From Waste to Wealth: The Untapped Power of Sericulture By-products

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OPEN ACCESS

Keywords

By-Products, Pupae, Sericulture, Waste

How to cite this article:

Biradar, R. R., Pavani, P. S. and Shweta. 2026. From Waste to Wealth: The Untapped Power of Sericulture By-products. *Vigyan Varta* 7 (01): 18-25.

ABSTRACT

Sericulture generates large volumes of valuable by-products, particularly silkworm pupae, litter, reeling effluents and plant waste, collectively termed seri-waste. These by-products possess immense nutritional, medicinal and industrial potential, making sericulture a sustainable, zero-waste enterprise. Silkworm pupae are rich in high-quality proteins, essential amino acids, vitamins, minerals and bioactive compounds with antioxidant, antimicrobial, anticancer and metabolic health benefits. Their oils contain beneficial unsaturated fatty acids, while larvae and excreta support biogas production, organic farming and compost enrichment. With the rising global demand for eco-friendly food and agricultural resources, the efficient utilisation of seri-waste offers a promising avenue for enhancing food security, environmental sustainability and rural livelihoods.

INTRODUCTION

Sericulture is an agro-based industry with a great capability of generating substantial employment particularly in rural areas through raw silk production. The resultant by-products of silk production whose economic values are less than the total cost involved in their reprocessing for beneficial use are often termed as 'sericulture waste' or 'seri-waste'. The major wastes and by-products are plant waste (leaves, fruits, stems and barks), silkworm waste, pupal waste, protein waste (sericin and fibroin), post-silk

extraction process, etc. The effective utilisations of these products are very much essential for placing sericulture as a promising occupation in farmers' mind. Therefore, the present sericulture not only focuses on income generation through cocoon selling but also through multiple reutilisations of by-products that can additionally benefit a farm's economy. The stages of waste generation in sericulture (both mulberry and non-mulberry) and their collection, consolidation and reutilisation in various agricultural and allied sectors. The current techniques and approaches for waste management and utilisation supported through latest research findings in broadening the sustainability of the sericulture. Sericulture, the practice of rearing silkworms, is best known for producing silk one of the most luxurious and valuable natural fibers. With the continuous growth of silk production, the volume of pupal waste generated by the industry has also increased substantially. According to the International Sericultural Commission (ISC, 2024), global silk production is projected to reach approximately 93,986 metric tonnes (MT) of raw silk in 2024. India, the second-largest producer of raw silk, is expected to contribute around 38,913 MT. Notably, for every kilogram of raw silk produced, the industry generates about 2 kilograms of dry pupae and 8.014 kilograms of wet pupae, highlighting the significant scale of by-product generation within sericulture operations.

Seri waste

Seri waste or sericulture waste refers to the by products generated during the process of silk production, including both mulberry and non mulberry sericulture. These waste includes silkworm litter, pupal waste, defective cocoons and reeling effluents. From one hectare of mulberry farm, about 15 metric tonnes (MT) of sericulture waste is produced annually.

Types of sericulture wastes

Mulberry stem and leaves

Used as livestock fodder, green manure, vermicompost, and biofuel feedstock. Leaves are primary feed for silkworms, while stems serve for fuel, handicrafts, mulching, and soil conservation. Valuable in pharmaceutical, nutraceutical and biopesticide formulations due to bioactive compounds.

Silkworm pupal matter and litter

Acts as nutrient-rich organic manure, improving soil fertility and crop yields. Applied in vermicomposting and biogas production. Rich in nitrogen, phosphorus, and potassium, it enhances microbial activity in soil. Useful in sustainable, chemical-free organic farming practices.

Pupae waste

Source of high-protein animal, poultry, and fish feed. Used in cosmetics, medicinal oils, and biofertilizers. Its protein hydrolysate benefits textile dyeing and pharmaceuticals. Also utilized for biodiesel production and as a protein supplement in food fortification and pet foods.

Pierced or defective cocoon

Employed in producing spun silk yarn, handicrafts, decorative items, and therapeutic fabrics. Extracted sericin and fibroin are used in cosmetics, biomedical products, and eco-friendly dyes. These cocoons reduce silk industry

waste and support rural cottage industries economically.

Reeling effluents

Rich in proteinaceous sericin and other bioactive compounds, reeling effluents are used to formulate biofertilizers, textile dyeing agents, cosmetic products, and biodegradable films. Also applied in wastewater treatment and pharmaceutical formulations, reducing environmental impact from sericulture processing waste.

