

Valorisation of Products and By-Products Resulting from Sericulture and Moriculture

Roxana Nicoleta Lazăr, Silvia Pătruică*

University of Life Sciences "King Mihai I" from Timisoara, Calea Aradului No. 119, 300645 Timisoara, Romania

Abstract

In addition to natural silk, sericulture activity also generates numerous by-products with high economic value, used in a wide range of fields: medicine, biotechnology, cosmetics, and agriculture. Their efficient management contributes to optimizing production and increasing the sustainability of the silk industry. Silk proteins, fibroin and sericin, have a significant impact in the medical and cosmetic fields, offering innovative solutions for tissue regeneration, skin care and the development of advanced biomaterials. The intelligent use of sericulture waste transformed into organic fertilizers contributes to improving soil fertility and supporting organic agriculture. Silkworm chrysalis is a high-quality protein source due to its high content of protein and essential amino acids. It can be used both in animal feed, including poultry, pigs and fish, and in the human food industry, with the potential to become a sustainable alternative to conventional proteins. Mulberry leaves (*Morus* spp.) are the main food source for silkworms, having great importance not only in sericulture, but also in the pharmaceutical and food industries. Mulberries are also appreciated for their nutritional value and beneficial health properties, being used in the food industry to obtain juices, jams and other derived products. Sericulture is not just an activity based on silk production, but offers multiple resources with varied applications, which can add economic value and support the development of related industries.

Keywords: *Bombyx mori*, cocoon, *Morus* spp., silk, silkworms.

1. Introduction

Sericulture is the science of raising silkworms (*Bombyx mori* L.), which is essential for the production of natural silk. Productivity in this area depends on factors such as breed genetics, nutrition and environmental conditions [1]. In the sericulture process, the activity practiced involves raising silkworms by feeding them with mulberry leaves (*Morus alba*) [2]. Silkworms, *Bombyx mori*, are valuable organisms due to their long history of domestication, well-studied biology, and multiple uses in research. They are widely used in insect genetics, biotechnology, toxicology and many other fields [3]. The main sericultural product obtained from the process of growing *Bombyx*

mori larvae is silk, which has strength and durability, elasticity, shine, antibacterial properties, and is hypoallergenic [4-7]. In addition to the silk thread itself, sericulture generates a series of by-products that have various economic and industrial uses: silkworm meal, silkworm droppings, unused or defective cocoons [8, 9].

Mulberry farming is the branch of agriculture dedicated to the cultivation of mulberries (*Morus* spp.), with the main purpose of providing food for silkworms (*Bombyx mori*). This practice is essential in natural silk production, as the quality and quantity of mulberry leaves directly influences the health and productivity of silkworms [10]. In addition to supporting the sericulture industry, mulberry farming can also have a significant economic impact due to the diversity of products obtained from mulberries [11]. The mulberry tree produces fruit that can be used for human consumption or for the production of juices and other food products. Mulberry bark,

* Corresponding author: Pătruică Silvia, 0723235653, silviapatruica@usvt.ro

although not a main product, can be used to obtain extracts, and mulberry roots can be used in the pharmaceutical industry or to obtain extracts with various applications [12, 13].

Sericulture production represents the set of economic results obtained from activities related to sericulture. These products are essential both in the textile industry and in various industrial, medical and pharmaceutical sectors due to the high value and multiple applications of silk and derived products. In addition to natural silk, which remains the main sericulture product, other products obtained in the sericulture process are also valuable and contribute to diversifying the sources of income from this branch [14]. Silk is produced by the silkworm *Bombyx mori* to form a cocoon, which provides the necessary conditions for the next stage in the metamorphic cycle [15]. Silk is valued for its unique qualities and is used mainly in the textile industry for the manufacture of fine fabrics, such as dresses, luxury suits, ties and bed linen, but also in the production of fashion accessories. Due to its special skin moisturizing and regenerating properties, it is also used in other industries, such as pharmaceutical and cosmetic [16, 17].

Fibroin is known for its unique combination of strength and elasticity. It has high tensile strength and can withstand high loads without breaking. Also, the moderate elasticity is due to less ordered areas in the fibroin structure that contribute to its flexibility. Resilience after deformation makes it a suitable material for textiles and industrial applications [18]. Fibroin's flexibility makes it easy to manipulate and transform into various forms, such as silk threads, essential in the textile industry. This strength makes it ideal for uses in products that require both strength and light weight [7].

