journal homepage: informahealthcare.com/journals/iphb20

Bombyx mori – A Review of its Potential as a Medicinal Insect

K.P. Singh & R.S. Jayasomu

To cite this article: K.P. Singh & R.S. Jayasomu (2002) Bombyx mori – A Review of its Potential as a Medicinal Insect, Pharmaceutical Biology, 40:1, 28-32, DOI: 10.1076/phbi.40.1.28.5857

To link to this article: https://doi.org/10.1076/phbi.40.1.28.5857

Pharmaceutical Biology
2002, Vol. 40, No. 1, pp. 28–32

1388-0209/02/4001-028$16.00

Review

Bombyx mori – A Review of its Potential as a Medicinal Insect

K.P. Singh and R.S. Jayasomu

National Institute of Science Communication (CSIR), Dr. K.S. Krishnan Road, New Delhi, India

Abstract

The importance of various stages of the silkworm, *Bombyx mori* viz., eggs, larvae, pupae, moths and its products, by-products and waste products as a potential medicinal source has been indicated. Larvae have been identified as a possible source of adipokinetic hormone (AKH), chymotrypsin inhibitors, β-*N*-acetylglucosaminidase, sex pheromone bombykol, amino acids, etc., apart from their value as health food especially for cardiac and diabetic patients, bronchial asthma, primary trigeminal neuralgia, vocal nodules and polyps and in the treatment of facial palsy and pain. Pupae are a source of proteins, vitamin B_1, B_2 and E, diapause hormone, amino acids, etc., and form a part of antibacterial and antihistaminic preparations. Male moths are used to treat sterility. Paste chlorophyll, pectin, phytol, carotene and triacontanol, solanesol, etc., extracted from silkworm feces are used in the treatment of various diseases such as hepatitis, acute pancreatitis, chronic nephritis, stomach and gastric disorders, leukocytopenia, blood cholesterol, etc. Phytol is used in the preparation of vitamin E and K while carotene in vitamin A. Pelade obtained from reeled cocoons is read-ily digestible and forms a valuable ingredient of food. It reduces cholesterol and blood sugar. Chrysalises separated from pelade contain palmitic, stearic, oleic and linoleic acids and serve as a food additive and in pharmaceutical preparations.

Keywords: *Bombyx mori*, larvae, pupae, pupal skin, exuviae, feces, sericin, pectin, phytol, paste chlorophyll.

Introduction

The silkworm, *Bombyx mori* L. (Bombicidae: Lepidoptera), basically a nocturnal moth, is a native of China but has long been domesticated throughout the world largely in the temperate and sub-tropical regions for its fine cocoon filaments. It is a monophagous insect, which derives required nutrients from mulberry (*Morus alba* L., Moraceae) leaves. Supplementation of minerals such as Mg, Zn, Ca, P, K, Fe and Mn improve larval development and cocoon characters (Rathinam & Chetty, 1991; Sarkar et al., 1995). *B. mori* exibits voltinism (frequency or number of annual broods) – uni-, bi- and multi-voltines, influenced by environmental factors, such as temperature, light, humidity, nutrition, etc. High quality exotic races/breeds imported from Japan, China, France and Italy and indigenously developed high yielding breeds are maintained at special centres, such as the Silkworm and Mulberry Germplasm Centre, Hosur, Tamil Nadu (Singh & Jayasomu, 1999).

In sericulture, apart from silk, there are many other by-products and waste products obtained at different stages of silkworm rearing. Eggs, larvae, pupae and feces find their use in pharmaceuticals, cosmetics and the paper and leather industry (Anon., 1996). In China, sericulture products are exploited considerably. Silk is made up of mainly two proteins, fibroin and sericin. Fibroin is secreted in the posterior part of the silk gland while sericin is from the middle part (Qader & Haque, 1996). Fibroin consists of many fine fibrillae bound together by sericin (Taraporewala & Shah, 1995). Silk fibroin is reported to have a high proportion of the amino acids, glycine, alanine and tyrosine. The mulberry silkworm, *Bombyx mori* is reviewed in this paper as a potential medicinal insect providing a variety of products with wide applications (Majumder, 1997; Raju, 1996).

Products

Eggs

The silkworm eggs are shown to contain chorionins, cysteine proteinase (Xia & Ding, 1989). The eggs are also used extensively in transgenic studies (Joy & Gopinathan, 1994).

