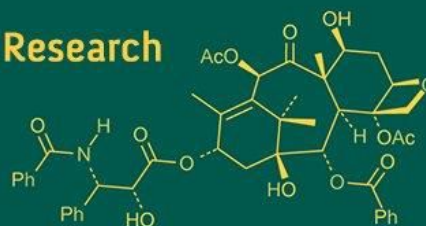


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Balancing Productivity and Sustainability: Supplementation in Sericulture

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Abstract

The nutritional status of the mulberry silkworm, *Bombyx mori* L., plays an important role in determining silk gland development, fibroin synthesis and overall cocoon productivity. Although mulberry leaves serve as the primary and natural diet for *B. mori*, variations in environmental conditions and cultivation practices often affect their nutritional composition, ultimately limiting silkworm growth and silk yield. This review highlights the advances in dietary fortification strategies to enhance physiological, biochemical and molecular processes involved in silkworm development and silk production. Studies show that b-complex vitamins and ascorbic acid act as essential cofactors and also as antioxidants by improving enzymatic reactions, nutrient absorption and tolerance to oxidative stress. Mineral supplementations, including zinc, calcium, magnesium, potassium, selenium and iron support trehalose metabolism, protein synthesis, hormonal regulation and nucleic acid activity within the silk gland, thereby enhancing larval growth and cocoon characteristics. Targeted amino acid enrichments particularly with glycine, alanine, serine and methionine, directly promotes fibroin synthesis by strengthening translational efficiency and silk gland protein. Probiotics contribute by stabilizing gut microbiota, improving digestive efficiency, activating immune pathways and increasing resistance to pathogens such as *Nosema bombycis*. Plant-derived extracts further enhance antioxidant capacity, immune responsiveness and metabolic activity. Additionally, emerging nano-enabled approaches shows promise in improving nutrient bioavailability and antiviral defence however, dosage optimization is essential to avoid cytotoxic effects. Overall, advances in nutritional biotechnology provide a practical and mechanistic basis for improving silkworm health and silk productivity, paving the way for precision feeding strategies that support sustainable and high-efficiency sericulture.

Keywords: Nutritional supplementation, Dietary fortification, Silk gland development, Amino acid enrichment, Probiotics, Nano-nutrition

Introduction

Sericulture is a unique agro-based sector characterized by its short gestation period, low environmental impact, and high labour intensity. The mulberry silkworm (*Bombyx mori* L. (Order: Lepidoptera), plays a pivot role in the silk industry due to its superior commercial silk producing ability. Silk production is highly dependent on the larval nutrition particularly the nutritive value of mulberry leaves which directly influences the cocoon quality and yield. Silkworm requires specific essential sugars, amino acids, proteins and vitamins for its normal growth. The production of cocoons is influenced by both the quantity and quality of mulberry leaves. Inadequate nutrition, especially during the fifth larval instar, results in smaller cocoons and reduced silk yield (Kawaguchi & Kubota, 1996). Although mulberry leaves naturally contain balanced nutrients, their quality often varies short due to environmental conditions and agronomic practices (Laskar & Datta, 2000). Efficient metabolism of the ingested and digested food has a direct impact on all genetic traits such as larval, economic and reproductive parameters (Shamsuddin, 2009). Studies have demonstrated that nutritionally enriched leaves promote better larval growth and superior cocoon characteristics (Seki & Oshikane, 1959). Consequently, nutritional fortification of mulberry leaves has emerged as an innovative strategy to enhance silkworm performance and maximize silk yield (Murugan *et al.*, 1998). It has been reported that the vitamins of B-complex group and certain essential sugars, proteins, amino acids, minerals etc., are

responsible for the proper growth and development of the silkworm, *B. mori* (Khan & Saha, 1997 & Faruki, 1998). It has been found that adding complimentary substances to the mulberry leaves improved the larval growth and post cocoon characters (Etebari, 2002; Etebari & fazilati, 2003) [18, 19]. The supplementation or fortification of mulberry leaves is a

recent technique in sericulture research to try achieving the target of maximizing the yield (Murugan *et al.*, 1998). Multiple researches in the recent years have successfully increased the quantity and quality of silk by applying plant extracts, sprinkling antibiotics, hormones, hormone analogs and vitamins to enrich the leaf nutrients.

