

Sericulture in Terms of Sustainable Development in Agriculture

Jedwabnictwo w ujęciu zrównoważonego rozwoju w rolnictwie

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Abstract

Sericulture is a branch of agriculture specializing in the cultivation of silkworms and cocoon production as well as the cultivation of white mulberry, which is the sole source of food for silkworm caterpillars. Due to the ecological nature of farming both mulberry silkworm and mulberry cultivation, as well as the possibility of managing and processing waste generated in the breeding process, it is fully in line with the trend of sustainable development. Raw materials obtained from silkworm farming constitute the basis for products valued by consumers due to their environmentally friendly production methods and an organic source of raw materials. Silk production can successfully contribute to the increase in popularity and practical application of the idea of sustainable development in agriculture.

Key words: sericulture, sustainable development, organic farming, circular economy

Słowa kluczowe: jedwabnictwo, zrównoważony rozwój, rolnictwo ekologiczne, gospodarka o obiegu zamkniętym

Sustainable development in agriculture

There have been many attempts to define the concept of sustainable development in agriculture (Adamska and Minta, 2017). The concept of sustainable development was made important by the Our Common Future Report, which were defined as development, as appropriate, should not be supported by meeting customer needs (Brutland Report, 1987). Many, created later, definitions share a common ground – the development of agricultural production with a simultaneous reduction of the negative impact on the natural environment and positive socio-economic effects.

Agriculture is also connected with Sustainable Development Goals, especially Goal no 2: Zero Hunger.

The idea of sustainable development in agriculture assumes effective development of agricultural production without unnecessary and excessive burdening the environment (Robertson and Harwood, 2001). The assumptions of such a method of farming guarantee the long-term acquisition of agricultural crops while limiting the degradation of natural resources. Sustainable development in agriculture emphasizes the elimination or as much as possible limitation of the exploitation of the natural environment by activities such as minimizing chemical treatment and heavy mechanization (Kutkowska, 2007). These measures are expected to produce organic farming crops free of pollutants and pesticides, which will provide the farmer with a reliable source of income. In this way, the economic needs of agricultural producers and the quality requirements of consumers will be met, while avoiding the degradation of the natural environment. Also worth attention in the context of sustainable development is the concept of the circular economy, which minimizes the consumption of raw materials and reduces the amount of waste

generated in the production process thanks to the management of waste as substrates for subsequent processes (Shevchenko et al., 2021). Sericulture, despite its niche importance in both Polish and European agriculture, is an excellent example of the practical application of sustainable development in agricultural production and the circular economy (Grześkowiak and Łochyńska, 2021). Taking into account the fully ecological nature of obtaining silk raw materials, silk production should become an important direction in modern agriculture. The aim of this work is to present the mulberry silkworm breeding process and the multidirectional use of silk raw materials and the directions of waste management generated by silk production, while presenting the social dimension of the development of silkworm.

Breeding of mulberry silkworms in terms of sustainable development, organic farming and circular economy

Silk-making was born in ancient China, from where, after nearly 2,000 years of exclusivity in the art of silkworm breeding and silk fabric production, it spread to Japan, India and Korea, from where it reached Europe (Dening, 2020). Silkworms were bred to obtain silk, from which prized fabrics were made and sold at a gold price. Nowadays, silkworm farming enables the multi-track use of raw materials obtained during the breeding process and the management of waste as raw materials for the production of other products (Manjunath et al., 2020). It is worth mentioning that all products obtained in this way are fully organic. The insect's life cycle lasts about a month and falls in June, so it does not interfere with most agricultural work (Łochyńska, 2016). The life cycle consists of eggs, five larval stages, a pupa and a butterfly (imago) (Figure 1).



Figure 1. The life cycle of mulberry silkworm: 1 – eggs, 2 – 4 caterpillars, 5 – pupae, 6 – cocoons, 7 – butterfly on cocoons, 8 – mating butterflies, 9 – female laying eggs (Fot. J. Grześkowiak)