Accepted: July 30, 2001

Address correspondence to: Dr. K.P. Singh, Wealth of India Division, Indian Journal of Traditional Knowledge, National Institute of Science Communication (CSIR), Dr. K.S. Krishnan Road, New Delhi-110012, India. Tel: +91-011-5786301-07(7 lines) ext. 234, Fax: +91-011-5787062, E-mail: somu@niscom.res.in

Larvae

Several chemical constituents, such as insulin-like growth factor-II (IGF II), adipokinetic hormone (AKH), chymotrypsin inhibitors, β-*N*-acetylglucosaminidase, DOPA, quinone amine conversion factor and sex pheromone bombykol [(10*E*, 12*Z*)-10,12-hexadecadien-1-ol] have been reported from the larvae (Marumoto et al., 1992; Ishibashi et al., 1992; Shinohara et al., 1993; Nagamatsu et al., 1995; Ozawa et al., 1993; Aso et al., 1995; Matsumoto et al., 1996). Interleukin-3 produced from the silkworm is reported to be biologically identical to IL-3 produced from mammalian cells (Datta, 1994). A lutein binding protien has also been purified from fifth instar larvae (Jouni & Wells, 1996). Healthy silkworm larvae are sterilized and vacum dried and sold as commercial food in Hong Kong, China, Korea and Japan. In powder form it is used as a common source of animal protein in soups and sauce preparations (Ramakanth & Raman, 1997).

Processed larvae are used in special diets for cardiac and diabetic patients because of their low cholesterol content (Ramakanth & Raman, 1997). The silkworm larvae can serve as a bioreactor for the production of low cost vaccines against various infectious diseases (Datta, 1994). Processed larva of *B. mori* infected with the fungus *Beauveria bassiana* (Bals.-Criv.) Vuill. (anamorphic Hypocreales, Ascomycota) is one of the constituents of various Chinese decoctions used for the treatment of bronchial asthma, facial palsy and pain, primary trigeminal neuralgia, vocal nodules and vocal polyps (De-zi, 1991; Sen, 1991; Xue-ping et al., 1991; Chang-xiong et al., 1993). Male worms are used in the preparation of a Chinese drug "pill" which causes male infertility (Hai-bo, 1989). The extract of *B. mori* has androgen like action in rats and mice (Cai et al., 1991). Silkworm larvae are freeze-dried at $\leq -30\,°C$, made into a powder/film and incorporated into health food. The additive protects the liver and prevents diseases among the aged (Hirabayashi et al., 1996). The extract of larvae is one of the constituents of an anti-acne cream with minimal side effects and high clinical efficacy. The larvae have also been found to contain D66b and *e*-human carcinoembryonic antigen proteins (Song & Wang, 1994; Yamanaka et al., 1996). The hemolymph of silkworms is rich in glutamine, histadine, lysine, serine and glycine. The amino acid content is proportional to the weight of the silk gland. The amino acids weigh up to 140 µg/gland (Chitra & Sridhara, 1972). Three novel antibacterial lebocin peptides have also been reported from the hemolymph of silkworm immunized with *Escherchia coli* (Hara, 1995; Abraham et al., 1995).

Pupae

Silkworm pupae are used as food and as a source of oil for medicines (Anon., 1996). The pupae contain vitamin B_1, B_2 and vitamin E. Important chemicals, such as chitin and triacontanol have also isolated from the exuviae (Majumder, 1997). Diapause hormone (DH) is reported to have been isolated from the pupae. Pupae contain 48.7% protein and 30% fat while spent pupae contain 26% oil and 75% protein (Rao, 1994; Anon., 1979). Fat constitutes about 30% of the total dry weight of pupae. Analysis of pupae shows that they contain ether extractives 31.1%; crude protein, 51.6% in addition to amino acids such as lysine and methionine (Koreleski et al., 1993). The content of oleic and linoleic acids in the fat are similar to those of animal fats. The protein of silkworm pupae is rated higher than the protein of soyabean, fish or beef. Artificial fibres and membranes are made out of pupal protein. It is used as a raw material for preparing peptones, amino acids and flavored products with high nutritive value. Silkworm pupal cakes of high nutiritive value are common in Japan. The pupal odor is removed by a process of fermentation and deodorisation (Majumder, 1997).