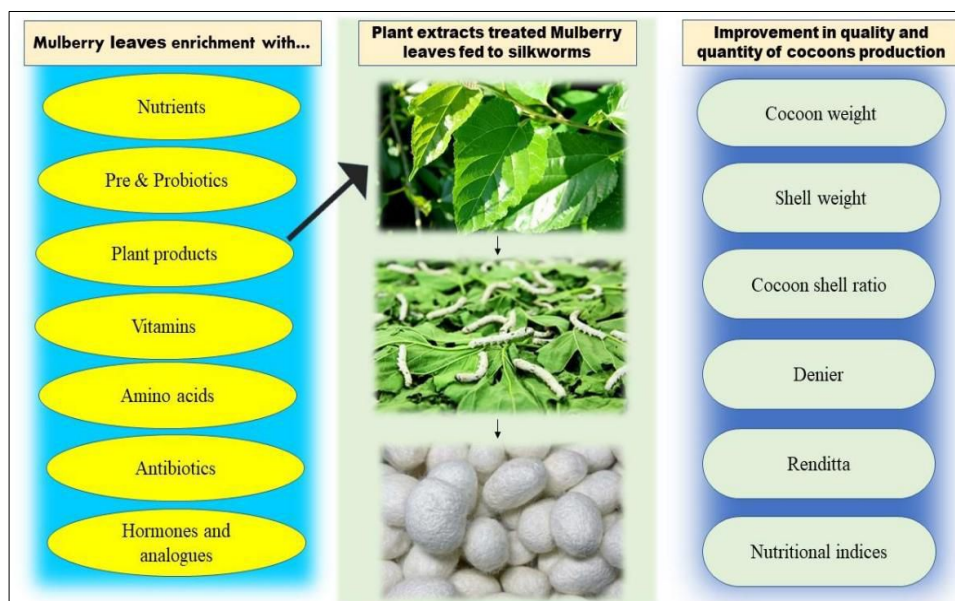


Fig 1: Effect of additives on silkworm growth and development (Nath *et al.*, 2023)

Vitamins

Vitamins are organic substances that are ingested through food and are necessary for a number of physiological functions of an organism, including growth, reproduction and metabolism (Bentea *et al.*, 2011) [10]. It is an important component in silkworm diet (Akhtar & Asghar, 1972) [3] as they work as coenzymes and facilitate enzymatic activities without being consumed or produced themselves and are needed in very small quantities (Douglas, 2017) [17]. Vitamins are classified into water soluble (B and C) and fat-

soluble vitamins (A, D, E and K). Among these, enrichment of mulberry leaves with vitamin A, D or K for silkworm do not seem to have been studied (Kanafi *et al.*, 2007) [50]. The important vitamins for the growth and development of *B. mori* larvae have been reported to be biotin, choline, folic acid, inositol, nicotinic acid, pantothenate, riboflavin, and thiamine (Horie & Ito, 1963; Horie *et al.*, 1966) [37, 38]. The B-complex group of vitamins, which are the main vitamins required by insects, has been demonstrated to have a substantial effect on insect growth and development.

