Review Article

Innovative utilization of sericulture resources to value added products – a review

ABSTRACT

A number of by-products, popularly called as wastes are generated in different activities such as host plant cultivation, rearing of silkworms, production of silkworm seeds to produce quality commercial cocoons. Primarily sericulture is practiced to get the silk, while it also provides many by-products and even its wastes can be utilized to prepare various value added products which are intensive used not only in research line but also in the manufacture of products of day to day needs and make more cost effective. Cut and pierced cocoons are the raw materials for production of spun yarn and handicrafts of making good-looking value added products like garlands, bouquets, flower vase, birds and greeting cards etc. which are sold at a premium. Silk waste is well utilized in the production of spun silk fabric, ornaments, parachutes and cosmetic industry. The value of sericulture activity has increased by 10–25 percent as a result of the use of its by-products. Silk wastes have promising applications which broadens the sustainability of sericulture industry and thus prove to be remunerative in earning an additional income.

Keywords: *Host plants; silkworms; silk moths; rearing waste; defective cocoons; silk waste*

1. INTRODUCTION

Sericulture is a high-demand, agro-based livelihood sector mostly used by persons from average economic backgrounds in rural and semi-urban locations. The silkworm culture involves different activities such as cultivation of host plant to produce quality leaves, rearing of silkworms and production of silkworm seed to produce commercial cocoons and silk. A supplementary product that results from a manufacturing process is called a by-product. A number of by-products, popularly called as wastes are generated in different sericulture activities [1]. Mostly, sericulture is used to produce silk, but it also yields a lot of byproducts, and even their waste can be used to make a wide range of highly-valued items which are intensive used not only in research line but also in the manufacture of products of day to day needs and make more cost effective. However, utilization of by-products of sericulture activity has not kept pace with the quantum jump country had in the production of silk over the past two decades and there are many by-products which can be put to better use for turning the industry into a more profitable and economically viable unit. The utilization of by-products of sericulture activity has enhanced the value of sericulture activity by 10-25 per cent. The utilization of sericultural wastes can be converted into a full-time enterprise which ultimately reflected in the increased returns to the growers, reeler and traders and earn an additional income during their leisure time. The systematic utilization of secondary waste products is furnished below:

2. CULTIVATION OF SILKWORM HOST PLANTS AND THEIR UTILIZATION

Cultivation of host plant is the first most important step for rearing of silkworm. The quality leaves are utilized for feeding the silkworm for good growth and development. Besides this the pruned branches, bark, stems, fruits and unused leaves are the secondary products of host plants.

2.1. UTILIZATION OF MULBERRY SILKWORM (*Bombyx mori*) HOST PLANTS

The mulberry *Morus species* are known as the primary food source for mulberry silkworms and is widely cultivated worldwide. The unused leaves and different mulberry plant parts such as twigs, branches, roots are considered as wastes and can be utilized for making value added products as fire wood, fuel, cattle feed and manures.

2.1.1. Mulberry leaves

Mulberry leaves are rich in calcium, phosphorus, magnesium, vitamins, B, C and K. Additionally; they contain antioxidants, specifically the flavonoids kaempferol and quercetin as well as the anthocyanins. The leaf contains 18 amino acids and has medicinal properties [2] which are used for the treatment of conjunctivitis and blood pressure. Mulberries are traditionally used in several parts of India, China, Afghanistan, Bulgaria, Georgia, Azerbaijan, and other countries where ruminants are fed diverse forage diets. Dairy heifers had higher voluntary intake and thus higher potential of milk production, when consuming mulberry fodder rather than the cassava tree (*Manihot glaziovii*) and Leucaena (*Leucaena diversifolia*) [3]. Mulberry leaves, owing to their high carotene content, can form a valuable source of vitamin A for the health of poultry birds and increased egg production with desirable yolk colour without any adverse effect on body weight and egg quality[4]. The mulberry tea is prepared from mulberry leaves and contains no caffeine. Mulberry tea, mulberry leaf extract and mulberry leaf juice have medicinal properties and are used to treat Alzheimer's disease hyperlipidemia, artherosclerosis, diabetes, throat infection, irritation, inflammation and diarrhea.