Silkworm larvae

It is estimated that 100 grams of the larvae of Bombyx mori consist of 54% protein, 8% fat, 6% fiber and 6% ash, as well as 390 kcal of energy. Due to their high protein content, larvae are fed to younger animals, including reptiles, as a nutritional supplement. Pharmaceutical companies use a complete protein extract from silkworm larvae possessing anti-diabetic activity, or the food industry uses it an additional nutraceutical. According to the research, the silkworm has the greatest potential to drop blood sugar when it is prepared on the third day of the fifth instar, created using the freezing-dry method, and taken as powder as compared to other methods. Silkworm has traditionally been used as a diabetic treatment in oriental nations such as China, Korea and Japan and several studies have recently proven the silkworm's blood glucose lowering impact. Humans can readily digest and absorb silkworm powder. It can also improve the physiological activities of the gastrointestinal tract, Cramps, bloating and other illnesses can be treated using dehydrated silkworm larvae that were killed by the white muscadine disease. It is believed that mulberry-eating silkworms have better health benefits than other species.

Silkworm excreta

Silkworm has traditionally been used as a diabetic treatment in oriental nations such as China, Korea and Japan and several studies have recently proven the silkworm's blood glucose lowering impact. Humans can readily digest and absorb silkworm powder. It can also improve the physiological activities of the gastrointestinal tract, cramps, bloating and other illnesses can be treated using dehydrated silkworm larvae that were killed by the white muscadine disease. It is believed that mulberry-eating silkworms have better health benefits than other species. Silkworm drops are now again used to produce healthy alcoholic beverages like sansho. According to Lochynska and Frankowski (2018), silkworm breeding waste and caterpillar excreta produce biogas and methane yields comparable to or higher than common agricultural manures. Breeding waste, due to its higher dry matter and energy content, shows greater methane efficiency, with nearly 80% of total methane generated within the first 10 days and complete degradation by day 19.

Utilisation of silkworm pupal products (Mahanta *et al.*, 2023)

Nutritional profile of silkworm pupae

Silkworm pupae are rich in many nutrients. Protein, fat and sugar are the most abundant substances, as well as minerals, vitamins, polyphenolic compounds, and many other nutrients.

Silkworm Pupae Protein (Zhou *et al.*, 2022)

Bombyx mori has a high protein content of 55.6% dry weight and is the most abundant dry matter in silkworm pupae. Biologically active peptides are peptides containing from several to several dozen amino acids, which have a variety of physiological functions. These pupae proteins can be hydrolysed to produce a variety of biologically active

peptides, which in turn can perform the pharmacological functions of silkworm pupae. The amino acid composition of the proteins is essentially the same in the different species of silkworm pupae, all consisting of 18 amino acids (except for *Eri* silkworm pupae). Of these, eight essential amino acids meet the requirements of the WHO/FAO/UNU recommendations. In addition, there are 10 non-essential amino acids that meet human requirements. Compared to hen eggs, pupae are higher in Phe and Pro. Therefore, silkworm pupae are considered to be a high-quality source of protein and an important nutrient in silkworm pupae.

Table 3. Amino acid composition of different species of silkworm pupae proteins

Amino Acid (g/100 g of Protein)	*Bombyx mori* Pupae	Eri Silkworm Pupae	*Antheraea pernyi*	Hen Egg
Asp	10.9	9.89	6.41	8.92
Thr	5.4	4.75	4.64	4.47
Ser	4.7	5.25	4.64	6.72
Glu	14.9	12.9	12.74	12.13
Gly	4.6	4.94	4.42	3.02
Ala	5.5	6.05	6.26	5.03
Cys	1.4	0.53	1.5	1.90
Val	5.6	5.36	6.63	5.42
Met	4.6	2.31	1.47	2.81
Ile	5.7	4.42	7.95	4.88
Leu	8.3	6.63	3.24	8.11
Tyr	5.4	6.4	2.06	3.81
Phe	5.1	5.24	8.10	4.82
Lys	7.5	6.59	4.54	6.54
His	2.5	2.67	2.94	2.09
Arg	6.8	4.41	4.12	5.70
Pro	4.0	6.46	12.22	3.38
Trp	0.9	NA	4.05	1.72

Antioxidant Activity

There are two peptides extracted from silkworm pupae exhibited strong antioxidant activity in HepG2 cells, as evidenced by ROS reduction, superoxide dismutase (SOD) expression, and glutathione (GSH) production activity.