Table 1: B-Vitamins, their coenzymes and enzymatic functions (Ferdous, 2016) [23]

B-vitamin	Coenzyme form	Enzymatic function
Thiamine (B ₁)	Thiamin pyrophosphate (TPP)	Aldehyde group removal or transfer
Riboflavin (B ₂)	Flavin adenine dinucleotide (FAD); Flavin mononucleotide (FMN)	Hydrogen transfer
Nicotinamide (B ₃)	Nicotinamide adenine dinucleotide (NAD ⁺); Nicotinamide adenine dinucleotide pyrophosphate (NADP ⁺)	Hydrogen transfer
Pantothenic acid (B ₅)	Coenzyme A (CoA)	Acyl-group carrier or transfer
Pyridoxine (B ₆)	Pyridoxal phosphate	Amino-group transfer, Carboxyl group transfer, racemization
Biotin (B ₇)	Biocytin	Carboxyl group removal or transfer
Folic acid (Folacin) (B ₉)	Tetrahydro folic acid (FH ₄)	One-carbon transfer
Vitamin B ₁₂ (Cyanocobalamin)	Coenzyme B ₁₂	1,2-shift of hydrogen atom, methyl-group carrier

Oral supplementation of different dosages of vitamin B and C to the multivoltine silkworm variety BSR-95/14(M) larvae in their third, fourth, and fifth instars resulted in significant changes in larval and pupal parameters (Ahsan *et al.*, 2013) [2]. Multi-vitamins at a rate of 2.5% boosted biological and economic parameters such larval weight, pupal weight, male and female cocoon weight, and egg productivity (Etebari & Matindoost, 2005) [21]. While vitamins were beneficial to silkworms, a high dose of vitamin B₃ in the diet disrupted feeding and normal growth and development. As a result, silkworm larvae experienced symptoms of "nicotinamide hypervitaminosis," including

immobility, dyspepsia, skin darkening, brownish fluid exuding from the anus, and swelling of the rectal muscles (Etebari, 2004) [20]. In the third, fourth, and fifth instars, there was an improvement in larval length, weight, and food consumption at a concentration of 2% vitamin D3. As a result, it also attained the maximum shell weight, cocoon weight, and cocoon shell ratio (Akram *et al.*, 2017) [4]. α -tocopherol is slightly effective in increasing the number of eggs laid by moths and β -carotene has also some growth-promoting effect (Ito, 1978) [43]. Enrichment of mulberry leaves with E vitamin did not have significant effect on food consumption in silkworm larvae (Mosallanejad, 2002) [63].

Ascorbic acid (vitamin C) has antioxidant benefits that lowers oxidative pressure and reactive oxygen species, which enhances the midgut's absorption of nutrient-dense foods (Felton & Summers, 1993) [22]. Ascorbic acid acted both as a phagostimulant and nutrient for the *B. mori* (Ito, 1961 a, b) [41, 42]. At 0.2% concentration of vitamin C, improved the nutritional parameters such as the food consumption rate, food utilization rate, digestibility rate, food consumption index, and coefficient of food utilization, as well as the growth rate of larval (width and length) (V instar), pupal (width, length, and weight), and cocoon (width, length, and weight) (Balasundaram *et al.*, 2013) [9] besides the biochemical performance of the larva under thermal stress (40 ± 2 °C was used in the lab) was positively modulated by foliar supplement of ascorbic acid at a rate of 0.2% by facilitating the production of good quality cocoons, from larvae exposed to thermal stress (Aneesha & Kumar, 2022) [5]. Maximum improvement in larval weight, pupation rate, cocoon weight and shell weight was recorded in 0.50% Vitamin C (ascorbic acid) fortification (Tantray & Kanika, 2011) [60].

Table 2: Comparison of quantitative requirements for B-vitamins of the silkworm with the amounts in mulberry leaves (Ito, 1978) [43]

Vitamin	Minimum amount required (mg/g of dry diet)	Amount in mulberry leaves (mg/g of dry matter)
Biotin (Bs)	1	0.2–0.8
Choline	750	930–1550
Inositol	1000	4000
Nicotinic acid (Bs)	20	69–99
Pantothenic acid (Bs)	20	16–35
Pyridoxine (Bs)	5	43–50
Riboflavin (Bs)	5	13–21
Thiamine (Bs)	0.5	6.7