2.1.2. Mulberry Fruits

The mulberry fruit is a rare and valuable dessert fruit. The full-bodied flavour of this fruit is a good balance of sweet in taste with full of antioxidant, anti-mutagen and anti-obesity nutritional properties of vital importance for human metabolism. Mulberry fruits are used in the preparation of jams, jelly, pulp, fruit drink, fruit sauce, cake, fruit tea, fruit powder, food colorant, cooling beverages, vinegar and wines and also helpful in curing the diseases like diarrhea, intestinal ulcers, cancer, Alzheimer and heart disease [5]. It creates new opportunities for the global industrial exploitation of mulberry fruits. Such a use of the mulberry has been overlooked for the sake of using only mulberry leaf for the sericulture industry. The health benefits of mulberry fruits are numerous and include substantial amounts of minerals [5] which are represented in table 1.

Table 1: Nutritional value of mulberry fruits

Nutrient elements	Nutritional value
Malic Acid	35.4-198.5 mg/g
Citric Acid	5.5-23.4 mg/g
Moisture	8.75%,
Protein	1.5%,
Fat	0.4%,
Carbohydrate	8.3%,
Fiber	1.4%,
Mineral Matters	0.9%,

2.1.3. Mulberry twig, branches and wood stem

A number mulberry branches are remained as a left-over during silkworms rearing. This can be composted successfully, independently or together with other remnants from silkworm rearing and can be used as good organic fertilizer, non-commercial fuel [6,7]. Mulberry twig branches and wood stem are used in cosmetics-for hair lotions; moisture products for skin, paper industry, wood processing for furniture, preparation of pens, as biogas, in the food industry for natural coloring, alcohol ennobling and in the textile industry for making the so called "artificial cotton" for making the sport items like cricket bats and value added products like wood art [8] low cost particle board [9]. The milky juice exuded by the mulberry is effective against the action of certain bacteria and yeast.

2.1.4. Mulberry roots

Mulberry roots have cathartic and anthelmentic effects and are one of the main ingredients in the medication "Glucosidase," which is used to treat high blood pressure [10]. Deoxyjirimycin (DNJ), an alkaloid considered to be potent against the AIDS virus, is present in the

root bark extract of black mulberries (*Morus nigra*). “Sang bai Pi”, Chinese medicine which is used to cure cough, asthma and many other diseases and have been reported to contain flavonoids showed positive activity against HIV [11] and Morusin, a prenylated flavonoid isolated from *Morus alba* with various biological activities inhibits tumor promotion [12,13] work together to protect the baby's delicate skin.

2.2. UTILIZATION OF ERI SILKWORM (*Samia ricini*) HOST PLANTS

Castor (*Ricinus communis*) is the most important food plant of eri (*Samia ricini*) silkworm while Ailanthus tree (*Ailanthus spp.)*, Jatropha (*Jatropha curcus*) and Tapioca (*Manihot utilissima*) being considered as its secondary food plants.

2.2.1. Castor

Castor is regarded as one of the most promising non-edible oil crops because of its high yield and annual seed production, which are used to prepare fuel and biodiesel. Castor oil is used in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold resistant plastics, nylon, pharmaceuticals, perfumes, waxes and polishes [14, 15].

2.2.2. Ailanthus species

Ailanthus species are used in several value added products such as for animal feed, fuel, timber, pharmaceutical applications and many more. Its wood has a desirable appearance and characteristics that are comparable to those of other hardwood species of similar densities per weight [16]. *Ailanthus* has a history of being used for pulp and is accepted at pulp mills in Virginia that use hardwoods. *A. excelsa* tree has medicinal and an aromatic property like leaves and bark is useful for the treatment of against asthma, bronchitis and dysentery [17]. Additionally, the leaves and bark are very well-known for their tonic properties that are used after childbirth. The juice of the leaves and fresh bark is prepared as a herbal remedies for pain relieving.