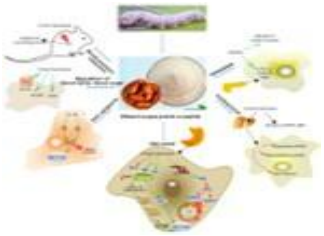

Fig. 3: Functions of silkworm pupal proteins

Antibacterial Activity

Firstly, it was found that silkworm pupa oil has antibacterial activity. The antimicrobial activity of silkworm pupa oil was determined using the minimum inhibitory concentration (MIC) method, and it was found that it significantly inhibited the growth of a staphylococcus sciuri strain CD97, with the best effect being achieved at 110 μL/mL.

Anti-cancer effect

Currently, cancer is mostly treated with radiotherapy and chemotherapy, which have side effects on the body, so finding natural antitumor drugs would be a better option. In vitro studies found the protein hydrolysates and amino acids in silkworm pupae had anticancer effects and were cytotoxic to human stomach cancer cells, breast cancer cells, and liver cancer cells. Both silkworm pupa protein and silkworm pupa oil were found to have anticancer activity. Silkworm pupae proteins act as anticancer agents by affecting the division cycle of cancer cells and inducing the production of apoptotic factors to promote apoptosis.

Antiapoptotic Effect

Silkworm pupae are rich in a low-molecular-weight lipoprotein that has been shown to be a member of the 30 K family of proteins that transport lipids and inhibited apoptosis in mammalian cells. Initially, researchers found that the haemolymph of silkworm pupae had apoptosis-inhibiting activity against virus-infected insect cells.

Regulation of Blood Pressure, Blood Sugar and Blood Lipids

Silkworm pupae also have a regulating effect on blood sugar and blood lipids. Silkworm pupae powder acts as an alpha-glucosidase inhibitor and lowers postprandial blood sugar levels. It also promotes fat metabolism and reduces fat accumulation in rats. This means

that silkworm pupae have the potential to be developed as a drug to lower blood sugar levels in diabetics with the same weight loss effect.

Silkworm pupae oil (Zhou *et al.*, 2022)

In silkworm pupae, the oil content is second only to protein. Of the four different species of silkworm pupae, *Eri* silkworm pupae has the highest oil content, at 26.2%. We summarise

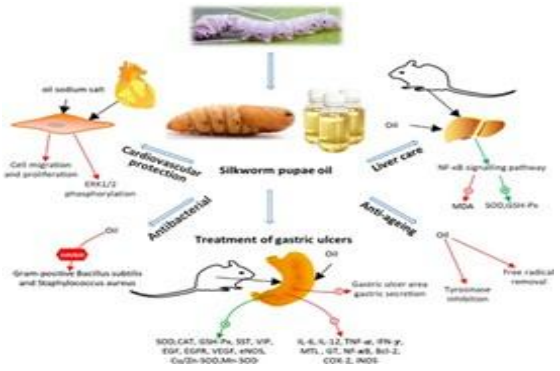

Fig 4: Functions of silkworm pupal oil

the fatty acid composition of the different varieties of silkworm pupae oil in Table 2. As can be seen from the table, all the different silkworm pupae oils contain high levels of unsaturated fatty acids, with 77.71% in *Antheraea pernyi*. In addition to the fatty acids listed in the table, silkworm pupae also contain eicosapentaenoic acid and docosahexaenoic acid, which are Omega-3 fatty acids and have an important role in promoting human health. Oil is an important nutrient, and silkworm pupae are not only rich in oils but also contain high levels of unsaturated fatty acids, especially polyunsaturated fatty acids, which have significant nutritional value as a source of edible oil.

Table 4. Fatty acid composition of different species of silkworm pupae oil

Fatty acids (Percentage of Fatty acids)	Mulberry silkworm	Eri silkworm	Tasar silkworm	Sunflower oil
Myristic acid (C14:0)	0.1	ND	NA	NA
Palmitic acid (C16:0)	24.2	26.98	17.25	5.6
Palmitoleic acid (C16:1)	1.7	1.82	1.14	NA
Stearic acid (C18:0)	4.5	4.73	2.23	2.2
Oleic acid (C18:1)	26.0	15.89	29.15	25.1
Linoleic acid (C18:2)	7.3	5.49	7.14	66.2
α-Linolenic acid (C18:3)	36.3	44.73	40.28	NA
Saturated fatty acids	28.8	31.71	19.48	7.8
Monounsaturated fatty acids	27.7	17.71	30.29	25.1
Polyunsaturated fatty acids	43.6	50.22	47.42	66.2

Cardiovascular Protection

Silkworm pupae oil sodium salt was found to significantly reduce platelet-derived growth-factor-induced abnormal migration and proliferation of vascular smooth muscle cells. Silkworm pupae oil sodium salt treatment down-regulates ERK1/2 phosphorylation levels in vascular smooth muscle cells. The findings of these studies could inform the prevention and treatment of cardiovascular disease, perhaps *via* the development of medicines or functional foods for the treatment of cardiovascular disease.