Minerals

Minerals are necessary for many metabolic processes and it cannot be synthesised by insects. The inorganic components of mulberry leaves, which contains important minerals, is essential for disease resistance, balanced growth, metabolic regulation and total silk yield. Mineral deficiencies have negative effect on silkworms as they are essential for their proper growth and development. Deficiency in minerals cause lower ingestion of potassium, calcium, magnesium, and phosphorus results in lower body weight in *B. mori* (Iwanari, 1976) [45]. It requires calcium, iron, magnesium, manganese, phosphorus, potassium and zinc for their growth and development (Ito, 1978) [43]. Magnesium is essential for the activity of trehalose synthase (Murphy & Wyatt, 1965) [66]. The optimum concentration of selenium (Se) was found to be 50 µM, which had a positive impact on larval growth, cocoon and reproductive parameters like, prolonged larval stage, increased larval, cocoon, and pupal weights, and enhanced number of eggs laid by the female moth. Conversely, 200 µM of selenium (Se) treatment showed harmful effects on silkworms and caused a notable decline in growth, cocoon production and reproduction. Zinc is known to be essential for the synthesis of lipids, proteins and carbohydrates as well as for shortening the duration of larval and pupal stages. (Bhattacharya & Kaliwal, 2005) [11]. Combination of zinc sulphate, magnesium sulphate and potassium chloride at a concentration of 100ppm, 200ppm and 100 ppm respectively, to mulberry silkworm enhanced the larval,

cocoon and silk reeling related traits by improving silk yield (Murugesu, 2020) [67]. Fecundity of moths were increased by zinc fortified mulberry leaves besides it also improved shell cocoon ratio, silk-body ratio, raw silk percentage, renditta and decreased denier. In terms of all larval growth and economic cocoon characters the larvae reared on 2 µg /ml zinc chloride supplemented castor leaves showed better performance (Bora *et al.*, 2022) [13]. The growth and antioxidant defense mechanisms of tasar (*Antheraea mylitta*) silkworm were improved by foliar application of zinc, in addition zinc supplementation had positive impact on improving the larval fitness, quality and quantity of silk production.

Calcium carbonate (CaCO₃) at 0.20% had superior egg, larval, pupal and cocoon characteristics (Rahman *et al.*, 2025). Cobalt is essential for the various physiological processes in insects, including immune function and pathogens resistance (Khan & Lang, 2023) [51]. In the Nistari race of *B. mori*, treatment with cobalt, iodide, potassium, calcium chloride, and potassium nitrate boosted the silk gland's protein, RNA, and DNA contents (Dasmahapatra *et al.*, 1989). Potassium promotes the growth of silkworm to maximum extent (Mahadeva, 2016) [59]. Haemolymph trehalose and fat body glycogen content increased after feeding with potassium sulphate (Bhattacharya & Kaliwal, 2005) [11].

Probiotics

Probiotics are live microbial food supplements that support microbial balance and quicker cellular growth and development. (Fuller, 1993) [25]. In addition to producing lactic acid, probiotics decrease the pH of the digestive system, stop infections from growing, reduce intestinal inflammation, increase immunity, and enhance intestinal tract health in general (Gheorghe *et al.*, 2024) [28]. The addition of specific probiotic bacteria, such as *Lactobacillus rhamnosus*, *Saccharomyces boulardii* and *Bifidobacterium longum*, as a supplement to silkworms enhanced their development rate, cocoon weight, and silk quality, all of which raised the profitability of sericulture firms. Additionally, a decline in feed conversion costs and mortality rates was also noticed (Bhuvana *et al.*, 2024) [12]. All kinds of probiotics, regardless of concentrations, improved every parameter (Moustafa, 2024) [65].

The highest food assimilation conversion rates and improvements in commercial parameters such as silk ratio, ERR, shell weight and cocoon weight were shown by *Samia ricini* D. larvae fed with probiotic-fortified (2% Darolac) *Ricinus communis* leaves (Anitha *et al.*, 2015) [6]. *Staphylococcus gallinarum* strain SWGB 7 enhanced the both larval and cocoon parameters including silk productivity, filament length, filament weight with finer denier. Azolla boosted larval weight, silk gland weight, ERR and larval duration particularly at 2% concentration (Shruti *et al.*), most successfully improved female fecundity and the shell ratio % of males (Moustafa, 2024) [65].

