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Value Addition Span of Silkworm Cocoon - Time for Utility Optimization

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Realizing the scope of utilizing by-products of silk cocoons by applying appropriate methods is the immediate crave to optimize returns. The nutritive value of pupae suits for human diet, feed for poultry, carps, fish, rabbits, piggery and dogs. The pupal skin, fat, oil, cocoon palade have applications in oleo chemical, soap, glycerin, cosmetic, artificial fibres, membranes and n-triacontanol isolation. The pupal proteins Chitin, Shinki fibroin, Serrapeptidase, glucosamine are latent precursors of post surgical, anti-carcinogenic, anti-inflammative, anti-bacterial, anti-histaminic, gastric, hepatitis, pancreatitis, leukocytopenia, neurological, ophthalmic, blood pressure, cardiac and diabetic medicines and for preparation of vitamins A, E and K. The silk and its proteins sericin and fibroin are potentially used for wound healing, diabetes, impotence, sinusitis, arthritis, edema, cystitis, epididymitis, tissue regeneration, cancer, post-surgical trauma and used as anti-oxidatives, bio-adhesives, ultra violet screens and bio-active textiles. The waste cocoons can be used in making art crafts like garlands, carpets, overcoats, decoratives and greeting cards. The in-depth research towards utility optimization and make aware this reality to sericulturists, reelers, weavers, traders, entrepreneurs, policy makers etc., is the upright want of the today's Sericulture industry.

Key words: Silkworm Cocoon, By-products, Value addition, Utility optimization

Introduction

In spite of world wide remarkable augmentation of by-product value to bump up the cost benefit ratio, India has not kept pace in sericultural fronts. The by-products presently felt as wastes, can put to better use in generating the value-based products and thereby catapult the industry to a more profitable and economically viable spot. The full utilization of silkworm cocoons as different marketable products and such an integrated operation can certainly make the Sericulture more practical (Aruga, 1994; Choudhury, 2003; Dandin and Nirmal Kumar, 2007; Han *et al.*, 2002; Katti *et al.*, 1996; Koundinya and Thangavelu, 2005; Majumder, 1997; Mani, 1997; Raju, 1996; Velayudhan *et al.*, 2008). The cost of end product i.e. the silk can be proportionately brought down by the combination of regulating the processing methods and converting the wastes as useful by-products. The optimal by-product utility concept can be highly useful to sericulture industry, which can help in elevating the socio economic status of the rural poor rearers. Profitable conversion of wastes / by-products to high value utilities through phyto and post harvest technologies (Majumdar, 1997), the collaboration of Seri scientists with related industries, to locate functional activities for potential applications (Koundinya and Thangavelu, 2005; Kumaresan *et al.*, 2007) can reduce the production cost, pollution, recycles resources to cater the ever growing population and their demanding wants.

Present situation

The rearing of silkworm is almost a prerogative for the Indian rural farmers and Ericulture is a subsidiary occupation in providing supplementary income to a large number of tribal populations of North East India. Majority of the host plants of all four types of silks i.e. mulberry, Tasar, Muga and Eri silkworms are available as cultivated or nature grown and the different agro climatic conditions have made the Sericulture as major commercial avocation. The production of 16525, 1485, 350 and 115 MTs of mulberry, Eri, Tasar and Muga raw silk respectively by India during 2006-07 indicates the quantum potential of silk cocoon and by-product raw material. The major por-

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Table 1. Biochemical constituents of pupae (in percentage) of domestic silkworm (Aruga, 1994; Roychoudhury and Joshi, 1995)

Pupal form	Water	Fat	Protein	Glycogen	Chitin	Ash
Dried	7.18	29.57	49.98	4.65	3.73	2.19
Sqashed	6.32	15.20	60.77	5.78	4.63	2.73
Fat free	5.49	00.47	72.82	6.92	5.55	3.27

tion of farmers belongs to economically poorer sections and unaware the full potential of by-products. The cocoons produced were sold for their immediate livelihood to reelers, who offer the rate assessing only the silk yield and the value addition through by-products was never thought of. The silk cocoons were mainly utilized for silk production, seed production and seldom for animal feed, oil extraction, fertilizer and art crafts. Incidentally, the nutritional values of the chrysalis made sericulture more important as delicacy than its silk. However, the trends on cost benefit ratio and comparison with other alternative cash crops made the farmers, reelers, weavers, traders and entrepreneurs to have a second thought on utilizing silk cocoons on all possible angles for revenue.

