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Potential of Natural Dyes in Artificial Diet Formulation for Eri Silkworm (*Samia ricini*): A review

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Abstract
The Eri silkworm (*Samia ricini* Donovan) represents a significant non-mulberry silk producer with immense economic potential in the sericulture industry. Through benefits including year-round rearing, controlled nutritional supplementation, and cost-effectiveness, artificial food formulation has become a viable substitute for natural host plant feeding. Because of their bioactive qualities, which include growth promoting, antibacterial, and antioxidant effects, natural dyes originating from plant, microbial, and animal sources offer unique functional ingredients that could improve the quality of artificial diets. This thorough analysis looks at the state of artificial diet development for Eri silkworms, investigates the biochemical characteristics and possible uses of natural dyes in diet formulation, and talks about the ways in which these substances may affect cocoon parameters, silk quality, larval growth, and development. A sustainable method of increasing the rearing efficiency of Eri silkworms while preserving environmental compatibility and possibly raising the commercial value of Eri silk products is the use of natural dyes into artificial diets.

Keywords: Artificial diet, Eri silkworm, *Samia ricini*, Natural dyes, Sericulture, Bioactive compounds, Silk quality

Introduction

The Eri silkworm (Samia ricini) is an important non-mulberry silk-producing insect with significant economic and ecological value, particularly in India's sericulture sector. Traditionally, its rearing depends on fresh host plant leaves, mainly castor, which poses challenges such as seasonal availability, labor intensity, and environmental dependency. To overcome these limitations, artificial diet formulations have been developed to ensure controlled and continuous rearing. However, these diets often fail to match the nutritional efficiency and silk quality achieved through natural feeding. In this context, natural dyes have emerged as promising bioactive additives due to their antioxidant, antimicrobial, and growth-promoting properties. Derived from plant, microbial, and animal sources, these compounds may enhance larval health, improve cocoon parameters, and increase silk quality. This review explores the potential of incorporating natural dyes into artificial diets as a sustainable and innovative approach to improving Eri silkworm rearing and productivity.

Eri Silkworm: Economic and Ecological Significance

The Eri silkworm (*Samia ricini* Donovan, Lepidoptera: Saturniidae) is a multivoltine, polyphagous insect indigenous to the northeastern regions of India, particularly in the northeastern regions of India where it forms an integral component of traditional agroforestry landscapes. (Hussain and Rasid, 2024, Revati and Sunita 2025) [11, 29]. Unlike the mulberry silkworm (*Bombyx mori*), Eri silkworm is a non-mulberry silk producer that naturally feeds on castor (*Ricinus communis*) and several other host plants (Das *et al.*, 2023) [5]. Eri silk, also known as "Ahimsa silk" or "peace silk," is distinguished by its unique properties including thermal insulation, softness, durability, and washability, making it commercially valuable in the textile industry (Pal *et al.*, 2013) [27]. Table 1. Shows the Various types of silk, including Mulberry (79%), Eri (13.32%), Tasar (6.8%), and Muga (0.54%), each with unique qualities and uses (Savithri *et al*, 2013). According to Sharma and Sunita 2025 [29, 34], phenotypic analysis revealed that all eco races of Eri silkworm were multivoltine with consistent egg and cocoon characteristics, but showed significant variation in larval coloration and markings. Revati *et al.*, says that Eri-culture (Samia ricini Donovan) in India has generated substantial amounts of organic waste, including frass, cocoon remnants, pupae, and plant residues, which are traditionally disposed of through environmentally harmful methods. Economic analysis reveals potential revenue generation of ₹8-12 per kg of processed waste through organic fertilizer production, while integrated waste management systems can reduce carbon footprint by 25-30%. However, challenges include limited processing technology accessibility, economic constraints, and inadequate policy support. Sunita and Revati synthesized that the recent technological developments that have significantly increased output and silk quality include silkworm genetic engineering, improved mulberry and non-mulberry growing methods, and automation in rearing systems. Integrating sustainability into sericulture involves the adoption of organic farming, eco-friendly pest control methods, soil and water conservation and efficient waste management.

Table 1: Comparative characteristics of major silk types

Parameter	Eri Silk	Mulberry Silk	Tasar Silk	Muga Silk
Scientific name	*Samia ricini*	*Bombyx mori*	*Antheraea mylitta*	*Antheraea assamensis*
Feeding habit	Polyphagous	Monophagous	Polyphagous	Monophagous
Primary host	Castor	Mulberry	*Terminalia* spp.	*Machilus* spp.