Mulberry leaves enriched with 500 ppm and 5.00 ppm of spirulina and thyroxine showed enhancements in larval weight, cocoon weight, shell weight, shell ratio, shell percentage, and yield/10,000 larvae by number and weight by reducing the larval period (Maqbool *et al.*, 2023) [60]. Higher concentrations of spirulina (400 ppm) had a beneficial effect on silkworm development *i.e.*, larval length, width, weight and weight of the pupa including the

economic parameters like cocoon weight, shell ratio percentage, and silk filament length (Asaf and Mahavishnu, 2018; Pande and Sharma, 2023) [8, 72]. The survival rate was 91% for larvae supplemented with *Lactacaseibacillus casei*, compared to 68% for a control group of silkworm larvae infected with *Nosema bombycis* on the second day of the fourth instar. Growth characteristics were considerably higher in larvae that additionally received *L. casei* when infected with *N. bombycis*. Through a variety of processes,

including altering the composition of the gut microbiota, increasing the activity of digestive enzymes and boosting phenylalanine biosynthesis, *Bacillus subtilis* improves silkworm growth and silk output. There is a critical function of amino acid metabolism in insect-microbiome symbiosis and indicate *B. subtilis* as a critical function of amino acid metabolism in insect-microbiome symbiosis and indicate *B. subtilis* as a viable probiotic for improving artificial diet systems in Lepidoptera.

Table 3: Specific properties of probiotic strains (Priyadharshini *et al.*, 2021) [75]

Aspects	Probiotic strain properties
Safety	✓ Non-pathogenic, non-toxic, non-allergic, and non-mutagenic. ✓ Able to adhere and colonize the epithelial cell lining to establish itself in the colon. ✓ The ability to adhere to the epithelium secures the strain from being easily flushed out by peristaltic movements.
Performance	✓ Able to survive in sufficient numbers and adhere to the intestinal mucosal surface. ✓ Stimulate an immune response that positively affects the host. ✓ Survive the environmental conditions in their target site of action and proliferate in this location.
Technological	✓ Probiotic strains should be easy and inexpensive to reproduce. ✓ Large-scale production, good viability, and stability of the product during storage. ✓ Stress resistance during processing and storage, with the process and product application robustness. ✓ Able to survive particularly in the harsh environmental conditions of the small intestine (e.g., gastric and bile acids, and digestive enzymes). ✓ Resistant to phages and to have good sensory properties.

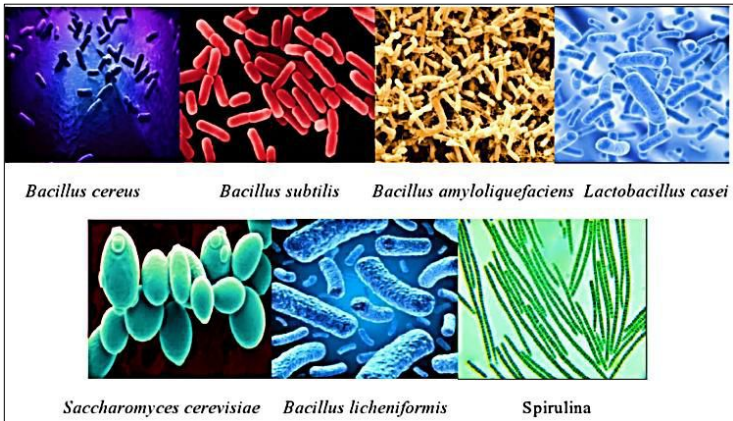


Fig 2: Types of probiotics used in silkworm rearing (Khan & Khaliq, 2022) [52]