The only feeding stage is the caterpillars, whose food source is mulberry leaves (Grześkowiak and Łochyńska, 2017). Maintaining silkworm farming requires adherence to hygiene rules that prevent the spread of diseases to endanger the breeding caterpillar population. An effective way to prevent epizootic diseases is regular cleaning of the litter boxes and the observance of sanitary rules by breeders. Caterpillars are bred on various types of bedding (Grześkowiak and Łochyńska, 2021). So far, recycled or paraffin paper has been popular. There are reports of the use of alternative breeding methods using banana leaves as bedding (Das, 1994). It is a fully biodegradable raw material that decomposes quickly, which translates into the reduction of waste generated in the breeding process. The silkworm caterpillars, due to their intensive growth from only 1 mm after hatching from the eggs, to 12 cm in the fifth larval stage, are considered to be one of the most voracious animals. It is assumed that for the rearing of caterpillars from 10 grams of eggs, 530 kg of fresh white mulberry leaves should be provided (Łochyńska, 2016). Breeding from 10 grams of eggs will provide about 270 kg of excrement and breeding waste, which can be successfully used as an organic fertilizer. Literature data indicate the content of valuable micro- and macroelements in silkworm excrement, which can be successfully absorbed by plants – N, P₂O₅, K₂O, CaO, MgO, Cu, Mn, Zn (Łochyńska and Frankowski, 2020). In addition, studies using silkworm manure in fertilizing plant crops increased

the absorption of nutrients and organic matter in the soil, which translated into improved soil fertility and, consequently, an increase in yields. The research on the effect of fertilization of hemp with silkworm manure showed the effect of increasing the biomass yield (applied dose 15 t / ha) and higher seed yielding (dose 30 t / ha) (Łochyńska and Frankowski, 2021). The use of silkworm manure as fertilizer is not only an effective way of managing breeding waste, but also an effective alternative to commonly used inorganic fertilizers, which translates into limiting the chemicalization of the natural environment (Kociszewski, 2013). In addition, it is possible to fertilize mulberry with silkworm excrement, which is an ideal example of a circular economy. The waste from silkworm farming becomes fertilizer for the host plant for silkworm larvae (Stephan-Giermek, 2019). Another, also effective and efficient way of managing waste - both excrements and breeding waste, is the production of biogas. Łochyńska and Frankowski (2018) showed that both types of waste have a high potential for obtaining biogas. Fermentation in mesophilic conditions allows for the production of 167.32 m³ / Mg TS of methane and 331.97 m³ / Mg TS of biogas from silkworm excrements and from silkworm farm waste to 256.59 m³ / Mg TS of methane and 489.24 m³ / Mg TS of biogas, respectively (Łochyńska and Frankowski, 2018). At the end of the fifth larval period, the caterpillars begin the spinning process that takes about a week. In this period, the necessary equipment are mountages for spinning – most often made of wood, but also of plastic and straw. There are reports of the use of used plastic bottles as dispersants (Singh et al., 1994). It is a way to reuse plastic packaging. The result of spinning process are cocoons, which are a raw material source for both the textile and cosmetics industries. Processing cocoons to obtain silk fabrics and silk proteins - sericin and fibroin requires inhibition of the insect development cycle by subjecting the cocoons to high temperature (Łochyńska, 2016). This is necessary in order to maintain the continuity of the silk thread. It is necessary for the proper course of the silk fabric production process. Silk is a naturally derived animal protein fiber. Due to numerous properties, such as hygroscopicity, gloss, resistance to creasing, flexibility and durability, it is appreciated by consumers all over the world, but due to high production costs, it remains a luxury good (Grześkowiak and Łochyńska, 2017). Taking into account the environmental burden resulting from the excessive production of clothes and textiles made of artificial fibers and problems with their disposal, silk, although relatively expensive compared to textile products made of artificial fibers, is not only a very durable material that can be used for years, but also is fully biodegradable (Łochyńska, 2018). Estimated data show that the fashion industry generates about 92 million tons of waste each year, and by 2030 an increase of as much as 60% is forecast (Dalton et al. 2020). Due to the problem with textile waste, natural fibers should gain popularity due to sustainable production methods, lower consumption of environmental resources in the production process and longer life of textiles based on natural fibers and their full biodegradability. After uncoiling the cocoons and obtaining a silk thread, pupae remain as waste. Due to the high content of protein (21,5%) and fat (25-30%), pupae can be successfully used as an alternative source of protein in animal and human nutrition (Wu et al., 2020). As mentioned earlier, cocoons can be used as sources of silk proteins – sericin and fibroin, valued for their unique properties in the cosmetics industry, bioengineering and medicine (Mondal et al., 2007). Cocoons are an organic source of silk proteins free of impurities. Due to the moisturizing, smoothing, firming and antiseptic properties, they are successfully used as an ingredient in cosmetics and biomaterials (Padamwar and Pamar, 2004). Failure to break the life cycle leads to the escape of butterflies from the cocoons. After leaving the cocoons, butterflies immediately start mating, after which the female lays eggs (about 2,500 eggs from one female), which, after appropriate storage, will be used for hatching in the next breeding season (Grześkowiak and Łochyńska, 2021). It is important that all products based on silk raw materials are fully organic and obtained using ecological methods. In turn, waste generated at various stages of the breeding process is processed and reused (Figure 2).