2.2.3. Jatropha

The biomass wastes are leaf and stem from pruning, fruit hull, seed husk and oily-cake.The seed contains 28-30% oil, easily soluble in alcohol, used in manufacturing of soap, tooth brush and leaves are used as green manure in tea garden and have good hair stimulant. Jatropha waste is also utilized as fertilizer, briquettes, adsorbent, resin and bioactive compost. It can also be used as a feedstock for dye, biogas, liquid oil, gasifier combustion, and the creation of polymer composites. These wide utilizations make jatropha very suitable for biofuel proposes [18].

2.2.4. Tapioca

Tapioca is a staple food for millions of people in tropical countries. Besides using as a source of food, the tuber is used in manufacture of sago, starch, glucose and dextrine. Tapioca powder is commonly used as a thickener for soups and other liquid foods. In addition, it serves as a binder for natural paints and medicinal tablets. The flour is used to make tender breads, cakes, biscuits, cookies and other delicacies [19]. Sago boosts breast milk production and is beneficial for digestive problems, making it one of the most significant foods for nursing moms. Tapioca starch is well accepted as sizing material for cotton, jute and paper industries. Moreover, starch is utilised in the production of matchboxes, explosives, fire crackers, dry cells and so on.

2.3. UTILIZATION OF MUGA SILKWORM (*Antheraea assamensis*) HOST PLANTS

Som (*Persea bombycina*) and sualo (*Litsea polyantha*) are the primary and mejankori (*Litsea cubeba*) the secondary food plants of muga silkworm (*Antheraea assamensis*). Despite being very soft and lacking strength, som and sualo wood can be utilised to make decorative items and as a raw material for pulp and paper. The mejankori (*Litsea cubeba*) tree is also referred to as “Chinese Pepper” or “Mountain Pepper”. *Litsea cubeba* oil is used for treating digestive ailments, chills, back pain and muscular aches and also has antimicrobial properties [20].

2.4. UTILIZATION OFTASAR SILKWORM (*Antheraea mylitta*) HOST PLANTS

Tasar silkworm feeds primarily on Arjun (*Terminalia arjuna*), Asan (*Terminalia tomentosa*) and Sal (*Shorea robusta*). Tropical tasar silkworms are mainly found in the Central India like Ranchi, Jharkhand, Madhya Pradesh, Uttar Pradesh and Maharashtra. These plants are most widely used for traditional medicinal purposes throughout the World because they have antibacterial, antifungal, antiprotozoal, antiviral, ant diarrhoeal, analgesic, anti-malarial, antioxidant, anti-inflammatory, anticancer, wound healing and cardiovascular effects. *Terminalia chebula* is known as the king of plants in Ayurveda due to its broad range of medicinal uses [21]. Sal is very strong and durable timber, used for decorative furniture, making doors, windows, cots, wooden handles, and railway sleepers [22].

3. SILKWORM REARING AND THEIR UTILIZATION

Silkworm rearing is the important activity of sericulture industry to produce good quality cocoons. During the period of rearing, lots of wastes like unfertilized eggs, unused leaves, larval excreta, dead, diseased, unhealthy larvae, etc. are generated which can be used to get different valuable products.

3.1. Silkworm eggs

The silkworm eggs contain 56.00% albumin, 19.20% fats and 7.70% sugars. They are consumed, used as an extract to stimulate male libido (as is customary), and are high in proteins, glycoproteins, embryo inductors, and vitamins B1 and B2, which have hepatic protector action and energizing properties, hypolipidemic and hypoglycemic effect. Silkworm eggs are processed into proteic extract used in the pharmaceutical industry with hepatic protein action and also in the food industry [23]. This extract is sold in Romania as the Human fort B product. It is believed that the silkworm eggs, if eaten by heavy alcohol drinkers they give up drinking completely because they start feeling alcohol disgust. However, this fact has not been proved scientifically.