Live pupae are used as a medium to synthesize antibacterial peptides *in vivo* (Koul et al., 1994). Live healthy pupae are used in antibacterial protein preparations (Lakshminarayan & Rao, 1970; Rajiv & Vijayakumar, 1996). Pupal oil is used to treat liver and blood diseases (Koul et al., 1994). Silkworm cocoons when hydrolyzed in HCl give composite amino acids (>75.64%) having medicinal applications with low toxicity (Xiong et al., 1988b). A therapeutic tar is obtained from the pupae. The bactericidal and antihistaminic activities of the tar are superior to those from plant sources (Kanebo Ltd., 1981). Pupal skin contains chitin, which can be converted into various useful products like chitosan, chitin sulphate, chitin nitrate, chitin xanthate, sodium carboxymethyl chitin. The pupae yield chitin up to 4% of dry weight. Chitin and chitosan derivatives are used in wound dressing, controlled release of drugs, and contact lenses. They are also useful for enhancement of dissolution properties of poorly soluble drugs (Katti et al., 1996). Chrysalis oil obtained from the spent pupae represents a potential source of linolenic rich oil. After low temperature crystallization, chrysalis oil is quite similar to that of linseed oil (Majumder & Sengupta, 1979).

Moths

Adult moths are used in making wine and medicines. Male moths are used in Chinese medicine to treat sterility (Rajiv & Vijayakumar, 1996; Raju, 1996; Anon., 1996). A unique lipophilic peptide (VAP peptide) has been isolated from the heads of male moths. It acts as a bioactive material for inducing egg diapause (Imai et al., 1996).

Waste products

Proper utilization of sericulture and silk waste adds a value of up to 40% to the silk industry. Silkworm feces act as a raw material for variety of products such as paste chlorophyll, sodium copper chlorophyllin, pectin, phytol, carotene and triacontanol, which are used in the pharmaceutical and food industries (Raju, 1996). The feces have been found to contain solanesol, a highly valued precursor for many cardiac drugs (Babu, 1994). Chlorophyll extracted from the feces of silkworm is used as a medicine for gastric disorders such as ulcer and hepatitis. It is also used to treat liver and blood diseases (Rajiv & Vijaykumar, 1996; Koul et al., 1994). Sodium copper chlorophyllin extracted from paste chlorophyll shows antibacterial activity and has medicinal applications. It is used in the treatment of hepatitis, acute pancreatitis, chronic nephritis, stomach disorders and various leukocytopenia. A growth hormone has also been reported from silkworm litter (Majumder, 1997). At least two types of chlorophyll, a and b, are obtained from silkworm litter in the ratio of 3 : 1 and are used in medicines and cosmetics in China and Japan. Paste chlorophyll serves as a raw material for chlorophyllin. Pectin, carotene, phytol and triacotanol are also obtained from the left over feces after the extraction of chlorophyll. Pectin from silkworm feces reduces blood triglyceride and blood cholesterol (Raju, 1996). Phytol extracted from silkworm feces is used in the preparation of vitamin E, K, and carotene as a source of vitamin A (Rajiv & Vijaykumar, 1996; Koul et al., 1994).

Pelade, the inner layer of the cocoon shell obtained from reeled cocoons is a valuable ingredient of food in China and Japan. Reeled cocoons yield 10% of pelade. It is readily digestible and reduces cholesterol and blood sugar (Ramakanth & Raman, 1997). Protein and amino acids are also extracted from pelade. Chrysalises separated from pelade, dried and crushed and are incorporated into food for animals (Bedi, 1996; Xiong et al., 1988a). It contains palmitic acid, 24.4; stearic, 16.0; oleic, 27.2 and linoleic, 19.9%, and at least 8 amino acids (Lin et al., 1983). It serves as food, food additive and in pharmaceuticals. Deodorizing methods have also been given to remove any unpleasant odor from the proteins (Zhang et al., 1988; Li, 1988; Xiong et al., 1988b; Wu et al., 1994).