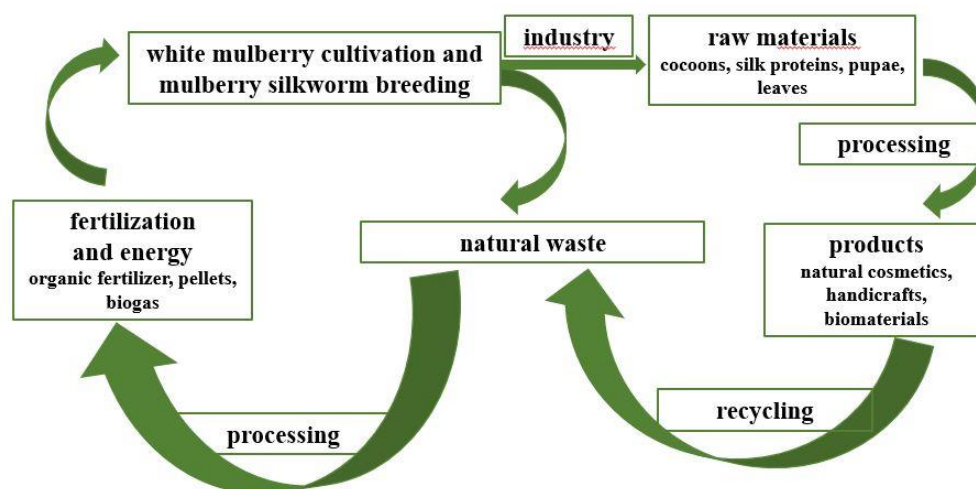


Figure 2. Management of waste from mulberry silkworm breeding and white mulberry cultivation in a circular economy system (own study based on Sękowski, 2016).

The host plant of the mulberry silkworm caterpillars – white mulberry, due to the low soil requirements and low susceptibility to diseases and pests, does not require fertilization, which means that the feed for silkworm larvae is free from pollutants, heavy metals and pesticides (Łochyńska and Oleszak, 2011). In addition, white mulberry can also be used as a herbal raw material, constituting an additional source of income for farmers. Due to the need for annual pruning and shaping of white mulberry bushes, methods for the management of wood chips for energy purposes have also been developed, due to the high energy potential of mulberry (Frankowski et. al, 2021). Pellets and mulberry-based briquettes can be both a source of ecological fuel for growers and an attractive product to offer to consumers. In addition, mulberry is known to be used as a plant used in environmental protection to eliminate contamination from degraded soils (Jiang et. Al., 2017). Both the possibility of multi-directional use of silk raw materials and the management of breeding waste and mulberry plantation make silk not only not negatively affecting the natural environment, but also a source of raw materials for various industries, while improving the socio-economic conditions (Figure 3).