Voltinism	Multivoltine	Multivoltine	Univoltine	Multivoltine
Silk texture	Soft, woolly	Smooth, lustrous	Coarse, textured	Fine, golden
Cocoon color	White-cream	White-yellow	Brown-tan	Golden
Commercial value	Moderate	High	Moderate	Very high
Washability	Excellent	Poor	Moderate	Moderate
Annual production (MT)	~6,000	~500,000	~8,000	~120

The global demand for natural fibers and sustainable textile production has renewed interest in Eri sericulture as an economically viable cottage industry. Traditional Eri silkworm rearing depends entirely on the availability of fresh castor leaves, which creates several limitations including seasonal constraints, labor-intensive leaf collection, storage difficulties, and vulnerability to environmental fluctuations (Nurkomar *et al.*, 2022) [26]. These challenges have prompted researchers to develop artificial diet formulations that can standardize rearing conditions and potentially enhance productivity.

Evolution of Artificial Diet Technology in Sericulture

Artificial diet development for silkworms began in the 1960s with pioneering work on *Bombyx mori*, where researchers successfully formulated synthetic diets that could partially or completely replace mulberry leaves. The concept of artificial feeding was revolutionary, offering controlled nutritional composition, elimination of pesticide contamination, reduction in labor costs, and independence from climatic conditions affecting natural host plants.

For Eri silkworm, artificial diet research has progressed through multiple generations, from simple leaf powder-based formulations to complex nutrient-optimized synthetic diets (Gokulakrishna and Selvamuthukumaran 2023) [8]. However, despite significant advances, artificial diets for Eri silkworm still face challenges in matching the growth performance, cocoon quality, and silk characteristics achieved through natural leaf feeding. This gap has driven research into functional additives that can bridge the nutritional and physiological differences between artificial and natural diets.

Natural Dyes: From Traditional Colorants to Functional Ingredients

Natural dyes have been used for centuries in textile coloration, food preservation, and traditional medicine. These compounds, extracted from plants, insects, fungi, and bacteria, represent a diverse group of bioactive molecules including flavonoids, anthocyanin, carotenoids, betalains, quinones, and indigoids. Beyond their coloring properties, natural dyes possess significant biological activities that have garnered attention in pharmaceutical, nutraceutical, and agricultural applications (Martins *et al.*, 2016 [20]; Li N. *et al.*, 2022).

Recent research has revealed that many natural dyes exhibit antioxidant, antimicrobial, anti-inflammatory, and immunomodulatory properties (Lis *and* Bartuzi 2023; Santiago *et al.*, 2023) [19]. When incorporated into insect diets, certain natural pigments have demonstrated effects on growth rate, immune response, disease resistance, and even the quality of insect-derived products. This functional potential Positions natural dyes as promising candidates for inclusion in artificial diet formulations for Eri silkworm, where they may serve dual roles as nutritional supplements and bioactive compounds that enhance overall rearing performance.

Nutritional Requirements and Artificial Diet Composition for Eri Silkworm

The nutritional requirements of Eri silkworm larvae encompass macronutrients (proteins, carbohydrates, lipids), micronutrients (vitamins and minerals), and various bioactive compounds that support growth, development, and silk production (Kashung *et al.*, 2023) [14]. Proteins serve as the primary building blocks for tissue development and silk synthesis, with requirements varying across larval instars. Carbohydrates provide the essential energy for metabolic processes, while lipids contribute to membrane structure, hormone synthesis, and energy storage. Research has established that Eri silkworm larvae require approximately 20-25% protein content in their diet for optimal growth. The amino acid profile is particularly critical, with essential amino acids including methionine, lysine, tryptophan, and threonine playing vital roles in larval development and silk protein synthesis (Baig *et al.*, 2025) [30]. Carbohydrates, primarily in the form of digestible polysaccharides and simple sugars, should constitute 40-50% of the diet dry weight to meet energy demands.

Current Artificial Diet Formulations

Castor leaf powder is a common basis element in contemporary artificial diets for Eri silkworms, which are then supplemented with nutrients to mimic the nutritional profile of fresh leaves. Mulberry leaf powder, soybean powder, wheat flour, rice bran, yeast extract, vitamins (ascorbic acid, vitamin E, B-complex), minerals (calcium, magnesium, iron, zinc), cellulose, sucrose, preservatives (sorbic acid, methyl paraben), and water are common ingredients.

Larval acceptance and intake of artificial diets are strongly influenced by their morphological characteristics. Feeding behavior and nutrient utilization efficiency are influenced by texture, consistency, palatability, and moisture content (70–75%). Another problem with artificial diet preservation is that microbial contamination can quickly deteriorate diet quality and introduce infections that endanger the health of larvae.

Natural Dyes: Sources, Chemistry, and Biological Activities

Classification and Sources of Natural Dyes

Natural dyes can be categorized based on their sources into plant-derived dyes (the most abundant category), animal-derived dyes, microbial dyes, and mineral pigments (Melo Miranda *et al.*, 2025) [21]. Table 2.Plant-based dyes are extracted from various parts including roots, bark, leaves, flowers, fruits, and seeds, with each source offering unique chemical profiles and properties.