Gastric and Hepatoprotective Effects

Animal studies have found that silkworm pupae oil has a protective effect against hydrochloric-acid/ethanol-induced gastric ulcers. Silkworm pupae oil reduced the area of gastric ulcers and gastric secretions and increased the PH in the stomach of mice and use of silkworm pupae oil reduces oxidative damage and inflammatory responses in mice. Silkworm pupae oil also reduced acetaminophen-induced acute liver injury and alcohol-induced hepatotoxicity and oxidative stress in mice by inhibiting the oxidative-stress-mediated NF- κB signalling pathway. Silkworm pupae might serve as a potential drug resource for the treatment of gastric ulcers and the prevention of acute liver injury.

Other Important Pharmacological Functions of Silkworm Pupae

In addition to the above pharmacological functions, silkworm pupae also have antifatigue, antiaging, antigenotoxic, and alcohol detoxifying effects and inhibit the proliferation of fibroblasts. Moreover, silkworm pupae are suitable as bioreactors for the expression of heterologous proteins, which

is important for the development of vaccines and the production of recombinant proteins.

Table 5. Mineral composition of different species of silkworm pupae

Minerals (mg/100 g Dry Weight)	*Bombyx mori*	Eri Silkworm Pupae	*Antheraea pernyi*
Phosphorus	474	584	272
Iron	26	24	4
Calcium	158	74.2	63
Zinc	23	7.24	3.57
Copper	0.15	1.75	0.73
Magnesium	207	178	154
Manganese	0.71	2.54	NA
Chromium	1.69	NA	9.84

Among the content of eight minerals in the three types of pupae, from which it can be seen that phosphorus, calcium, and magnesium are higher in the pupae. The type and content of minerals in pupae can vary depending on the type of pupa and the environment in which they have grown. It is worth noting that the sodium-to-potassium (Na: K) ratio in silkworm pupae is very low, except for the minerals listed in the table. Na:K predicts the occurrence of non-communicable diseases, suggesting that consumption of silkworm pupae may reduce the likelihood of non-communicable diseases. Non-communicable diseases include stroke, hypertension, cardiovascular disease, etc. Some pupae are also rich in selenium, which can be enriched in the pupae protein. Selenium-rich pupae play an important role in cancer prevention and defence against oxidative stress.

Table.6. Comparison of vitamin composition of mulberry silkworm pupae and chicken meat

Vitamin	Silkworm pupae (mg/100 g)	Chicken meat (mg/100 g)
Vitamin A	273.99	99.83
Vitamin B1	1.91	0.1
Vitamin B2	5.43	0.1
Vitamin B3	15.20	11.2
Vitamin B5	12.49	0.8
Vitamin B7	144.51	-
Vitamin B9	0.41	-
Vitamin B12	500.00	0.0004
Vitamin C	5.70	-
Vitamin E	34.47	0.1
Reference	(Sadat *et al*., 2022)	(Michael, 2019)

Table 6 suggests that the vitamin contents in silkworm pupae is highest compared to that of chicken meat which implies that silkworm pupae is a rich source of vitamins.

Why silkworm pupa as alternative food source?

Population growth surge

In the current Scenario It is estimated that by 2050, there will be an additional 2.5 billion people and 70% increase in food demand. The sustainable food sources to maintain nutritional security without further environmental degradation.

Insufficient crop yields

Due to climate change, soil degradation & water scarcity are affecting agricultural productivity. Insect like Silkworm require less land & less Sensitive to climate Variation. making them reliable food option.

Insects as protein

Silkworm pupa rich in high quality proteins with essential amino acids required by humans comparable to meat. Their short life cycles and efficient feed conversion ratios make them an eco-friendly and protein alternative for sustainable human and animal nutrition.

Global insect consumption

Over 2 billion people consume insects as part of their traditional diets. Introducing silkworm pupae into the mainstream market can diversify food sources, as insects hold great potential as accessible, sustainable and nutritionally valuable food alternatives.

