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Utilization of Sericulture Byproducts: A Pathway to Zero Waste

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Sericulture is a unique agro-based industry where almost every component has potential for diverse utilization. Apart from silk, the primary product, sericulture generates a wide range of by-products and wastes such as perforated cocoons, chrysalides of *Bombyx mori*, silkworm litter, leftover mulberry leaves, diseased larvae, exuviae, and plant biomass including roots, stems, and fruits of mulberry. Traditionally, only the silk filament has been exploited on a commercial scale; however, with appropriate processing technologies, these secondary resources can be transformed into value-added products. This approach not only reduces waste but also enhances profitability, enabling farmers to earn two to three times more than from cocoon production alone. Recognizing the immense potential of these resources, there is an urgent need to promote research on their systematic utilization, diversification, and commercialization. Scientific interventions focused on value addition to sericultural by-products will ensure sustainability, strengthen rural livelihoods, and establish sericulture as a multi-product functional industry rather than a single-product sector.

Resources from Mulberry (Morus alba)

Mulberry (Morus alba), the principal food plant for silkworms, is widely cultivated in Asia, where it has also been used in traditional medicine for centuries. The plant is a reservoir of bioactive compounds, including flavonoids and other phenolics, which exhibit strong antioxidant, anti-inflammatory, and anti-diabetic properties.

During silkworm rearing, considerable amounts of mulberry-based waste are generated, including:

- Silkworm excreta (approximately 60% of consumed food),
- Unutilized and leftover leaves (20–30%),
- Harvested leaves (10–20%) that remain unused,
- Exuviae from moulting larvae, and
- Weak, diseased, or dead larvae.

These residues, if scientifically processed, can be converted into valuable inputs for agriculture, animal husbandry, pharmaceuticals, and nutraceuticals.

Utilization of Mulberry Leaves

Mature and surplus mulberry leaves can be employed for multiple applications:

Silkworm Diets: Artificial or semi-synthetic silkworm diets can be formulated using unused mature leaves.

Human Health: Mulberry tea, enriched with antioxidants, helps regulate blood pressure and blood glucose levels. The leaves are rich in vitamins, proteins, and essential amino acids, making them a promising functional food.

Animal Feed: The rich protein and carbohydrate content of mulberry leaves serves as a good green fodder like other fodder to livestock, rabbits and pigs. They are also suitable as poultry feed. The unused leaf after feeding to the silkworm is used as fodder to increase the milk of

livestock. One hactare mulberry garden sustains 3 - 4 milch animals, which adds additional income of Rs.8, 000 – 10,000 to a family.

Medicinal Applications: Certain mulberry species, such as *Morus bombycis*, contain N-methyl-1-deoxynojirimycin (DNJ), a compound effective against diabetes mellitus and known to inhibit HIV infectivity. Leaf decoctions of *Morus australis* are traditionally used as gargles to relieve throat inflammation. In vitro studies reveal that mulberry leaf extracts reduce inflammatory proteins and oxidative DNA damage in human white blood cells.

Utilization of Mulberry Fruit

Mulberry fruits are nutrient-rich, containing carotene, thiamine, riboflavin, nicotinic acid, and vitamin C. They are used in:

Functional Foods: Fresh juice acts as a natural vitamin tonic.

Processed Products: Preparation of spiced squash, appetizers, jams (e.g., rosella–mulberry blend in 70:30 ratio), and syrups, which can be stored under refrigeration for up to six months.

Fermentation Products: Fruits are used to produce vinegar and fruit-based beverages.

Mulberry shoots for basket making

Mulberry is a fast-growing perennial plant capable of withstanding repeated pruning, which enables it to produce a large volume of biomass throughout the year. The stems, twigs, and leaves are traditionally utilized in multiple ways, with twigs and dried leaves commonly used as fuel for household cooking. From one hectare of mulberry plantation, approximately 10–12 tons of stems and twigs can be harvested annually—enough to meet the yearly fuelwood requirement of a family of six to eight members. An important feature of mulberry is the resilience and flexibility of its shoots, which makes them suitable for handicraft purposes. The plant produces numerous branches with relatively small leaves, while the shoot biomass outweighs the leaf yield, reflecting its high biological productivity. Owing to their pliability, mulberry twigs can be easily bent and woven, making them ideal for basket preparation and other rural craft activities.

Mulberry as sport material

Mulberry is well known for the manufacture of sports article and toys, turnery items. The hardwood of species such as *Morus laevigata*, *Morus serrata*, and *Morus indica* is especially valued for its fine grain, durability, and smooth finish. These qualities make it suitable for crafting tennis rackets, cricket bats, bobbins, pulleys, handles, and various turnery products.

The wood's fine texture not only enhances its polishing quality but also increases its desirability in toy making and other decorative works. *M. laevigata* in particular is known for its natural resistance to termites, which adds to its utility as a construction material. In the Andaman and Nicobar Islands, this species has traditionally been used as poles in house building due to its strength and pest resistance.