Major classes of plant-derived natural dyes include flavonoids (quercetin, kaempferol, rutin), anthocyanins (cyanidin, delphinidin, pelargonidin), carotenoids (β-carotene, lycopene, lutein), betalains (betacyanins and betaxanthins), quinones (alizarin, lawsone, juglone), and indigo compounds (Nguyen *et al.*, 2024) [25]. Animal-derived dyes include carminic acid from cochineal insects and Tyrian purple from mollusks, while microbial sources provide compounds such as riboflavin from fungi and various pigments from bacteria (Sen *et al.*, 2019) [35].

Table 2: Major natural dyes with potential applications in Eri silkworm artificial diets

Natural Dye	Source	Main Pigment(s)	Color	Key Bioactivities	Extraction Yield	References
Turmeric	*Curcuma longa* (rhizome)	Curcumin, demethoxycurcumin	Yellow-orange	Antioxidant, anti-inflammatory, antimicrobial	2-5%	Sureshbabu *et al.*, 2023; Kotha and Luthria, 2019 [15, 39]
Beetroot	*Beta vulgaris* (root)	Betacyanins, betaxanthins	Red-purple	Antioxidant, anti-cancer, neuroprotective	0.5-1.5%	Wang *et al.*, 2022 [18]
Spinach	*Spinacia oleracea* (leaves)	Chlorophyll, carotenoids	Green	Antioxidant, vitamin source, anti-inflammatory	1-3%	Ebrahimi *et al.*, 2023 [7]
Mulberry	*Morus* spp. (fruits)	Anthocyanins, flavonoids	Purple-black	Antioxidant, anti-diabetic, cardioprotective	1-2%	Santiago *et al.*, 2023 [33]
Moringa	*Moringa oleifera* (leaves)	Chlorophyll, carotenoids	Green	Antioxidant, antimicrobial, immunomodulatory	2-4%	Ebrahimi *et al.*, 2023 [7]
Indigo	*Indigofera tinctoria* (leaves)	Indigotin	Blue	Antimicrobial, anti-inflammatory	0.5-2%	Santiago *et al.*, 2023 [33]
Saffron	*Crocus sativus* (stigma)	Crocin, crocetin	Yellow-red	Antioxidant, neuroprotective, mood-enhancing	15-25%	Sanchez-Vioque *et al.*, 2012 [32]
Marigold	*Tagetes* spp. (flowers)	Lutein, zeaxanthin	Yellow-orange	Antioxidant, vision support, antimicrobial	1-3%	Mishra *et al.*, 2024 [22]
Annatto	*Bixa orellana* (seeds)	Bixin, norbixin	Orange-red	Antioxidant, antimicrobial	2-4%	Vilar *et al.*, 2014; Muruganandham *et al.*, 2025 [24, 42]
Red cabbage	*Brassica oleracea* (leaves)	Anthocyanins	Purple-red	Antioxidant, anti-inflammatory, hepatoprotective	0.3-1%	Wiczkowski *et al.*, 2013 [44]

Biochemical Properties and Mechanisms of Action

The biological activities of natural dyes stem from their complex chemical structures, which enable interactions with cellular components and biochemical pathways. Flavonoids, for instance, exhibit potent antioxidant activity through their ability to donate hydrogen atoms and chelate metal ions, thereby neutralizing reactive oxygen species that cause cellular damage (Tanaka *et al.*, 2003) [41]. This antioxidant capacity is particularly relevant in insect physiology, where oxidative stress can impair growth, development, and immune function. Many natural dyes demonstrate antimicrobial properties through multiple mechanisms including disruption of microbial cell membranes, interference with DNA replication, inhibition of protein synthesis, and disruption of metabolic pathways (Mouro C. *et al.*, 2023) [23]. These antimicrobial effects could prove valuable in artificial diet formulations by reducing contamination risks and potentially enhancing larval disease resistance. Carotenoids function as ‘Provitamin A’ precursors and play essential roles in vision, growth, reproduction, and immune response in insects (Tan *et al.*, 2022) [40].

Natural Dyes with Potential Applications in Sericulture

Several natural dyes show particular promise for incorporation into Eri silkworm artificial diets based on their nutritional value and bioactive properties. Turmeric (curcumin) possesses strong antioxidant and anti-inflammatory activities, with research in other insect systems demonstrating positive effects on growth and immunity (Sureshbabu *et al.*, 2023; Kotha and Luthria, 2019) [5, 15]. Beetroot (betalains) provides nutrients while offering antioxidant protection (Wang *et al.*, 2022) [18]. Spinach and moringa (chlorophyll and carotenoids) supply essential vitamins and minerals alongside their pigment content (Ebrahimi *et al.*, 2023) [7].