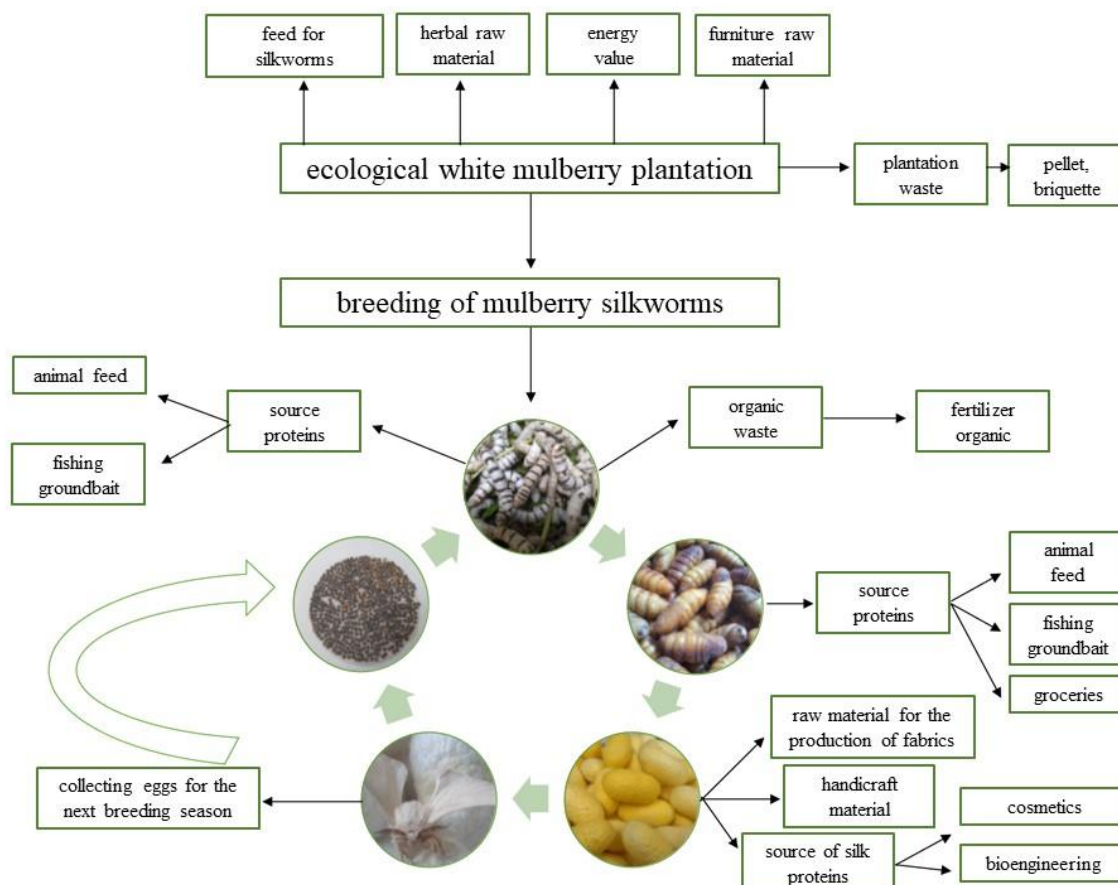


Figure 3. Multidirectional use of raw materials and management of silk waste (own study).

The social dimension of silk production in the context of sustainable development

In ancient China, a few had the honor of breeding silkworms. The breeders were faced with numerous demands (Dening et al., 2020). Women played a special role in the breeding of silkworms. Usually, they were responsible for both silkworm breeding and the collection and processing of cocoons. Also, further work related to obtaining the fabric remained the domain of women. Contemporary silk production also remains dominated by women. Due to the short development cycle of the insect and the breeding period that does not interfere with the timing of most field work, it allows women living in rural areas to combine silkworm farming not only with carrying out other tasks on the farm, but also with the simultaneous fulfillment of household duties. Research conducted by scientists from India shows that there is a clear division of responsibilities related to silkworm farming and white mulberry cultivation according to gender. The activities of women in terms of breeding are focused on feeding the caterpillars, keeping the nursery clean and collecting cocoons. These are activities that can be performed where you live, and can help you combine extra work with housework. The collection of white mulberry leaves, work on plantations related to tree formation and fertilization remain the domain of men (Feyso et al., 2021). In addition, studies have shown that silkworm breeding in India contributes to women's income growth despite low education and to improving their socio-economic situation (Raveesha et al., 2016). Due to the simple and clearly defined breeding methods and principles of plantation, as well as the repeatability of the activities performed, silk production may

become an effective method of activating the community living in rural areas. The possibility of creating producer groups and cooperatives associating silkworm farmers, mulberry growers and processing cocoons may improve the socio-economic situation of rural inhabitants. The association of farmers, breeders and growers brings many benefits, including common use of equipment, mutual assistance, obtaining higher prices for the offered products and increasing their quality (Pilichowski, 2018). Undoubtedly, a significant advantage of cooperation is the exchange of experiences in terms of farming, mulberry cultivation and cocoon processing. It is also worth mentioning the sociological dimension of the association of agricultural producers, which results in the deepening of social ties and the elimination of competition for cooperation, which brings more benefits compared to individual activities (Pilichowski, 2018). Fully ecological methods of silkworm breeding and white mulberry cultivation make the offered raw materials and products based on them fully organic and environmentally friendly. In addition, many of them are handicrafts, which significantly increases their economic value. Undoubtedly, the development of silk production in rural areas is also conducive to establishing social contacts and integrating the environment of a given community (Vathsala, 1994). The family character of farms dominating in Poland (Sobiesiak-Penszko and Pazderski, 2019) favors the development of silk production. Moreover, thanks to the variety of work, sericulture is an activity that engages all generations and can be a factor preventing social exclusion of older people. In turn, the growing interest in honey bee breeding observed in recent years can be successfully used to increase interest in silkworm breeding (Popovych, 2019). Silk industry may become an effective way to raise the economic status of farms and an attempt to take steps to transform activities into organic production, while creating new jobs in various sectors (Figure 4).