Amino acids

Amino acids are precursors of proteins are essential to all living organisms including the silkworms, they are the building components of proteins. It contains both an amino group and a carboxylic group. One of the numerous processes associated with gene expression that amino acids considerably impact is the role of the proteins that mediate messenger RNA (mRNA) translation. Four amino acids—alanine, serine, glycine, and tyrosine found in the diet of silkworms are the primary source of silk fibroin (Kirimura, 1962; Ito, 1983) [53, 44]. Mulberry leaves provide 72% to 86% of the amino acids that silkworms need, and over 60% of those amino acids are used to make silk fibre (Lu & Jiang, 1988) [57]. Economic parameters like filament length, shell percentage, cocoon productivity and larval lifespan were greatly enhanced by methionine addition. Total protein, total free amino acids, and antioxidant activity were all elevated in the silkworm haemolymph and in silk gland tissues (Qayoom *et al.*, 2025) [77]. The larvae fed mulberry leaves treated with 1% alanine exhibited the highest cocoon weight, length, width, shell ratio, and fibroin content (Muzamil *et al.*, 2023) [69]. Glycine, alanine, and serine concentrations of 10 ppm, 100 ppm, and 100 ppm respectively, produced the highest

levels of mature larval weight, effective rate of rearing, cocoon weight, shell weight, shell ratio, and filament length (Murugesh *et al.*). Enrichment of mulberry leaves with different amino acids *viz.*, glycine, alanine and asparagine (Radjabi *et al.*, 2010) [78], arginine and histidine (Chakrabarthy & Kaliwal, 2012) [14] and serine (Gokul, 2015) [30] has increased the larval, cocoon, reeling and silk productivity-related parameters.

Plant extracts

The concept of including plant extracts in silkworm diets is based on the understanding that certain phytochemicals (compounds derived from plants) may enhance insect physiology. These compounds can enhance the absorption of nutrients, facilitate better digestion, and trigger metabolic pathways that stimulate the production of silk (Hajam *et al.*, 2024) [31]. In order to mitigate the quality-related issues in silkworm rearing, low-quality mulberry leaves can be efficiently improved with leaf powder extracts in water, water-ethanol mixtures, or superior-quality leaf dust. Powdered leaf preparations from high-quality leaves can be stored for use in later seasons to resolve leaf quality issues. Nux Vomica improved larval weight, shell weight, silk ratio, filament

length and filament weight (Hiware, 2006) [36]. The full-grown larvae weight, mature larval weight, cocoon weight, shell weight, filament length, shell ratio, and silk productivity (4.097 cg/day) all considerably increased when *Psoralea coryleifolia* supplemented leaves were fed to silkworms. Larval growth and yarn properties were most positively impacted by *Psoralea coryleifolia* and *Psoralea niruri* (Gobena & Bhaskar, 2015) [29]. The oils from fenugreek and pumpkin showed the longest average silk filaments. Additionally, the oils employed in their study increased the silk filament characteristics and cocoon indices.

When *Alpinea galanga* L. rhizome extract was given to mulberry silkworm through supplementation, the larval time was decreased but the larval weight, cocoon, pupa, shell weight, and shell ratio increased. Additionally, a rise in granulocytes and plasmocytes strengthened *B. mori* defense mechanism (Jespa & Renuga, 2022) [46]. In mulberry silkworm 8 mg/ml of lentil (*Lens culinaris*) showed the highest matured larvae, cocoon weight, shell weight, shell percentage, yield of cocoon per 10000 larvae by weight, and filament length approximately equivalent to 1210.66 m (Islam *et al.*, 2023) [40]. Biological traits like 5th instar larval weight, 100% pupation and cocooning rates, and economic traits like cocoon weight, shell weight, pupal weight and shell ratio were significantly improved by *Echinacea purpurea* (2%) extract. Biochemical markers such as total protein (79.53 mg/ml), peroxidase activity (13.63 O. D units/min/ml), and phenol oxidase (17.66 O. D/min/ml) also showed notable increase (Moustafa, 2023) [64].