Mulberry-derived anthocyanin could provide functional benefits beyond the nutritional contribution of mulberry leaf powder already used in many formulations. Indigo from plants like *Indigofera tinctoria* has traditional associations with silk dyeing and may offer unique bioactive properties (Santiago *et al.*, 2023) [23]. Saffron (crocin and crocetin) represents a premium option with documented antioxidant and metabolic effects, though cost considerations may limit its practical application. Annatto from *Bixa orellana* seeds offers carotenoid supplementation with antimicrobial properties (Vilar *et al.*, 2014; Muruganandham *et al.*, 2025) [24, 42].

Integration of Natural Dyes in Artificial Diet

Potential Benefits of Natural Dye Supplementation

The incorporation of natural dyes into Eri silkworm artificial diets could address multiple limitations of current formulations through several mechanisms. First, the antioxidant properties of many natural dyes could protect dietary components from oxidative degradation, extending shelf life and maintaining nutritional quality. Simultaneously, larvae, potentially enhancing their physiological resilience to environmental and metabolic stresses, would consume these antioxidants. Second, the antimicrobial activities of certain natural dyes could reduce dependence on synthetic preservatives, creating a more natural diet composition while controlling microbial growth. This dual preservation effect protecting both the diet and the larvae could improve overall rearing hygiene and reduce disease incidence. Third, natural dyes rich in vitamins and minerals could enhance the nutritional completeness of artificial diets, providing essential micronutrients in bioavailable forms.

Considerations for Dosage and Formulation

The successful integration of natural dyes into artificial diets requires careful consideration of dosage levels, as beneficial effects typically follow dose-response relationships with potential toxicity at excessive concentrations. The optimal concentration range must balance efficacy against potential negative effects on palatability, digestibility, or physiological processes. Stability and bioavailability represent critical factors, as many natural dyes are susceptible to degradation by light, heat, oxygen, and pH changes.

Formulation strategies may need to incorporate stabilizing agents or encapsulation technologies to preserve bioactive properties during diet preparation, storage, and consumption. Additionally, the chemical form and matrix in which natural dyes are presented can significantly influence their absorption and utilization by larvae. Interactions between natural dyes and other diet components must be evaluated, as synergistic or antagonistic effects could occur. For instance, the presence of certain minerals might enhance or inhibit the antioxidant activity of flavonoids, while pH levels could affect the stability and bioactivity of anthocyanin.

Effects on Growth, Development, and Physiological Parameters

Larval Growth and Development

The influence of dietary components on insect growth follows complex patterns involving nutrient sensing, hormonal regulation, and metabolic integration. Natural dyes incorporated into artificial diets could affect larval growth through multiple pathways. Enhanced antioxidant status may improve cellular function and reduce metabolic stress, potentially accelerating growth rates and reducing larval duration (Hu *et al.,* 2023). Improved gut health resulting from antimicrobial effects could enhance nutrient absorption efficiency, translating to better growth performance.

Table 3: Comparative performance parameters: Natural leaf vs. artificial diet (Zhang *et al.,* 2022 [45]; Gokulakrishnaa and Selvamuthukumaran, 2023; Hu *et al.,* 2023) [8]

Parameter	Natural Castor Leaf	Standard Artificial Diet	Target with Natural Dyes
Larval duration (days)	28-32	35-40	30-34
Larval weight (g)	8.5-9.5	7.0-8.0	8.5-9.0
Survival rate (%)	85-92	70-80	80-88
Cocoon weight (g)	4.5-5.2	3.8-4.5	4.3-5.0
Shell weight (g)	0.45-0.52	0.35-0.42	0.42-0.50
Shell ratio (%)	10-11	9-10	10-11
Silk productivity (kg/10,000 larvae)	4.0-4.5	3.0-3.5	3.8-4.3
Economic coefficient	0.28-0.32	0.22-0.26	0.27-0.31

Studies on other insect species have demonstrated that dietary supplementation with plant extracts containing natural dyes can modify growth trajectories. Research on honeybees fed pollen containing various flavonoids showed enhanced development and colony performance (Jaganathan and Mandal, 2009) [12]. Similar investigations with fruit flies indicated that anthocyanin supplementation could extend lifespan and improve stress resistance, suggesting broad applicability of these compounds across insect taxa. For Eri silkworm specifically, the goal would be to achieve growth rates and developmental timing comparable to natural leaf feeding while maintaining or improving overall larval health (Gokulakrishnaa and Selvamuthukumaran, 2023) [8]. Natural dyes might also influence the uniformity of development within populations, an important consideration for commercial rearing operations where synchronous development facilitates management.