Silk film is used for artificial skin, blood vessel and in surgery. As food it reduces blood pressure in human beings (Koul et al., 1994). Fibroin extracted from the silk glands of *B. mori* is used for polyacrylamide gel electrophoresis in the presence of sodium dodecyl sulfate (SDS-PAGE) (Yu et al., 1996). Sericin in raw silk acts as a silk allergen. It causes contact dermatitis (Inou et al., 1997). Floss contains tannins having potential antifungal, antibacterial and antiviral properties (Pandey & Makkar, 1991).

Discussion and conclusion

Agro-industry has its advantages especially in a developing country like India where resources and labour are not scarce. Advancement in the rural sector is necessary for India to progress. Agro-products not only enhance rural development but also provide food security, a challenge to a nation whose population is approximately one billion. Development in the rural sector to a certain extent addresses the social issues too. The silk industry, as an important component of agro-based structures, provides considerable opportunities to improve rural livelihoods. Though there has been a lot of research input in this industry for widening its scope and avenues, the same has not been communicated effectively. The knowledge investment and the prospective development in this sector need to be propagated. The silkworm *B. mori*, the source of natural silk, from eggs to adults, has been reported to have wide potential in pharmaceutical, cosmetic and food industries. In this review an attempt has been made to highlight its potential as a medicinal insect.

As a source of animal protein and vitamins, the larvae and pupae are economical and abundantly available. If managed properly, it should address if not malnutrition, protein deficiency to some extent in rural areas. The larvae, pupae and their waste and by-products serve good for common urban ailments, such as bronchial asthma, diabetics, gastric disorders such as ulcer and hepatitis, high blood cholesterol, blood pressure, cardiac and other old-age problems. The pupal oil serves good for liver and blood diseases, common among the poor. Diabeties is no more uncommon in India. Pelade, the inner layer of cocoon shell is reported to reduce cholesterol and blood sugar. The possibility of mass production of pelade should be explored. As an agent of male infertility, the male worms have an urgent role to play in population control programmes. The larvae can be exploited for their antibacterial and antihistaminic activities and cosmetic value. The genetic analysis of *B. mori*, with its 400 mapped mutations, hundreds of geographical races and genetically improved strains for qualitative and quantitative traits, cloned genes encoding proteins with diverse functions, has further explored its role as an ideal molecular genetic resource for solving broad range of biological problems (Nagaraju, 2000). The review, at its level, considers the silkworm *B. mori*, a potential medicinal insect whose impact awaits proper attention and exploitation for the betterment of mankind.

References

Abraham EG, Nagaraju J, Salunke D, Gupta HM, Datta RK (1995): Purification and partial characterization of an induced antibacterial protein in the silkworm, *Bombyx mori*. *J Invertebr Pathol 65*: 17–24.

Anonymous (1979): Silkworm a new source of oil. *Indian Farmers' Dig 12*: 3.

Anonymous (1996): By-products for better revenue. *Indian Silk 35*: 3.

Aso Y, Yamamoto K, Yoshinaga T, Yamamoto H, Yamagami T (1995): Partial purification and characterisation of DOPA Quinone Imine conversion factor from larval hemolymph of the silkworm, *Bombyx mori*. *Biosci Biotech Biochem 59*: 277–281.

Babu GR (1994): Drugs from silkworms and their feces too. *Sci Rep 31*: 51.

Bedi GS (1996): Silk industry in Brazil. *Indian Silk 34*: 35–42.

Cai C, Zhi X, Huan-ying W, Long-qiang Z, Shu-han Y, Yuan L

(1991): Pearl pharmaceutical manufactory of Guanxi pearl Company. *Qinzhou China J Chin Mat Med 16*: 368–370.

Chang-xiong Z, Yao-jie X, Jian-hua Z, Gui-min M, Lai-en Y (1993): Vocal nodules and vocal polyps treated with Xiaojie Kaiyin powder and its influence on hemorheology. *J Trad Chin Med 34*: 486–488.

Chitra C, Sridhara S (1972): Amino acids in the silk glands of the silkworm, *Bombyx mori* L. *Curr Sci 41*: 52–54.

Datta RK (1994): Silkworms to produce human vaccine. *Indian Silk 33*: 33–35.

De-zi Z (1991): Treatment of bronchial asthma with Ningxiao Drink in 85 patients. *Shandong J Trad Chin Med 10*: 23.

Hai-bo H (1989): Treatment of 376 cases of male infertility with Zengjing pill. *Jiangxi J Trad Chin Med 20*: 10–11.