3.2 Silkworm larva

All silkworm larvae are not capable for spinning of silk to form their cocoons. In sericulturally advanced countries like China, Hong Kong and Japan, the healthy silkworms are sterilized and sold as commercial food in dried and powdered form. It is used as a common animal protein for human consumption in soup and sauce preparation. Because of its low cholesterol present, it is used as a diet of cardiac and diabetic patients in South Korea [24, 25]. Dead and rejected silkworm larvae are utilized as poultry feed. Silkworm guts from mature silk glands of dead larvae are also used in bait and surgical stitching [26].

3.3. Silkworm rearing bed residue

The silkworm larval excreta, exuviae, waste leaves are used as fuel, manure or compost, cattle feed and in the production of bio-gas. Silkworm litters are also useful in preparation of pencil covers, carbon, plastics and in the extraction of growth hormones [26].

3.4. Silkworm excreta

The silkworm larval excreta are utilized as poultry, cattle, sheep, goat feed and a source of fuel, compost, medicine and cosmetics. The amount of nitrogen, phosphorus and potassium present in the silkworm litter are 1.40, 0.40 and 0.80%, respectively. Once they are composted, these can be added to the soil. Silkworm litters can be effectively used as raw material in the biogas plant along with cowdung to produce fuel. Silkworm larval litter with a better biogas yield (96.20% more than cowdung) can be utilized as a supplement to cowdung in the biogas plant [27]. Furthermore, hens feeding on silkworm litter lay eggs with more xanthophyll content (0.017 mg per egg). Chlorphyll, Carotene, phytal, pectin is extracted from litters and used as edible colour and in the preparation of candy, vitamins, plant growth promoters, wine, ice-creams and also colouring agent for tooth paste and cosmetics. Incense sticks can also be prepared from silkworm excreta [28]. Furthermore, when compared to other agricultural crop wastes, silkworm litters have a well-known nutritional composition [29] (Table 2).

Table 2: Constituents of silkworm litter and other cattle feeds

Feed	Moisture	Crude protein	Crude fat	Crude fibre	Soluble non-nitrogenous matter
Silkworm litter	12.2	15.4	2.6	19.6	36.2
Wheat bran	11.1	18.3	3.4	9.9	51.0
Paddy husk	9.1	13.2	16.1	8.1	33.3
Wild grass	8.5	5.7	1.5	31.5	38.8

3.5. Silkworm pupa

The silkworm pupa is also one of the major by-products in silk industry. In some parts of India, china and Japan, the silkworm pupae are used as an edible human food and regarded as delicious food item. The dried pupae contain 25-35% fat oil and 50% protein, 5-8% amino acids, 8-10% sugars, few vitamins like- B1, B2 and E, minerals like calcium, phosphorous, copper and iron [30]. A single human being can obtain 75% of their daily protein needs from 100 g of dried silkworm pupae [31]. Chitin is a component of pupal skin used as food additive to increase the loaf volume in wheat flour bread. In Japan, pupal cakes and biscuits are prepared and sold as silkworm pupal cakes due to their high nutritive value for human consumption [32]. Silkworm pupa has medicinal properties and is used to treat anti-inflammatory and anti-tumefying, tuberculosis, urinary infection, bronchitis, lowering blood pressure and blood sugar. The pupae of silkworms are utilized as pupal oil to make cosmetics (cream, soap, lotion, and emulsion) that are used to light lamps because of their high fat content (in excess of 30%) [33]. Defatted pupal powder is also used as source of nutrient for pig, chicken, fish and cattle. A splendid material of candle made from pupa is produced in Italy by the process of hydrogenation.