Cocoon Parameters and Silk Quality

Cocoon production represents the culmination of larval development and the primary economic output of Eri sericulture. Table 3. Shows that the Key parameters include cocoon weight, shell weight, shell ratio, silk content, and the physical properties of silk fibers including tensile strength, elongation, and denier (Pal *et al.,* 2013) [27]. The nutritional status and physiological condition of mature larvae directly influence these cocoon characteristics through effects on silk gland development, protein synthesis, and spinning behavior. Natural dyes could potentially enhance cocoon parameters through improved larval health and optimized silk protein synthesis. The antioxidant protection provided by compounds like flavonoids might preserve the integrity of silk proteins during synthesis and storage within silk glands (Zhang *et al.,* 2022) [45]. Additionally, certain natural dyes might directly or indirectly influence the expression of genes encoding silk proteins (fibroin and sericin), potentially modifying silk composition and properties (Lee J. *et al.,* 2021) [16]. The color and luster of Eri silk represent important quality attributes that influence market value. While Eri silk is naturally white to cream-colored, subtle modifications in color tone or enhanced natural luster could increase commercial appeal. Dietary incorporation of specific natural dyes might impart desirable characteristics to silk fibers while maintaining the fundamental properties that make Eri silk valuable (Bonet-Aracil *et al.,* 2016) [3].

Immune Function and Disease Resistance

Insect immune systems, though simpler than vertebrate immune responses, provide crucial defense against pathogens through innate mechanisms including physical barriers, antimicrobial peptides, cellular responses, and melanization. The nutritional status and presence of immunomodulatory compounds in the diet significantly influence immune competence in insects. Many natural dyes possess immunostimulatory properties demonstrated in various biological systems (Catanzaro *et al.,* 2018; Hong *et al.,* 2025) [4, 9]. Flavonoids can enhance cellular immune responses, while carotenoids support both cellular and humoral immunity (Jagetia and Aggarwal, 2007) [13]. For Eri silkworm larvae, improved immune function could reduce mortality from bacterial, viral, and fungal infections, a significant challenge in artificial diet-based rearing systems where disease outbreaks can cause substantial economic losses. The gut microbiome plays an increasingly recognized role in insect health and development, and natural dyes with selective antimicrobial properties might help maintain beneficial gut microbial communities while suppressing pathogenic organisms. This prebiotic-like effect could enhance nutrient utilization, support immune development, and improve overall larval health. Curcumin, in particular, has shown significant immunomodulatory effects through modulation of inflammatory pathways and enhancement of antioxidant defenses (Sadeghi *et al.*, 2023) [31].

Current Research and Experimental Evidence

Table 4: Summary of research on natural additives in silkworm artificial diets

Study Focus	Silkworm Species	Additive Used	Concentration	Key Findings	Reference
Turmeric supplementation	*B. mori*	Turmeric powder	0.5-2.0%	Improved larval weight (12%), reduced disease (18%)	Pareek *et al.*, 2023 [28]
Moringa leaf addition	*S. ricini*	Moringa powder	1.0-3.0%	Enhanced cocoon weight (8%), better shell ratio	Aneesha and Kumar, 2022 [1]
Anthocyanin effects	*B. mori*	Mulberry fruit extract	0.5-1.5%	Increased antioxidant enzymes, improved survival	Wang *et al.*, 2022 [18]
Carotenoid supplementation	*B. mori*	β-carotene	50-200 ppm	Better immune response, enhanced silk quality	Tan *et al.*, 2022 [40]
Herbal extract mixture	*S. ricini*	Mixed plant extracts	2.0%	Improved growth rate, cocoon parameters	Li *et al.*, 2023
Natural preservatives	*B. mori*	Plant-derived compounds	Variable	Extended diet shelf life, maintained quality	Dipankar *et al.*, 2025 [6]
Flavonoid supplementation	*B. mori*	Quercetin	0.1-0.5%	Enhanced immunocompetence, stress resistance	Shi G. *et al.*, 2020 [37]

Studies on Natural Additives in Silkworm Diets

Table 4. Shows that the Research on natural additives in sericulture has primarily focused on *Bombyx mori*, providing foundational insights for Eri silkworm applications. Dietary supplementation with plant extracts, vitamins, and minerals has shown significant effects on growth, cocoon parameters, and silk quality (Li *et al.*, 2023) [5]. Turmeric powder supplementation improved larval weight and reduced disease incidence, while moringa leaf powder enhanced growth rate and cocoon characteristics (Pareek *et al.*, 2023; Aneesha and Kumar, 2022) [1, 28], suggesting that natural dye-rich compounds beneficially influence silkworm physiology.

Studies on other insects provide supporting evidence: carotenoid supplementation enhanced immune function and stress resistance in honeybees (Tan *et al.*, 2022) [40], while anthocyanin-rich diets extended lifespan and improved antioxidant status in fruit flies (Wang *et al.*, 2022) [18]. These cross-species findings establish precedents for biological activity of dietary natural dyes.

Analytical Methods for Evaluating Effects

Comprehensive evaluation of natural dye effects requires multifaceted analytical approaches across four key domains:

1. **Growth parameters:** larval weight gain, instar duration, survival rates, and developmental abnormalities; cocoon weight, shell weight, shell ratio, and silk yield;

2. **Biochemical markers:** enzymatic antioxidants (SOD, CAT, GPx), total antioxidant capacity, and lipid peroxidation products;

3. **Physiological responses:** hemocyte counts, phenol oxidase activity, antimicrobial peptide expression, and nutritional efficiency indices (consumption index, growth rate, conversion efficiency);

4. **Silk quality:** tensile strength, fiber morphology (SEM), chemical composition (FTIR), and crystallinity (XRD). These integrated approaches enable thorough characterization of natural dye effects across multiple biological levels.