Sericin is a hydrophilic protein, being the main component that coats fibroin. It is known for its unique properties that make it useful in various fields, including biomedicine, cosmetology, and textiles. Extraction of sericin from silk cocoons involves separating it from fibroin, the main structural component of silk thread. The methods used for sericin extraction are: soaking cocoons in water at high temperatures [19], enzymatic extraction [20], alkaline or acid extraction [19], ultrasonic extraction [20].

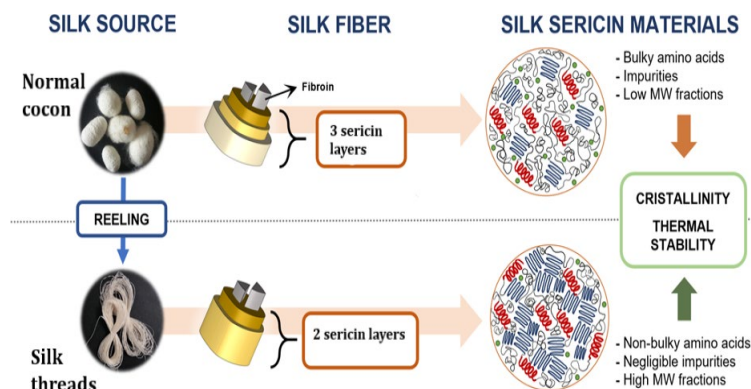


Figure 1. The main productions of silkworms [21]

The chrysalis is the intermediate stage between the larva and the adult. This is formed in a cocoon consisting mainly of the two fundamental proteins of silk (fibroin and sericin). The chrysalis is inside the cocoon in a state of metabolic rest, preparing for the transition to the adult stage [22]. Chrysalises from silkworms (*Bombyx mori*) are rich in protein, healthy fats and minerals, making them a valuable ingredient in the diet of farm animals (such as poultry or fish) as well as in pet food, as a sustainable source of nutrients [23]. They can also be used in the cosmetic industry due to their beneficial properties for skin and hair,

which come from their bioactive components, such as fibroin and sericin [24].

Sericultural residues can be used as natural fertilizers. To utilize sericulture waste, the composting method can be practiced, which is the most common method of utilizing it. Mixing chrysalises, excrement and plant debris leads to the formation of a nutrient-rich compost, which can be used as organic fertilizer [22]. Soil fertility is improved by sericultural residues stimulating the activity of beneficial microorganisms, which help decompose organic matter and create healthy, productive soil. The contribution to sustainable agriculture is made by the use of

sericulture residues, which reduces the amount of organic waste generated by the sericulture industry

and supports the transition to organic agricultural practices [25].

Table 1. Sericulture products and by-products

Category	Product	Estimated quantity	Observations	Scientific source
Silk cocoons	<i>Bombyx mori</i>	830 tons	Maximum production in Romania before the post-1990 decline	[26]
Raw silk	Fibroin + sericin	~120 tons (estimated)	Obtained by spinning doughnuts	[26]
Chrysalis	By-product	~500 tons (estimated)	Used in feed, cosmetics and compost	[22, 23]
Sericin	Water-soluble protein	~10–15% from the cocoon mass	Extracted by thermal, enzymatic or chemical methods	[19, 20]
Sericultural compost	Debris + chrysalis	Variable	Used as organic fertilizer	[25]
Natural silk export	China (comparative)	>40% of world production	China dominates the global silk market	[27]

Moriculture products. Moriculture is an important branch of agriculture, with multiple economic and ecological benefits. Mulberry (*Morus* spp.) is cultivated mainly for its leaves, used as exclusive food for silkworms (*Bombyx mori*), but it also offers other valuable products, such as wood, fruits and seeds, with a wide range of uses in the food, pharmaceutical, cosmetic and construction materials industries [28-30].

Mulberry leaf (*Morus* spp.), due to its recognized therapeutic properties, has multiple health benefits; the most common form of administration used is tea. Studies show that polyphenols and flavonoids in the leaves can inhibit enzymes that break down carbohydrates, thus helping to reduce blood sugar levels [31]. Due to its antioxidant properties, drinking mulberry leaf tea can support the immune system and reduce the risk of chronic diseases and cardiovascular disease [32].