Scope and span of value addition

Nutritive and dietary uses

In North East India, the eri pupae were sold at Rs.25/- to 60/- per kg and this alone will fetch Rs.19440 = 00 per ha/yr (Singh and Suryanarayana, 2003). Source of income from ericulture will be from spinning (48%), from eripupae (37%) and from eri waste (15%) (Sahay *et al.*, 1997) and however, it is not same with mulberry, tasar and muga cultures. Pupae contain crude protein (55 ~ 60%), total lipids (26%), free amino acids (5 ~ 8%) and 100 gms of dried silkworm pupae can provide 75% daily protein requirement of human individual (Singh and Suryanarayana, 2003). The vitamins like pyridoxal, riboflavin, thiamine, ascorbic acid, folic acid and minerals like calcium, iron and phosphorus make the pupae more nutritive and also found used for better lactation in tribal women (Koundinya and Thangavelu, 2005; Roychoudhury and Joshi, 1995; Singh and Suryanarayana, 2003). The characteristics like refractive index-1.47 at 30°C, acid value-67.37, safonification value-150.88, iodine value-174.91, cholesterol %- 0.36 of pupa oil made its utility as great prospect in food industry (Choudhury, 2003). Pupal protein is used as raw material for preparing amino acids and flavoured products with high nutritive value (Aruga, 1994). In terms of protein, fat, vitamins and calories the silk worm pupae are equal to meat and better than the protein of soya bean, fish or beef. The exoskeleton of pupae contains large amounts of crunchy chitin, which can supplement cereal diet of rural people. The use of pupae in chocolates, chilli sauce has vast potential for commercializing the concept. The domestic silkworm pupae have high nutritive values as they contain water, protein, fat, glycogen, chitin and ashes (Table 1), good quantities of vitamins, minerals and lipid fractions (Table 2) and rich proportion of essential amino acids in pupa, cocoon pelade and silk fiber (Table 3). Silkworm pupae were eaten by Chinese as food (Roychoudhury and Joshi, 1995) and Pectin, the pupal by-product used as thickener in candy, jelly, jam, fruit juices and ice creams (Raju, 1996). Chitin, a component of pupal

Table 2. Particulars of six vitamins, three minerals and five lipid fractions of deoiled pupae of domestic silkworm (Roychoudhury and Joshi, 1995; Sahay *et al.*, 1997)

Vitamins	Minerals	Lipid fractions
Pyridoxal	Calcium	Glycerol trioleate
Riboflavin		Neutral lipid
Thiamine	Iron	Phospholipids
Ascorbic acid		Cholesterol
Folic acid	Phosphorus	Lionolenic acid
Nicotinic acid		

Table 3. Particulars of essential amino acids in pupae, cocoon pelade and silk fiber (Ramakanth and Raman, 1997; Kumaresan *et al.*, 2007; Roychoudhury and Joshi, 1995;)

Name of the amino acid	Quantity of amino acids		
	Pupa (mg/g)	Pelade (g/100g)	Silk fiber (g/100g)
Glycine	14	37	14
Aspartic acid	21	03	17
Glutamic acid	05	03	04
Serine	05	13	34
Threonine	07	02	10
Alanine	94	30	06
Lysine	05	01	03
Arginine	19	01	03
Valine & Metionine	199	04	03
Leucine & Isoleucine	500	02	02
Tyrosine	nil	nil	03
Histidine & Tryptophan	nil	nil	01
Phenylalanine	nil	nil	01
Praline & Cystine	nil	nil	01

skin used in different applications like 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 (Majumder, 1997). In Hong-Kong, China, Korea and Japan the healthy silkworm larvae are sterilized, vacuum dried and sold as commercial food and the cocoon palade powder was used in soups and sauce preparations (Ramakanth and Raman, 1997). The delicious fry, pakori, chop and cakes are prepared from the eri pre pupae and pupae (Singh and Suryanarayana, 2003). 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 (Ramesh *et al*., 2005). 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 (Kumaresan *et al*., 2007) and could be converted to diet for the crew of Control Ecological Life Support [CELIS], one of the most advanced and complicated closed ecological system in the world (Dandin and Kumar, 2007). Japan Aerospace Exploration Agency [JAXA] has released a pupal recipe during 36^{th} Scientific Assembly of the Committee on Space Rsearch [COSPAR] as astronaut food (Velayudhan *et al*., 2008).

Pharmaceutical and bio-medical uses

Chitin, a component of pupal skin used in post operational treatments such as conchotomy, deviatomy, polypectomy because of its easy usebility, less hemophase, greater pain relief and fastens healing of wounds (Katti *et al*., 1996). Chitin found as potent anti-microbial agent against *Staphylococccus aureus*, *Klebsiella pneumoniae*, *Asppergillus niger* etc., anti-fungal against *Trichophyton equinum*, its buffering activity against acids, as food additive to control carcinogenicity of food stuffs (Katti *et al*., 1996). Chitin also used as immuno-adjuvant (antiviral agent), bacteriostatic, fungistatic, anti-sordes agents in preventing carcinogenic bacteria from teeth and bio-compatible membrane to check bleeding in major surgeries (Katti *et al*., 1996). Silkworm proteins in the form of Serratio peptidase 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 medical field (Majumder, 1997). Certain proteins of silkworm and pupae used as specialty diets for cardiac and diabetic patients because they are easily digestible and reduces cholesterol and blood sugar by providing additional energy (Ramakanth and Raman, 1997). The silk derivatives have diversified applications in epidermal recovery, bone formation, drug delivery systems and also in veterinary pharmaceuticals (Ramesh *et al*., 2005). Serrapeptidase, an enzyme derived from silkworm protein was used as non-steroidal anti-inflammatory agents for treating rheumatoid arthritis. The silk is used in anti-hay fever masks, gauze pads, bandages to treat dermatological disorders, as artificial skin, blood vessels, tendons, ligaments, contact lenses, catheters for surgical procedures and anti-coagulants. The silk is used as bandages to promote wound healing, potential material to fight diabetes, impotence, sinusitis, arthritis, idiopathic edema, cystitis, epididymitis, cancer and post-surgical trauma (Dandin and Kumar, 2007). The silk protein sericin used as anti-oxidative, bio-adhesive and also in wound healing treatments (Kumaresan *et al*., 2007). The glucosamine extracted from silkworm pupae can be used for treating osteoarthritis (Datta *et al*., 2007). 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 (Velayudhan *et al*., 2008).