Conclusion

Integrating natural dyes into artificial diet formulations for Eri silkworm (*Samia ricini*) represents a promising frontier in sericulture research. These dyes offer multifunctional benefits as bioactive compounds with antioxidant, antimicrobial, and growth-promoting properties, while supporting sustainability and consumer preferences for natural products. Though current knowledge of silkworm nutrition provides a foundation, significant research gaps remain regarding effects on growth, development, and silk quality. Successful natural dye-supplemented diets could improve artificial diet performance, reduce disease incidence, and enhance silk quality, strengthening Eri sericulture's economic viability. Future research should combine systematic screening, mechanistic studies, and applied development through interdisciplinary collaboration. As global markets increasingly value sustainable textiles, natural dye incorporation offers a nature-inspired pathway to advance Eri silk production competitiveness.

References

1. Aneesha U, Kumar CVS. Foliar supplementation of ascorbic acid modulates biochemical performance of silkworm, *Bombyx mori* under thermal stress. Journal of Thermal Biology, 2022, 104 https://doi.org/10.1016/j.jtherbio.2021.103184.
2. Baig MM, Tatsuke T, Konno K, Hirayama C, Kobayashi I, Tomita S. Growth performance and gene expression analyses reveal the viability of tree of heaven, *Ailanthus altissima* as diet for the Eri silkworm, *Samia ricini* (Lepidoptera: Saturniidae). Applied Entomology and Zoology,2025:60:211-220. https://doi.org/10.1007/s13355-025-00914-y.
3. Bonet-Aracil M, Díaz-García P, Bou-Belda E, Sebastia N, Montoro A, Rodrigo R. UV protection from cotton fabrics dyed with different tea extracts. Dyes and Pigments,2016:134:448-452. https://doi.org/10.1016/j.dyepig.2016.07.045.