Mulberries are known for their health benefits, being an important source of antioxidants, vitamins and minerals. The compounds contained have anticancer and cardioprotective properties. Eating mulberries can help regulate blood sugar and improve digestion. They can also be used to prepare juices, jams, wines and other food products [33, 34].

Mulberry seeds play an essential role in ameliorating and improving varieties. They are used in agricultural

research to obtain more productive varieties that are more resistant to climatic conditions. In addition, they contain essential oils rich in beneficial fatty acids, being used in the cosmetic industry to manufacture moisturizing creams and oils. Recent research has shown that mulberry seed extracts may have beneficial effects on skin health and the immune system, due to their high phytonutrient content [35].

In addition to leaves, fruits, and seeds, mulberry wood is another valuable product of this crop. Due to its density and strength, it is used in carpentry, sculpture, furniture manufacturing, and even in the making of musical instruments. It can also be used as a biomass source for heating [36].

The importance of sericulture and mulberry production is not only a topic of local interest, but is part of a broader international research framework, being also addressed in studies such as the one conducted by Doliş et al., 2022 [37], which highlights Romania's contributions to the conservation of the genetic resources of the *Bombyx mori* species and the valorisation of mulberry leaves in animal and human nutrition. In research, the variability of phenotypic characters of silkworms is analysed in relation to the stages of biological development, proposing genetic improvement methods through the selection of inbred lines and commercial hybrids with high performance.

Table 2. Products from sericulture and moriculture and their main use

Product	Origin	Main uses	Real bibliographic sources
Natural silk	<i>Bombyx mori</i> (cocoon)	Luxury textiles, accessories, cosmetics, regenerative medicine	[8]
Fibroin	Silk component	Industrial textiles, biomedicine, composite materials	[8, 22]
Sericin	Fibroin coating	Cosmetics, pharmaceuticals, textiles, biomedicine	[19, 20]
Chrysalis	Silkworms	Animal feed, cosmetics, nutritional supplements	[22, 23]
Sericultural residues	Sericultural waste	Compost, natural fertilizers, organic farming	[6, 22]
Mulberry leaves	<i>Morus spp.</i>	Worm food, medicinal teas, antidiabetic supplements	[30]
Mulberry fruit	<i>Morus spp.</i>	Juices, jams, wines, antioxidants, cardioprotection	[35]
Mulberry seeds	<i>Morus spp.</i>	Agricultural research, cosmetic oils, phytonutrients	[35]
Mulberry wood	<i>Morus spp.</i>	Furniture, sculpture, musical instruments, biomass	[36]

At the same time, the study includes the evaluation of the protein value of mulberry leaves from Romanian and international varieties (China 32, Eforie, Ichinose, Ukraine 107, Kayrio Nezumigaeshi), based on the content of essential amino acids such as glycine, alanine, serine and tyrosine, which form 90% of silk proteins. This research confirms the agricultural and zootechnical potential of moriculture in Romania and supports the integration of this branch into sustainable and bioeconomic development strategies.

4. Conclusions

The study highlights the multifunctional potential of products and by-products obtained from sericulture and moriculture, highlighting the essential role they play in the economy, organic agriculture and industry.

Fibroin and sericin, proteins specific to silkworms, offer valuable applications in cosmetology, regenerative medicine and the textile industry, being appreciated for their antioxidant, moisturizing and biocompatible properties. Mulberry leaves, fruits and seeds, rich in bioactive compounds such as flavonoids and polyphenols, contribute to maintaining metabolic health and preventing cardiovascular diseases, being used in functional food products, supplements and medicinal teas.

Silkworm chrysalis represent an alternative source of protein for aquaculture and the poultry industry and can be transformed into biological fertilizers, with beneficial effects on soil microbiota and its structure. The ecological recovery of sericulture waste, such as uneaten leaves, excrement and damaged cocoons, supports sustainable agriculture and contributes to reducing the amount of organic waste generated by the industry. Mulberry farming, as an integrated agricultural branch, provides valuable resources for the wood industry, construction and handicrafts, through the exploitation of mulberry wood and germplasm used in the improvement of varieties.

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