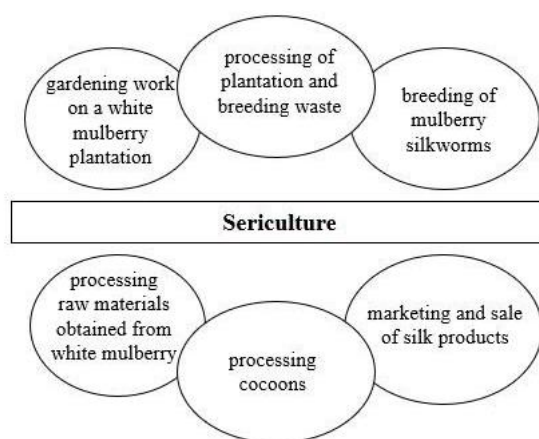


Figure 4. Professional activation by creating new jobs in the silk sector (own study).

In Poland, the silkworm breeder was entered on the official list of professions, where the position, working conditions and requirements for breeders were characterized. Moreover, the profile of professional and social competences necessary to perform the profession with the possibilities of professional development was defined (Ministry of Family, Labor and Social Policy, 2018).

Conclusions

Both global and European economies relied heavily on a linear model that used raw materials to produce products that turned into unnecessary waste after use (Sękowski, 2016). This method of world production has led to an imbalance between the availability of raw materials and the amount of generated waste. Similarly, agriculture aimed at increasing the efficiency of plant and livestock production has led to the excessive exploitation of the natural environment and its pollution. Currently, the process of transforming the world economy, including agriculture, into a circular economy model based on assumptions that waste from one production process becomes a raw material for another process is underway (Shevchenko et al., 2021). In this way, the amount of waste is significantly reduced and the negative impact of economic development on the natural environment. In the case of agriculture, a good direction is the further development of organic farming, which, due to the practices used in both plant cultivation and animal husbandry, significantly reduces the negative effects of agricultural activity on the natural environment (Jarecki et al., 2019). The ecological aspect, however, is insufficient to talk about sustainable development in agriculture due to the need to prove positive impacts in the socio-economic sphere. It is important that the development of agriculture is consistent with the social interest, which indicates many values of the rural environment, including clean air, cultural heritage, landscape and food security (Kołodziejczak, 2015). The deepening phenomenon of rural disruralisation (the decreasing role of agriculture in generating jobs and income for the rural population), resulting in a decline in the links between the rural population and agriculture, results from changes taking place in rural areas (Kłodziński, 2012). Sericulture may turn out to be an opportunity for the integration of rural communities inhabited by both multigenerational farmers and people who came to rural