4. Catanzaro M, Corsini E, Rosini M, Racchi M, Lanni C. Immunomodulators Inspired by Nature: A Review on Curcumin and Echinacea. Molecules,2018:23(11):2778. https://doi.org/10.3390/molecules23112778.
5. Das T, Kalita D, Das M. Effect of castor, *Ricinus communis* L. and banyan, *Ficus benghalensis* L. plants on economic traits of Eri silkworm, *Samia ricini* Donovan (Lepidoptera: Saturniidae). International Journal of Tropical Insect Science,2023:43:217-224. https://doi.org/10.1007/s42690-022-00919-y.
6. Dipankar B, Murugesh KA, Shanmugam R, Senguttuvan K, Marimuthu S, Radha P. Exploring the influence of plant extracts on silkworm growth and health: A review. Plant Science Today,2025:12(sp1):1-11. https://doi.org/10.14719/pst.7300.
7. Ebrahimi P, Shokramraji Z, Tavakkoli S, Mihaylova D, Lante A. Chlorophylls as natural bioactive compounds existing in food by-products: A critical review. Plants,2023:12(7):1533. https://doi.org/10.3390/plants12071533.
8. Gokulakrishnaa RK, Selvamuthukumaran T. Efficacy of artificial diet on economic parameters of Eri silkworm (*Samia ricini* Donovan). Uttar Pradesh Journal of Zoology,2023:44(7):32-36. DOI: 10.56557/UPJOZ/2023/v44i73465.
9. Hong Q, Lyu W, Zhang C, Yao W, Han Y, Chen N. Research trajectory and future trends in curcumin related to immunity: A bibliometric analysis of publications from last two decades. Front. Immunol.,2025:16:1559670. https://doi.org/10.3389/fimmu.2025.1559670.
10. Hu P, Li K, Peng XX, Kan Y, Yao TJ, Wang ZY, *et al*. Curcumin derived from medicinal homologous foods: its main signals in immunoregulation of oxidative stress, inflammation, and apoptosis. Frontiers in Immunology,2023:14:1233652. https://doi.org/10.3389/fimmu.2023.1233652.
11. Hussain MA, Rasid SS. Exploring the impact of food plants on the life cycle of *Samia ricini*: A study on Eri silkworm rearing. Journal of Entomology and Zoology Studies,2024:12(1):33-37. https://doi.org/10.22271/j.ento.2024.v12.i1a.9276.
12. Jaganathan SK, Mandal M. Antiproliferative effects of honey and of its polyphenols: A review. Journal of Biomedicine and Biotechnology,2009:830616. doi: 10.1155/2009/830616.
13. Jagetia GC, Aggarwal BB. "Spicing up" of the immune system by curcumin. Journal of Clinical Immunology,2007:27:19-35. https://doi.org/10.1007/s10875-006-9066-7.
14. Kashung S, Bhardwaj P, Saikia M, Mazumdar-Leighton S. Midgut serine proteinases participate in dietary adaptations of the castor (Eri) silkworm *Samia ricini* Anderson transferred from *Ricinus communis* to an ancestral host, *Ailanthus excelsa* Roxb. Frontiers in Insect Science,2023:3:1169596. https://doi.org/10.3389/finsc.2023.1169596.
15. Kotha RR, Luthria DL. Curcumin: Biological, pharmaceutical, nutraceutical, and analytical aspects. Molecules,2019:24(16):2930. https://doi.org/10.3390/molecules24162930.
16. Lee J, Nishiyama T, Shigenobu S, Yamaguchi K, Suzuki Y, Shimada T, *et al*. The genome sequence of *Samia ricini*, a new model species of lepidopteran insect. Mol Ecol Resour,2021:21:327-339. DOI: 10.1111/1755-0998.13259.
17. Li J, Deng J, Dong X, Liu L, Zha X. Metabonomic analysis of silkworm midgut reveals differences between the physiological effects of an artificial and mulberry leaf diet. Insects,2023:14(4):347. https://doi.org/10.3390/insects14040347.
18. Li N, Wang Q, Zhou J, Li S, Liu J, Chen H. Insight into the Progress on Natural Dyes: Sources, Structural Features, Health Effects, Challenges, and Potential. Molecules,2022:27(10):3291. https://doi.org/10.3390/molecules27103291.
19. Lis K, Bartuzi Z. Plant food dyes with antioxidant properties and allergies-Friend or enemy. Antioxidants,2023:12(7):1357. https://doi.org/10.3390/antiox12071357.
20. Martins N, Roriz CL, Morales, Barros L, Isabel, Ferreira CFR. Food colorants: Challenges, opportunities and current desires of agro-industries to ensure consumer expectations and regulatory practices. Trends in Food Science and Technology,2016:52:1-15. https://doi.org/10.1016/j.tifs.2016.03.009.
21. Melo Miranda B, Vilela Junior O, Santos Fernandes S, Mendes Lemos GR, Schwan CL, Aliaño-González MJ, *et al*. Potential of New Plant Sources as Raw Materials for Obtaining Natural Pigments/Dyes. Agronomy,2025:15(2):405. https://doi.org/10.3390/agronomy15020405.
22. Mishra DK, Singh S, Singh P. Therapeutic benefits and processing of marigold (*Tagetes* spp.): A Review. Indian Journal of Health care, Medical & Pharmacy practice, 2024, 5(1). https://doi.org/10.59551/IJHMP/25832069/2024.5.1.190.
23. Mouro C, Gomes AP, Costa RV, Moghtader F, Gouveia IC. The Sustainable Bioactive Dyeing of Textiles: A Novel Strategy Using Bacterial Pigments, Natural Antibacterial Ingredients, and Deep Eutectic Solvents. Gels,2023:9(10):800. https://doi.org/10.3390/gels9100800.
24. Muruganandham M, Tamilselvi Y, Sivasubramanian K, Velmurugan P, Oleyan Al-Otibi F, Sivakumar S. Sustainable dyeing of cotton, silk and leather using natural dye from *Bixa orellana* seeds: extraction, optimization and assessment of antibacterial activity. Front. Chem.,2025:13:1474160. https://doi.org/10.3389/fchem.2025.1474160.
25. Nguyen TL, Ora A, Häkkinen ST, Ritala A, Raisanen R, Kallioinen-Manttari M, *et al*. Innovative extraction technologies of bioactive compounds from plant by-products for textile colorants and antimicrobial agents. Biomass Conv. Bioref.,2024:14:24973–25002. https://doi.org/10.1007/s13399-023-04726-4.
26. Nurkomar I, Trisnawati DW, Tedy MH. Effect of different diet on survivorship, life cycle, and fecundity of Eri silkworm *Samia cynthia ricini* Boisduval (Lepidoptera: Saturniidae). Canadian Entomologist,2022:154:e25. https://doi.org/10.4039/tce.2022.12.
27. Pal S, Kundu J, Talukdar S, Thomas T, Kundu SC. An emerging functional natural silk biomaterial from the only domesticated non-mulberry silkworm *Samia ricini*. Macromolecular Bioscience,2013:13:1020-1035. DOI: 10.1002/mabi.201300013.