Cosmetic uses

Pupal skin protein derivative, chitin found used in cosmetic preparations and the absorbent/ resilient hybrid silk films used in wound healing and in de-scarring (Dandin and kumar, 2007; Katti *et al*., 1996). The silk bio-polymer used in manufacturing contact lences, tissue regeneration for treating burn victims and matrix of wound dressing (Ramesh *et al*., 2005). The silk fibroin peptides are used in cosmetics due to their glossy, flexible, elastic coating power, easy spreading and adhesion characters (Dandin and kumar, 2007). The silk protein, sericin due to its saturation, revitalization and UV rays absorption properties has got potential as skin moisturizer, anti-irritant, anti-wrinkle and sun protector in addition to shaping the hair by making soft and flexible (Kumaresan *et al.*, 2007). The silk worm pupal oil is used in cosmetics like hair oil, face powder, creams and body deodorants (Velayudhan *et al.*, 2008).

Animal feed uses

The pupae and silk waste are being used as poultry or fish feed (Iyengar, 2002). The de-oiled pupae fed hens improved their egg laying capacity with impact on the color of the egg yolk and the fat free pupae used as feed of carps and fish for better yields (Aruga, 1994). Silkworm pupae were used as food in piggery, poultry, pisciculture and as dog feed due to their richness in protein and fatty acids.

The silkworm pupae fed to hybrid magur fish has significant 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 (Ghosh, 2005). 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).

Chemical industry uses

The silk worm pupae oil has got wide uses in oelo chemical and food processing industries. Pupal fat is good raw material in soap, glycerin, cosmetic industries and fertilizer can also be generated from the pupa and pupal excreta. The n-triacontanol, a plant growth promoter is found in good quantities and being extracted from silkworm. The pupal skin which is available abundantly in the reeling and grainage sectors as a waste can be utilized as commercial raw material for various industries (Han *et al.*, 2002; Katti *et al.*, 1996). The silk worm pupal fat and oil is useful in soap/cosmetology industries and found working in anti-aging, darkening gray hair and body weight reduction (Velayudhan *et al.*, 2008).

Art craft uses

The eye catching art of cocoon craft is one of the very interesting utility of by-products which will give scope to develop human skills in addition to generate self employment and revenue. The value addition in post cocoon sectors is estimated to generate income ranging from 10 to 25% in total returns. Different articles like garlands, flower vase, wreath, pen stand, dolls, jewellery, wall hangings, wall plates, clocks, bouquets and greeting cards are being prepared using the waste silk cocoons (Vathsala, 1997). In Japan some laboratories have produced silk paper in different colors for making craft articles like flowers and lamp stands. The silk leather, a paint containing silk powder is used to decorate plastics, steel and fabrics. The hybrid silk, net raw silk, silk tow and silk wave were produced in Japan for making under garments, jackets, sweaters, carpets and furnishings (Singh *et al.*, 2002).

Other uses

Scientists in Korea and Japan have made innovative research on application of silk proteins as basic research material in biological and biomedical fields. The silk pupae are the potential base for culturing highly valuable mushrooms fighting cancer with strengthening immune system and silk fibers can be used for making bioactive textiles due to their anti bacterial activity (Koundinya and Thangavelu, 2005). The fibroin and sericin, the highly promising silk proteins with potential as biomaterial for tissue regeneration, bio-adhesive and ultra violet resistant uses (Dandin and Kumar, 2007; Kumaresan *et al*., 2007).

Conclusion

By-product utilization hopefully should play a crucial role in the coming years to make the sericulture an economically viable proposition enabling it to withstand competition from other cash crops. The useful conversion of by-products through indigenously available processing techniques brings additional income lead to socio economic up-liftment of rearers. The need for introduction of integrated processing complexes with redesigning of present practices deserves special mention to make the practice more attractive and people to participate enthusiastically. The operation of nutritive, pharmaceutical, bio-medical, cosmetic, animal feed, chemical industry, art craft, bio-indicative, bio-adhesive and bio-material values of silkworm cocoon, pupae, silk through methodical diversified dispensation certainly boosts up the Sericulture. The R&D institutions, Sericulture departments, policy makers should work towards popularize the concept of value addition with fitting trainings, multi discipline projects and global marketing outlets for effective by-product utilization in today's competitive competition. The realization of value addition span, application of suitable technology and optimization of utilizing by-products of silkworm cocoons by all the stake holders is the integrated want of silk industry.

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