3.6. Silkworm moth

The silkworm moth after egg laying become wastes and which can be utilized to produce many value added products. In addition, dead, unused and discarded moths are used as poultry feed, compost, biogas and also in the preparation of drugs. The discarded male moths used to brew medicinal wines. The moth oil contains 75% fatty oils, from which more than 50% are unsaturated fatty acids. The moth oil can be used to obtain textile dyes and superior soaps [34]. The extraction residue can be used in obtaining of monosodium glutamate or as fodder. The moth can also yield cellular cytochrome C for pharmaceutical use, uric acid or hormones and sex messengers of the Prothoracicotropic hormone (hormone of central nervous system) and diapause hormone type sexual hormone [35].

4. REELING AND SPINNING OF COCOONS AND THEIR UTILIZATION

All the cocoons are not suitable for commercial reeling and spinning purposes. The wastes such as deflossing waste, cooking waste, thread waste, plead layer or basin refuse, charkha waste, filature waste, re-reeling waste, throwster's waste are produced even from good cocoons. Biotic and abiotic factors like genetic defects, diseases, pest, improper mounting, early harvesting or improper transportation of cocoons are also responsible for producing defective cocoons. Spun silk is a cheaper silk thread obtained from damaged cocoons and wastes silk.

4.1. Defectives cocoons

Defective cocoons (melted, urinated, flimsy, flossy cocoons, double cocoons and pierced cocoons) cannot be used for quality silk production but they can be utilized in many value added products. It is categorized as grade-I by product because these are used in the production of spun silk i.e., gicha, katia etc. from which coarse varieties of fabrics such as gents chaddar, lady's scarves/stoles, curtains, table cloth, caps are produced [27, 36]. Matka yarn is obtained from pierced and cut cocoons by hand spinning process. Tasar cocoons have long and strong peduncles which is normally cut and separated from the cocoons before reeling and boiled in soap and soda solution to get the balkal yarn. The balkal yarn is well used in suiting. Dupion silk is produced from the double cocoons. After washing, drying, and beating the fiber is carded and spun into yarn in khadi system. The short filaments are found during the process of dressing which are used in the production of coarse yarn known as Noil yarn. Moreover, Cut and pierced cocoons are the raw materials for handicrafts of making good-looking value added products like garlands, bouquets, jewellery, birds and wall hanging, flower vase, greeting cards etc. which are sold at a premium.

4.2. Silk waste

Silk is actually a natural protein fibre, composed of two main proteins *viz.,* fibroin (73.5%) and sericin (22.28 %), besides it contains some waxes (3.02%), minerals and ash (1.11%) and negligible amount of ether and alcohol extract [23]. Primarily silk waste like thread waste, pelade waste, boiled off cocoons, re-reeling waste and throwster waste is well utilized in the production of spun silk fabric by using the traditional method "Takli" or "Pedal Charkha". Silk proteins have moisture retention and UV ray blocking properties and these are utilized in different cosmetics like cream, lotion and toothpaste [36]. Silk powder prepared from the silk waste is used in cosmetics and medicines for reducing blood pressure. Besides these, silk film is well utilized in making artificial blood vessel, artificial skin and as vector for medicines and enzymes. Sericin, the silk protein is obtained during cocoon cooking and degumming of silk and is used in chemical industry as well as the sericin mixed with water can be used in irrigation system to enrich the soil [37]. Silk serves as a raw material for the creation of noiseless gears used in precision machinery. French tire manufacturers utilize 22–24 denier silk in their production to make tires last longer than rubber. Parachutes are made from 13-15 denier silk fiber. These parachutes were used in World War-II [38]. Cozy and soft sky jackets, comforters and sleeping bags are also made from silk.

5. CONCLUSION

The various value added by-products can be prepared by the sericultural farmers at a very cheaper rate compared to other traditional items. It is clearly visible from the above information that nothing gets waste in sericultural activities. There is a tremendous scope for generating the additional employment to the rural people by converting the waste products into useful items with good remunerative products. So an integration of sericulture and utilization of sericultural wastes can be taken up as a source of secondary income even during the leisure period by aged and young age school dropouts.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONFLICTS OF INTEREST

Authors have declared that there is no conflict of interest.

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