28. Pareek A, Pant M, Gupta MM, Kashania P, Ratan Y, Jain V, *et al*. *Moringa oleifera*: An Updated Comprehensive Review of Its Pharmacological Activities, Ethnomedicinal, Phytopharmaceutical Formulation, Clinical, Phytochemical, and Toxicological Aspects. International Journal of Molecular Sciences,2023:24(3):2098. https://doi.org/10.3390/ijms24032098.
29. Revati S, Sunita A, Neelu K. Innovative utilization and management of Eri-culture waste for sustainable development. International journal of Entomology Research,2025:10(10):88-96. DOI: 10.5281/zenodo.(17466324.
30. Revati S, Sunita A. The Role of Biodiversity in enhancing climatic resilience of Eri silkworm and host plant ecosystems. Proceedings of National Webinar on Climate Change and Biodiversity, 2025, 7-14. https://doi.org/10.5281/zenodo.18369456.
31. Sadeghi M, Dehnavi S, Asadirad A, Xu S, Majeed M, Jamialahmadi T, *et al*. Curcumin and chemokines: Mechanism of action and therapeutic potential in inflammatory diseases. Inflammopharmacology,2023:31:1069-1093. https://doi.org/10.1007/s10787-023-01136-w.
32. Sanchez-Vioque R, Rodrigues-Conde MF, Reina-Urena JV, Escolano-Tercero MA, Herraiz-Penalver D, Santana-Meridas O. *In vitro* antioxidant and metal chelating properties of corm, petal and leaf from saffron (*Crocus sativus* L.) Ind Crop Prod,2012:39:149–153. https://doi.org/10.1016/j.indcrop.2012.02.028.
33. Santiago D, Cunha J, Cabral I. Chromatic and medicinal properties of six natural textile dyes: A review of eucalyptus, weld, madder, annatto, indigo and woad. Heliyon, 2023, 9(11). https://doi.org/10.1016/j.heliyon.2023.e22013.
34. Savithri G, Sujathamma P, Neeraja P. Indian sericulture industry for sustainable rural economy. Int. J. Economics, Commerce and Research,2013:3(2):73-78.
35. Sen T, Barrow CJ, Deshmukh SK. Microbial pigments in the food industry—Challenges and the way forward. Frontiers in Nutrition,2019:6:7. https://doi.org/10.3389/fnut.2019.00007.
36. Sharma R, Arya S. Study of morphological characters, growth and yield performance of Eri silkworm (*Samia ricini* Donovan) eco races. Intern. J. Zool. Invest.,2025:11(2):827-837. https://doi.org/10.33745/ijzi.2025.v11i02.080.
37. Shi G, Kang Z, Ren F, Zhou Y, Guo P. Effects of Quercetin on the Growth and Expression of Immune-Pathway-Related Genes in Silkworm (Lepidoptera: Bombycidae). Journal of insect science (Online),2020:20(6):23. https://doi.org/10.1093/jisesa/ieaa124.
38. Arya S, sharma r. tradition to innovation: sustaianable development in silk culture. proceedings of national Seminar on Sustainable Development Goals: Strategies and Challenges, 2025, 165-174. https://doi.org/10.5281/zenodo.16732575.
39. Sureshbabu A, Smirnova E, Karthikeyan A, Moniruzzaman M, Kalaiselvi S, Nam K, *et al*. The impact of curcumin on livestock and poultry animal's performance and management of insect pests. Frontiers in Veterinary Science,2023:10:1048067. https://doi.org/10.3389/fvets.2023.1048067.
40. Tan Z, Halter B, Liu D, Gilbert ER, Cline MA. Dietary flavonoids as modulators of lipid metabolism in poultry. Frontiers in Physiology,2022:13:863860. https://doi.org/10.3389/fphys.2022.863860.
41. Tanaka T, Higa S, Hirano T, Kotani M, Matsumoto M, Fujita A, *et al*. Flavonoids as Potential Anti-Allergic Substances. Current Medicinal Chemistry- Anti Inflammatory Anti-Allergy Agents,2003:2(1):57-65. https://doi.org/10.2174/1568014033355790.
42. Vilar DdeA, Vilar MS, de Lima e Moura TF, Raffin FN, de Oliveira MR, Franco CF, *et al*. Traditional uses, chemical constituents, and biological activities of *Bixa orellana* L.: a review. TheScientific World Journal, 2014, 857292. https://doi.org/10.1155/2014/857292.
43. Wang Y, Fernando GSN, Sergeeva NN, Vagkidis N, Chechik V, Do T, *et al*. Uptake and immunomodulatory properties of betanin, vulgaxanthin I and indicaxanthin towards Caco-2 intestinal cells. Antioxidants,2022:11(8):1627. https://doi.org/10.3390/antiox11081627.
44. Wiczkowski W, Szawara-Nawak D, Topolska J. Red cabbage anthocyanin: Profile, isolation, identification and antioxidant activity. Food Research International,2013:51(1):303-309. https://doi.org/10.1016/j.foodres.2012.12.015.
45. Zhang W, Wang X, Zhang Y, Wu S, Liu R. Flavonoid dyes from vine tea (*Ampelopsis grossedentata*) have excellent bioactive properties for dyeing and finishing of silk fabrics, 2022, 28. https://doi.org/10.1016/j.scp.2022.100708.