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Value Addition Of Silkworm Pupae

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Introduction

India produces about 40,000 MT of silkworm pupae on dry weight basis per annum. Dead pupae are highly perishable. Drying and disposal causes environmental pollution besides loss of nutrients. Conversion of this proteinaceous waste into a value added product helps to meet the increasing demand for proteins in animal production programmes and also it saves the cost of waste treatment and disposal. Silkworm pupae, the waste from filature basin are rich in protein (76%) and fat. It is also a good source of vitamins. Refined protein of pupae is superior to that of fish meal and about equal to that of beef. It is used as food in the eastern and north-eastern regions of the country. Fried pupae make a good edible dish. The pupae may be utilised as poultry feed. The pupae may serve as fish food.(Chrysalis oil) may be extracted from pupae. The pupal oil is dark brown in colour with fishy smell. About 27-30% oil can be extracted from the pupae on dry weight basis. Italy is the second largest producer of this oil following Japan.

Chemical composition of silkworm pupa

Pupa contains crude 50 - 60% proteins, 25 - 35% fats, 5-8% free amino acids, 8 – 10% sugars, E, B1, B2 vitamins, calcium, phosphorous, 100 g of dried silkworm pupae can provide 75% daily protein requirement of human individual. The vitamins like pyridoxal, riboflavin, thiamine, ascorbic acid, folic acid nicotinic acid, pantothenic acid, and minerals like calcium, iron copper, selenium and phosphorus make the pupae more nutritive and also found used for better lactation in tribal women (Koundinya and Thangavaleu, 2005). The silkworm pupae due to their high fat content (over 30%), are used as chrysalis oil to obtain

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cosmetic products (cream, soap, lotion, emulsion) and as protein powder for valuable animal's fodder.

High protein content

The silkworm chrysalis contains a large amount of proteins, fats and minerals and this by-product of reeling can be used to the best advantage of the poorer section of the society. About ten million kilogram of silkworm pupa is available from Karnataka every year according to crude estimate. The west Bengal too produces a large quantity of such chrysalis.

Silkworm pupa is rich in macro molecules such as protein, fat and carbohydrates. It is largely used as an edible item. It is a good source of protein with about 48.7% of the total macro molecules and fat content of 30% of the total weight. Pupal fat contains 66.8 % of total unsaturated fatty acids and linoleic acid accounts for 25.77 % of the total fat. The oil content of silkworm pupa is less than 10%. Further, carotenoids present in the silkworm pupa contains lutein and hexoxanthin, which are very good antioxidants.

Silkworm pupae are a good source of micro molecules like vitamins B1, B2 and E. The silkworm pupa after reeling is ready to be eaten as it comes from the reeling pan in boiled and cooked condition. BUN DAE KI –is an example of such high protein silkworm snacks, tinned and marketed in Korea prepared out of silkworm pupa. Besides a nutritious delicacy, silkworm pupa has many new usages in medical and cosmetics fields and brings in good value addition for such by-products.

Silkworm pupae as a nutritious and delicious human food

In some Asian countries like Korea, China, Japan, Thailand etc. the silkworm pupae are used as delicious human food. The characteristics like refractive index1.47 at 30^{o}C, acid value of 67.37, safonification value of 150.88, iodine value of 174.91,cholesterol per cent of 0.36 of pupa oil made its utility as great prospect in food industry. Pupal protein is used as raw material for preparing amino acids and flavoured products with high nutritive value. In terms of protein, fat, vitamins and calories the silkworm pupae are equal to meat and better than the protein of soya bean, fish or beef and has been found used for better lactation in tribal women. The exoskeleton of pupae contains large amounts of crunchy