Nutrient-rich insects

Edible insects like silkworm pupae are rich in proteins, omega-3 fatty acids, iron, zinc, and B-complex vitamins. Their superior nutrient density can effectively combat protein-energy malnutrition and micronutrient deficiencies in vulnerable populations.

Low emissions farming

Silkworm farming generates significantly lower greenhouse gas emissions. Compared to

conventional livestock. Requiring minimal water, land and feed, insects present a sustainable agricultural practice aligned with climate-smart, low-emission, and resource-efficient food production systems.

Beneficial silkworm properties

Apart from nutrition, Silkworm offer health promoting properties like antioxidant, anti-inflammatary and antimicrobial effect due to bio active compounds like Sericin, peptides. Their by-products support pharmaceutical, cosmetic, therapeutic and animal feed industries, promoting zero-waste, sustainable production systems.

Sustainable insect farming

Silkworm require lees feed, water, land produce minimal waste, that can utilized as by-products feed, making it sustainable. It contributes to circular economy practices by converting low-value waste into high-value proteins, oils, and fertilizers, ensuring environmental sustainability.

Silkworm pupae as a nutritious human food

As a delectable human food, silkworm pupae are used in various Asian nations like Thailand, Korea, India, China, and Japan. Silkworm pupae have been discovered to boost lactating ability in tribal women and are superior to soya beans, salmon or beef in terms of protein content. They are also comparable to meat in terms of calories, fat, protein, and vitamins. Pupae have a large amount of crunchy chitin in their exoskeletons, which can be a useful supplement to rural populations' cereal diets. Pupae have a lot of commercial potential when used in chili sauce or chocolate. Pectin, a byproduct of silkworm pupae, was used to thicken ice cream, jam, candy, jelly, and fruit juices. Chitin, a component of pupal skin is used for a variety of purposes, notably as an ingredient to increase loaf volume in wheat flour bread, and silkworm pupal cakes are produced and marketed in Japan due to their high nutritional content. In China, Japan, Hong Kong, and Korea healthy silkworm pupae are sterilized, vacuum-dried, and sold as commercial food products, whereas cocoon Palade powder was utilized in sauces and soups. The eri pre-pupae and pupae are used to make the delicious fry, pakori, chop and cakes in India

PUPAL BASED PRODUCTS


Pupae salad


Crispy pupa


Grill and fried silkworm

Canned pupa


Pupa chocolate


Masala pupa


Silkworm Pupae Pasta


Silkworm Pupae Ramen Noodles


De Oiled Silkworm Pupae Powder

Silkworm pupae for composting (Mahesh, 2020)

Dried silkworm pupae contain 8 per cent of nitrogen. Since the pupa contain high amount of nitrogen and protein along with micronutrients like zinc, copper, magnesium and manganese, there is a prospective potential for the bioconversion of pupal waste to enriched compost and utilization as a nutrient source. Application of Silkworm pupae residual bio compost (SPRB) along with chemical fertilizers significantly increased both growth and yield parameters of mulberry.

CONCLUSION

Silkworm pupae and other sericulture by-products hold immense potential beyond silk production, offering valuable applications in nutrition, agriculture, medicine and industry. Their rich protein, vitamin and mineral composition positions them as a sustainable alternative food source for a rapidly growing global population. The diverse pharmacological properties of pupal proteins and oils further enhance their relevance in healthcare and functional food development. Effective utilisation of seri-waste, including pupae, litter and reeling effluents, supports zero-waste farming and strengthens rural livelihoods. As the world looks toward eco-friendly, resource-efficient solutions, silkworm pupae emerge as a promising resource for ensuring food security, environmental sustainability and economic resilience.

REFERENCES

Lochynska, M. and Frankowski, J., 2018, The biogas production potential from silkworm waste. *J. Waste Manag.*, 79: 564-570.

Mahanta, D. K., Komal, J., Samal, I., Bhoi, T. K., Dubey, V. K., Pradhan, K., Nekkanti, A., Gouda, M. R., Saini, V., Negi, N. and Bhateja, S., 2023, Nutritional aspects and dietary benefits of "Silkworms": Current scenario and future outlook. *Front. Nut.*, 10:1121508-1121515.

Mahesh, D. S., 2020, Influence of Silkworm pupal residue bio compost (SPRB) on growth and yield parameters of Mulberry. *Int. J. Agric. Sci.,*12(2): 0975-3710.

Zhou, Y., Zhou, S., Duan, H., Wang, J. and Yan, W., 2022, Silkworm pupae: a functional food with health benefits for humans. *Foods*, 11(11):1594-1599.