Hara S, Yamakawa M (1995): A novel antibacterial peptide family isolated from the silkworm, *Bombyx mori*. *Biochem J 310*: 651.

Hirabayashi K, Takei M, Kanbe A (1996): Manufacture of silk proteins as food additives *Jpn Kokai Tokkyo Koho JP 08 19372 [96 19372]*, *23 Jan 1996*, *Appl 94/157608*, *8 Jul*: 3.

Imai K, Sugiura K, Komiya T, Yamashita O (1996): Isolation and partial structure of a unique lipophilic peptide, VAP peptide from the heads of male silkworm moths. *Biosci Biotech Biochem 60*: 355–357.

Inou A, Ishido I, Shoji A, Yamada H (1997): Textile dermatitis from silk. *Contact Dermatitis 37*: 185.

Ishibashi J, Kataoka H, Nagasawa H, Isogai A, Suzuki A (1992): Isolation and identification of adipokinetic hormone of the silkworm, *Bombyx mori*. *Biosci Biotech Biochem 56*: 66–70.

Jouni ZE, Wells MA (1996): Purification and partial characterization of a lutein-binding protein from the midgut of the silkworm, *Bombyx mori*. *J Biol Chem 271*: 14722–14726.

Joy O, Gopinathan KP (1994): Expression of microinjected foreign DNA in silkworm, *Bombyx mori*. *Curr Sci 66*: 145–150.

Kanebo Ltd (1980): Tar from silkworm pupa. Kanebo, Ltd. *Jpn Tokkyo Koho 80 27*, *885*, *24 Jul 1980*, *Appl 71/59*, *440*, *05 Aug 1971*: 3.

Katti MR, Kaur R, Gowri S (1996): Pupae skin a useful waste. *Indian Silk 35*: 5–8.

Koreleski J, Smyk D, Kubicz M, Gawlik Z (1993): Nutritive value of silkworm pupa meal (*Bombyx mori* L.). *Roczniki Naukowwe Zootechniki 20*: 291–297.

Koul S, Dhar A, Bindroo BB (1994): Industrial utilization of sericultural resources in China. *Pop Sci 3*: 29–34.

Lakshminarayana T, Rao SDT (1970): Studies on spent silkworm pupae and their lipids I. Mulberry and Tassar varieties. *Indian Oil Soap J 35*: 234–237.

Li X (1988): Method for extraction of amino acids from silkworms. *Faming Zhuanli Shenqing Gongkai Shuomingshu CN 86*, *104*, *864*, *10 Feb 1988*, *Appl 30 Jul 1986*: 6.

Lin SW, Njaa LR, Eggum BO, Shen HY (1983): Chemical and biological evaluation of silkworm chrysalid protein. *J Sci Food Agric 34*: 896–900.

Majumder SK (1997): Scope for new commercial products from sericulture. *Indian Silk 35*: 13–18.

Majumder SK, Datta RK, Kar R, Pavankumar T (1996): Pupa-waste, an alternative resource for isolation of lecithin. *Sericologia 36*: 555–557.

Majumder UK, Sengupta A (1979): Triglyceride composition of chrysalis oil, an insect lipid. *J Am Oil Chem Soc 56*: 620–623.

Marumoto Y, Teruuchi T, Enjoh T, Numata F, Sakano K (1992): Purification and refolding of recombinant human IGF II from silkworms infected with recombinant *Bombyx mori* nuclear polyhedrosis virus. *Biosci Biotech Biochem 56*: 13–16.

Matsumoto S, Ozawa R, Uchiumi K, Kurihara M (1996): Cell free production of the silkworm sex pheromone Bombykol. *Biosci Biotech Biochem 60*: 369–373.

Nagamatsu Y, Yanagisawa I, Kimoto M, Okamoto E, Koga I (1995): Purification of a chitooligosaccharidolytic β-N-acetylglucosaminidase from *Bombyx mori* larvae during metamorphosis and the nucleotide sequence of its cDNA. *Biosci Biotech Biochem 59*: 219–225.

Nagaraju J (2000): Recent advances in molecular genetics of the silk moth, *Bombyx mori*. *Curr Sci 78*: 151–159.