areas from cities. On the one hand, many years of practical experience of farmers in the field of animal and plant production, and on the other, support in the field of marketing, formal and legal or accounting activities offered by newly arrived rural residents may constitute an opportunity for effective integration of the rural environment. Sericulture seems to be an ideal example of the application of the idea of sustainable development in agriculture in a practical sense. Thanks to the use of fully natural breeding methods, it is a source of organic raw materials used in various sectors of the economy. Both biodegradability and the possibility of processing livestock waste mean that silk production does not pose a threat to the natural environment, while at the same time reaping economic benefits for employees in the silk sector. The undoubted value of silk production is the possibility of simultaneous development with respect for the environment and providing additional jobs and activation of rural environments (Biernat-Jarka and Trębska, 2018). Sericulture, which is part of the trend of organic farming and sustainable development, requires promotion, so that it can also be used in European countries, following the example of Asian and African countries, to provide an opportunity to improve the socio-economic conditions for people with lower education, socially excluded and unemployed. The chances of a successful silk-making development depend on several factors. Optimal soil and climatic conditions for mulberry cultivation are considered to be of key importance. Due to the low soil requirements of mulberry, it is a plant that is successfully cultivated even in degraded areas, which allows it to be planted in areas that cannot be fully used for agricultural crops (Caccam and Mendoza, 2010). Due to the favorable climatic conditions for mulberry cultivation in India, it is possible to derive several (from 5 to even 8) silkworm breeding cycles per year due to the availability of food – mulberry leaves (Stephan-Giermek, 2019). This is an important factor that not only influences the increase in profits for breeders compared to European breeders, who can derive a maximum of 2 silkworm development cycles during the year, but also reduces the risk of failure of the project from one breeding cycle by compensation in the next, which due to climatic conditions is not possible in Europe. Due to clearly defined breeding methods, silk production under appropriate soil and climatic conditions conducive to the development of mulberry may become a popular form of activation and additional income in rural areas, as shown by the example of one of the Indian provinces (Maharashtra), in which, despite the lack of previous silk traditions, but with favorable environmental conditions, silk-making was introduced in 1959, which became an integral part of the local agriculture (Patil et al., 2009). Also, examples of African countries show that, despite the lack of previous experience in both mulberry cultivation and silkworm farming, silk-making is becoming an occupation that is gaining popularity and developing due to the generated income under favorable climatic conditions (Abayneh et al., 2021). Undoubtedly, the advantage of the geographical location of some regions compensates for the shortcomings of long silk traditions and translates directly into a lower price of the offered raw materials and products from these markets. Nevertheless, for many consumers, European silk remains synonymous with centuries-old traditions and the manufacturing process of silk-based products, which means that they are able to offer a higher price for them. Also, the economic aspects of silk production are based on a multifactorial basis. The efficiency of cocoon production, which is considered the basic product resulting from silkworm breeding, depends on the climatic conditions, the experience of breeders, the necessity or lack thereof in adapting the premises to the needs of breeding, the possibility of implementing several breeding cycles per year, and labor costs (Kumaresan, 2008). In addition, issues related to the susceptibility of silkworm caterpillars to diseases that can lead to a reduction in the reared population, which ultimately translate into a lower number of cocoons produced, should also be taken into account. The differences related to the costs incurred for the purposes of breeding, largely affect the price of silk. Due to both favorable climatic conditions and lower than European labor costs in Asia and Africa, the prices of silk offered by local producers are lower compared to European producers. It is worth mentioning that the favorable climatic conditions in Asia and Africa make it possible to derive several breeding cycles per year, compared to a maximum of two in Europe. The main difference in the scale of silk production between Asian and European countries is mainly due to the fact that in Europe, silk production has a niche character, while in Asia it is an important sector of both agriculture and industry (Caccam and Mendoza, 2010). However, it should be noted that also in Asia and Africa, silkworm farming is an additional activity, constituting an additional source of income for households despite favorable climatic conditions (Kumaresan et al., 2008). The organization of silkworm farming on a larger scale is associated with the improvement of the breeding process through its mechanization, which in turn entails additional costs for breeders, and this is a solution practiced in large farms with a larger area (Stephan-Giermek, 2019). An important factor is the price offered to breeders for cocoons produced in stores. The vast majority of breeders do not process cocoons themselves to obtain fabric, but sell them to collectors, where they are further processed or exported (Abayneh et al., 2021). Due to the large number of breeders in Asian countries, the availability of the raw material is greater than in Europe. Nevertheless, it is a raw material considered to be of lower quality compared to that offered on European markets. Many European growers breed and cultivate mulberry under the convention of organic farming, which requires the fulfillment of numerous conditions, including restrictions on the use of plant protection products, ensuring appropriate conditions for farm animals, etc. For many consumers, certificates confirming the quality of the offered products are synonymous with sustainable production for which they are ready to pay a higher price. At the same time, one should not forget about the cultural dimension of silk production. It is China that is the cradle of silk production and has the longest tradition in the world related to the

cultivation of silkworms and the cultivation of mulberries. Nowadays, it is China and other Asian countries that, due to the role of potentates in silk production, are at the fore in introducing innovations and extensive research on silkworms, mulberry and silk. Undoubtedly, silk production, on the one hand, due to its long and rich traditions and ecological production methods, and, on the other hand, the ease of its implementation in areas not previously associated with silkworm breeding, is an effective activity aimed at the simultaneous development of rural areas while maintaining the identity of the countryside by referring to its traditions while respecting the natural environment.

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