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chitin, which can supplement the cereal diet of rural people. The use of pupae in chocolates, chilli sauce has vast potential for commercializing the concept. Silkworm pupae were eaten by Chinese as food and Pectin, the pupal by product used as a thickener in candy, jelly, jam, fruit juices and ice creams. Chitin, a component of pupal skin used in different applications like an additive to increase the loaf volume in wheat flour bread and in Japan cakes are prepared and sold as silkworm pupal cakes due to their high nutritive value. In Hong-Kong, China, Korea and Japan the healthy silkworm pupae are sterilized, vacuum dried and sold as commercial food and the cocoon Palade powder was used in soups and sauce preparations. The delicious fry, pakori, chop and cakes are prepared from the eri pre pupae. The free amino acids extracted from the cocoon Palade has wide utility in food industries as a cheap source of raw material and the Shinki fibroin, the hydrolyzed by-product from waste silk fiber consumed with milk or coffee. In Africa, the mature larvae of Saturniids used as a garnish in raw, dried and powdered form for human consumption and the roasted pupae, the dried product of pupae, the peaggie are consumed as food in Western United States. The silk protein has wide applications as food and drinks and could be converted to diet for the crew of Control Ecological Life Support [CELIS], one of the most advanced and complicated closed ecological systems in the world.

Silkworm pupa as astronaut food

A newly developed space cookie made of silkworm pupal powder is set to add more taste to astronauts diet. MasamichiYmashita, a researcher with Japan Aerospace Exploration Agency released a recipe for pupa cookies during the 36th scientific assembly of the committee on space research. The recipe comprises 3-6 g of silkworm pupal powder, 200 g of rice powder and 300 cubic centimetres of soymilk, soya sauce and salt. Astronauts may blend these materials with water and divide the mixture in to two small pieces which is unappetizing but apparently healthy.

Paints and Varnishes

Linseed oil 75% mixed with 25% pupal oil can be used for the manufacture of paints and varnishes. Sterol can be separated from this oil, which is very good hair tonic. Chrysalis oil can also be used for burning purpose. Many countries have already switched over the use of chrysalis oil for their textile industries and chrysalis powder can be used as moulding

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material in the Bakelite industry. After extracting oil from the pupae, the residue i.e. cake (KHALI) may be used as fish bait and poultry feed.

As an animal feed

Waste silkworm pupae (SWP) generate vast resources of nutrients for livestock and poultry. SWP is one of the unconventional top class protein (65-75%) and lipid. Among many alternative protein sources, SWP are considered as an important dietary protein source for poultry after proper processing at a reasonable cost (Iyengar, 2002). Pupae and silk waste are being used as poultry or fish feed. The de-oiled pupae fed hens improved their egg laying capacity with impact on the colour of the egg yolk and the fat free pupae used as feed of carps and fish for better yields. Silkworm pupae were used as food in piggery, poultry, and pisciculture and as dog feed due to their richness in protein and fatty acids. The silkworm pupae fed to hybrid magur fish has significantly enhanced growth to fetch 4~5 times more profit and this escalated the dried pupal cost to Rs.13~ 15 per kg from Rs. 2~ 3. The dried pupal feed has enhanced growth rate and egg quality in hens and improved survival rate, feed conversion rate and specific growth rate in fish. The deoiled feed of pupae made rabbits to gain better weight and growth of fur (Velayudhan*et al.*, 2008).

Silkworm pupae in cosmetic and chemical industry use

The silkworm pupae due to their high fat content (over 30%), are used as chrysalis oil to obtain cosmetic products (cream, soap, lotion, emulsion). Pupal skin protein derivative, chitin found used in cosmetic preparations and the absorbent/ resilient hybrid silk films used in wound healing and in descarring. The silkworm pupal fat and oil is useful in soap/cosmetology industries and found working in anti-aging, darkening gray hair and body weight reduction. The silkworm pupal oil is used in cosmetics like hair oil, face powder, creams and body deodorants. Pupal fat is good raw material in soap, glycerin, cosmetic industries and fertilizer can also be generated from the pupa and pupal excreta.