Ozawa RA, Ando T, Nagasawa H, Kataoka H, Suzuki A (1993): Reduction of the acyl group: The critical step in Bombykol biosynthesis that is regulated *in vitro* by the neuropeptide hormone in the pheromone gland of *Bombyx mori*. *Biosci Biotech Biochem 57*: 2144–2147.

Pandey RK, Makkar HPS (1991): Occurrence of tannins in silkworm cocoons; their possible role. *Sci Cul 57*: 44–45.

Qader MA, Haque MT (1996): Estimation of fibroin in posterior silkgland of *Bombyx mori* feeding mulberry leaves under different cultivation forms. *Pakistan J Zool 28*: 9–12.

Rajiv S, Vijayakumar (1996): Sericulture By-products of China. *Indian Silk 34*: 19.

Raju S (1996): Utilization of sericultural by-products – a Chinese example. *Indian Silk 35*: 19–20.

Ramakanth, Raman KVA (1997): Cocoon Pelade for better health. *Indian Silk 35*: 35.

Rao PU (1994): Chemical composition and nutritional evaluation of spent silkworm pupae. *J Agric Food Chem 42*: 2201–2203.

Rathinam KMS, Chetty JS (1991): Effect of fortification of mulberry leaves with minerals to silkworm, *Bombyx mori* L. *Indian J Seri 30*: 121–123.

Sarker AA, Haque MR, Rab MA, Absar N (1995): Effects of feeding of mulberry (*Morus* sp.) leaves supplemented with different nutrients to silkworm (*Bombyx mori* L.). *Curr Sci 69*: 185–188.

Sen C (1991): Treating 51 patients with facial palsy with "Miantan decotion". *New J Trad Chin Med 23*: 31–33.

Shinohara T, Aso Y, Shirai K, Fuji H, Funatsu G (1993): Purification of Chymotrypsin inhibitors from larval hemolymph of the silkworm, *Bombyx mori*. *Biosci Biotech Biochem 57*: 1067–1071.

Singh KP, Jayasomu RS (1999): *Bombyx mori* – an economical and medicinal insect (accepted in XVIIIth International Sericultural Congress, at Egypt).

Song TS, Wang BL (1994): Natural anti-acne creams. *Riyong Huaxue Gongye 6*: 283–285.

Taraporewala KS, Shah SA (1995): Comparative studies of degumming and bleaching of silk fibres. *Manmade Textile in India 38*: 63–64.

Wu J, Ma J, Yang J (1994): Manufacture of protein from silkworm chrysalis. *Faming Zhuanli Shenqing Gongkai Shuomingshu CN 1087346*, *01 Jun 1994*, *Appl 93108177*, *07 Jul 1993*: 5.

Xia B, Li Z, Ding Y (1989): Properties of ultraviolet spectrum of domestic silkworm chorionins. *Canye Kexue 15*: 45–48.

Xiong G, Gao H, Li Z (1988a): Method for preparing amino acids from silkworm chrysalises. *Faming Zhuanli Shenqing Gongkai Shuomingshu CN 86*, *107*, *613*, *02 Nov 1988*, *Appl 05 Nov 1986*: 6.

Xiong G, Li Z, Bai Y, Gao H, weng D (1988b): Research and production of composite amino acid used as medicine. *Xibei daxue Xuebao Ziran Kexueban 18*: 91–94.

Xue-ping W, Qing Z, Wen-tang L (1991): Treatment of 146 patients with primary trigeminal neuralgia with “Zhentong solution”. *Shanxi J Trad Chin Med 7*: 18.

Yamanaka T, Kuroki M, Kinugasa T, Matsuo Y, Matsuoka Y (1996): Preparation and characterization of two human carcinoembryonic antigen family proteins of neutrophils, CD66b and c, in silkworm larvae. *Protein Expression Purif 7*: 438–446.

Yu TY, Cai ZS, Huang WD (1996): Study of fibroin composition of *Bombyx mori* silk proteins by SDS-PAGE. *Gaodeng Xuexiao Huaxue Xuebao 17*: 829–831.

Zhang G, Zhang Y, Xe W, Mu C, Pang Q (1988): Method for the extraction of odorless protein from silkworm with organic solvents. *Faming Zhuanli Shenqing Gongkai Shuomingshu CN 86*, *101*, *511*, *27 Jan 1988*, *Appl 04 Jul 1986*: 4.