Utilization from Silkworm Rearing Waste

Silkworm rearing produces substantial biomass in the form of larval litter, diseased/dead larvae, and moulting exuviae. These wastes can be harnessed as follows:

Vermicomposting: Mulberry cultivation and silkworm rearing together generate a substantial amount of organic waste. On average, nearly 15 metric tons of sericultural waste is produced annually from a single hectare of mulberry farm. This waste includes silkworm rearing residues such as larval litter, leftover mulberry leaves, pupal cases, and farm by-products. Nutrient-wise, this biomass is equivalent to about 280–300 kg of nitrogen, 90–100 kg of phosphorus, and 150–200 kg of potash. Instead of leaving this material unutilized, its conversion into vermicompost provides a sustainable and eco-friendly solution. Vermicomposting employs a mixed culture of juvenile earthworms—primarily *Eudrilus eugeniae*, *Eisenia foetida*, and *Perionyx excavatus*—to decompose organic matter efficiently. The resulting vermicompost is a nutrient-rich organic manure containing approximately 1.8–2.0% nitrogen, 0.6–0.9% phosphorus, and 1.0–1.5% potash, along with essential

micronutrients and beneficial microorganisms. Studies have shown that vermicompost derived from sericultural waste is far superior to conventional farmyard manure, both in terms of nutrient content and microbial activity. Its regular application not only improves soil fertility and structure but also reduces the dependency on costly chemical fertilizers, making sericulture more economically and environmentally sustainable.

Animal Feed: Litter mixed with mulberry leaf residues is suitable as poultry feed.

Industrial Applications: Excreta are a source of chlorophyll, which finds uses in cosmetics and pharmaceuticals.

Biopesticides: Diseased or dead larvae can be exploited for the mass production of Bacillus thuringiensis, a natural bio-control agent.

Growth Promoters: Triacontanol, extracted from larval stages, enhances mulberry growth.

Renewable Energy: Silkworm litter, combined with cow dung, serves as raw material for biogas production. Phytol and carotene can also be recovered from larvae for industrial purposes.

Sericin: Sericin, a silk protein removed as waste during reeling, is now gaining attention as a bioactive molecule. With properties beneficial for skincare, wound healing, and drug delivery, it has become an important raw material in the pharmaceutical and cosmetic industries.

Pelade Layer: The pelade layer, generated during reeling, contains thin filaments with low sericin content. Modern processing techniques convert this material into usable silk fiber, thus minimizing waste.

Utilization from Silkworm Grainage

Grainage operations produce seri-wastes such as defective cocoons (pierced, stained, or flossy cocoons) and dead moths. These resources are valuable in:

Animal Feed: Pupal cakes, prepared from waste pupae, are high in protein and serve as feed for poultry, pigs, and rabbits.

Pet Food: Pupal powder is incorporated into pet biscuits due to its protein content (about 80%).

Oil Extraction: Silkworm pupae, a major by-product of sericulture, serve as a valuable resource for oil extraction. On a dry weight basis, pupae yield approximately 20% oil. This pupal oil is nutritionally and industrially important as it contains more than 70% unsaturated fatty acids, primarily α-linolenic acid and oleic acid, both of which are beneficial for human health. The high proportion of omega-3 fatty acids and alpha-linolenic acid (ALA) enhances its significance as a functional lipid source.

Traditionally, pupal oil has been extracted by boiling, and the crude oil obtained has found application in multiple sectors. In the cosmetics industry, it is used for manufacturing soaps, moisturizers, and skincare products. Historically, soaps derived from pupal oil were also employed in the degumming process of silk. Beyond cosmetics, the oil has notable industrial applications: in the jute industry as a lubricant (where rice bran oil is commonly used at present) and in leather processing as a substitute for fish oil.

A remarkable bioactive compound found in pupal oil is 1-Deoxynojirimycin (DNJ), a potent alpha-glucosidase inhibitor with therapeutic value in managing diabetes. The presence of such bioactive molecules further expands its pharmaceutical potential.

Due to its unique fatty acid profile and bioactive constituents, silkworm pupal oil is being explored for diverse uses, including in the production of paints, varnishes, candles, plastics, and even as a promising raw material for biofuel. Thus, pupal oil not only adds value to sericultural by-products but also contributes to health, industry, and sustainable resource utilization.

Handicrafts from Silk Waste

Defective cocoons are creatively repurposed into handicrafts such as wall hangings, vases, and greeting cards. These products not only add value to waste materials but also support rural artisans and promote cultural aesthetics.

Conclusion

Sericulture, long valued for its silk, is emerging as a comprehensive bio-resource industry with the potential to generate a wide range of value-added products. Every component of the system—mulberry plants, silkworm rearing residues, grainage by-products, reeling wastes, and defective cocoons—can be transformed into resources for agriculture, medicine, industry, energy, and handicrafts. Mulberry contributes leaves, fruits, shoots, and wood for food, fodder, health supplements, crafts, and sports goods, while silkworm rearing waste can be converted into vermicompost, animal feed, biogas, and bio-control agents. Similarly, pupal oil extraction, sericin recovery, and handicraft production from defective cocoons demonstrate how waste can be turned into high-value commodities.

By integrating these practices into mainstream sericulture, farmers can diversify their income streams, reduce waste, and achieve greater sustainability. The transformation of sericulture from a single-product activity into a multi-product functional industry not only enhances economic returns but also supports environmental conservation and rural livelihood security. With continued scientific innovation, policy support, and entrepreneurial initiatives, sericulture holds vast potential as a model for sustainable agro-based industries of the future.

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