Silkworm pupae in bio-medical and pharmaceutical industry

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Chitin, a component of pupal skin used in post operational treatments such as conchotomy, deviatory, polypectomy because of its easy usability, less hemophase, greater pain relief and fastens healing of wounds. Chitin found as potent anti-microbial agent against *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Asppergillusniger* etc., anti-fungal against *Trichophyton equinum*, its buffering activity against acids, as food additive to control carcinogenicity of food stuffs. Chitin also used as immuno-adjuvant (antiviral agent), bacteriostatic, fungistatic, anti-sordes agents in preventing carcinogenic bacteria from teeth and biocompatible membrane to check bleeding in major surgeries. Silkworm proteins in the form of Serrapeptidase is used in pharmaceuticals for anti-inflammatory, anti-tumefacient action of acute sinusitis, tonsiloctomy, oral surgery, during filling, cleaning and taking out teeth. The artificial fibres and membranes are prepared from pupal proteins are of good use in the medical field. Certain proteins of silkworm and pupae used as special diets for cardiac and diabetic patients because they are easily digestible and reduces cholesterol and blood sugar by providing additional energy. Serrapeptidase, an enzyme derived from silkworm protein was used as non-steroidal antiinflammatory agents for treating rheumatoid arthritis. The glucosamine extracted from silkworm pupae can be used for treating osteoarthritis. The pupae were used in medicinal wine since ancient days and for lowering fat, BP, blood sugar levels. They also used for treating liver hepatitis, pancreatitis, leukocytopenia, neurological, ophthalmic, anti-bacterial, anti-histaminic, gastric ailments and in preparation of vitamins A, E and K. The silk pupae are the potential base for culturing highly valuable mushrooms fighting cancer with strengthening the immune system and silk fibers can be used for making bioactive textiles due to their anti-bacterial activity. More than 30% of pupae oil is linolenic acid which is the raw material of human DHA exerting an important effect on human intellect and memory improvement, sightprotection and is a precaution chemical against hyperlipoidemia.

Silkworm pupae as compost

Silkworm pupae used as compost to obtain higher yields of agricultural crops. Sharma and Ganguly (2011) showed that, the silkworm pupal bio-waste can be converted to good quality fuels which may be used as biodiesel additives. The results of the experiment by Sangeetha *et al.* (2012) clearly indicated that the application of SLPW (Silkworm litter-pupal

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waste) + Vermicompost recorded significantly higher leaf yield (32,098.5 kg) and NPK content (3.11%, 0.39% and 2.48 %) respectively.

Silkworm Pupal Oil

Silkworm pupal oil is processed from raw fresh silkworm pupae. The techniques followed are drying, extracting, degumming, decidification, filtering, bleaching, off flavour, and moisture elimination andmolecular distillation refinement. While the silkworm pupal oil is used in hair oils, face creams and body deodorants. Pupal oil, used in the pharmaceutical industry (anti-inflammatory, antitumefying effect, lymphatic circulation stimulant) used in the treatment of sinusitis, otitis, bronchitis, asthma, tuberculosis, urinary infections and in post-surgery situations. In Japan, a product based on chrysalis oil is called Serratiopeptidase; while in China a product is called Gan Mo Le. From the same chrysalis oil, superior sodium and potassium soaps are obtained; varnishes and dyes used in the textile and tannery industry, lubricants, printing inks, plasticizer for PVC are amongst its other uses. The residue formed during the chrysalis oil's extraction is used as natural organic fertilizer and as food for poultry, pigs, and fish and fur bearer animals.

Applications of pupal oil

Due to the rich unsaturated fatty acids, especially α-linolenic acid in the silkworm pupal oil, it can be used in medicine, health food, nutritional food and high-end cosmetics and other industries except for eating.

Characters of Pupal oil

	Parameters	**Standard**
Sense	Colour	Light yellow
	Smell	No peculiar smell
Physical and chemical indicators	Water and volatile %	≤0.2
	Saponification %	≤0.3
	Iodine value (gI/100g)	≥120

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	Acid value of oil（mg KOH /g）	≤2.0
	Peroxide number (mmol/kg)	≤7.5
	Impurities	d 0.1
	Total content of unsaturated fatty acids(%)	≥70
	Content of Linolenic acid (%)	＞40
Health indicators	Lead (mg/kg)	≤1.5
	Arsenic (mg/kg)	≤1.0
	Mercury (mg/kg)	≤0.3
	Aerobic bacterial count (Cfu/g(ml))	≤1000
	Coliform bacteria (MPN/100g(ml)	≤40
	Moulds (Cfu/g(ml)	≤25
	Pathogenic bacteria (Cfu/g)	not found

Conclusion

By-product utilization hopefully plays a crucial role in the upcoming years to make sericulture an economically viable proposition to enabling it to withstand competitive for other cash crops. The major generated by-product in the silk reeling industry is the silkworm pupae which can be effectively used to raise the returns of silk cocoon realers in particular and cocoon growers at large.

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