It has been discovered that tulsi extract increased silkworm ability to withstand stress, particularly in adverse environmental circumstances by giving higher cocoon and more reliable silk output. A nutritional boost is provided by fortifying mulberry leaves with moringa extract, which increases silkworm growth rates and the length and strength of silk fibres (Hassan *et al.*, 2018) [32]. Higher yields and improved silk quality were obtained by lowering inflammation and boosting immunity, turmeric extract made silkworms healthier and less susceptible to diseases (Garcia *et al.*, 2023) [27]. Including ashwagandha extract in the diets of silkworms helped them to withstand environmental stressors, which results in more consistent cocoon yields and better silk quality (Hajam *et al.*, 2024) [31].

Nano-particles

When mulberry leaves were nutritionally fortified with riboflavin nanoparticles, larval growth development was significantly improved by 28.98%, silk gland weight increased by 111.392%, and silk yield increased by 194.44 (Kamala & Karthikeyan, 2019) [49]. Moderate doses of AgNps improved nutrient intake, positively impacted metabolic activity, and boosted silk yield. AgNps (25%) treated leaves showed notable changes in larval and cocoon dimensions, including length and width (3.66 cm and 2.40 cm) and cocoon weight (2.2117 g) (Prabu *et al.*, 2011) [74]. AgNPs at low concentration i.e., 400mg/L (Meng *et al.*, 2017) [61], 100/mg/L (Pandiarajan *et al.*, 2018; gad *et al.*, 2020) [25, 26] enhanced larval and cocoon parameters by increasing the metabolic pathways but at high concentrations (1600mg/L) (Meng *et al.*, 2017) [61], increases the oxidative stress, apoptosis and cause cell necrosis. TiO₂ nanoparticles are non-toxic and increase *B. mori* feeding efficiency, which in turn promotes cocoon

production and protein synthesis (Zhang *et al.*, 2014) [61]. Additionally, it enhances cocoon characteristics and larvae survival rates following BmNPV (Fometu *et al.*, 2022) [24] and BmCPV infection. Application of Poly (N-isopropyl acrylamide) (PNIPAM) nano-particle at a concentration of 0.4 and 0.6 mg/mL shows a significant decrease in microbial infestations (*Aspergillus niger*) of tasar silkworm (Verma *et al.*, 2013). γ -Fe₂O₃ NPs at concentration of 100-mg/L showed enhanced growth, survival, and economic traits of silkworm. Phycogenic γ -Fe₂O₃ NPs hold potential to establish new methods to enhance the nutritional, immunological health and cocoon economic traits in silkworm *B. mori* (Adikesavan *et al.*, 2026) [1].

Milk

The multipurpose liquid milk contains bioactive materials in the form of proteins, fatty acids, minerals, carbohydrates and other nutrients that helps in silkworm growth and development. It is also rich in peptides, enzymes, and polyamines, all of which are essential for regulating the many regulatory processes (Haug *et al.*, 2007) [33]. Silkworms fed with milk-treated leaves exhibited an increase in weight by 310% over seven days as compared to the 153% increase observed in the control group. Additionally, cocoon weight also increased by 8%. This enhancement was linked to the rich nutrients in milk, such as protein, carbohydrates, fatty acids and minerals which support metabolism and silk gland growth (Konala *et al.*, 2013) [55]. Mulberry leaves fortified with bovine milk resulted in the highest larval weight (3.24 g), cocoon weight (1.25 g), pupal weight (0.96 g) and shell weight (0.27 g) (Nivetha *et al.*, 2024) [71]. Mulberry Larvae fed supplemented with milk showed increase in development rate, larval weight, and cocoon formation, as well as differences in cocoon weight, silk percentage, pupal weight and all crucial traits for silk production (Ruiz-Erazo *et al.*, 2023) [80].

Honey

Free amino acids, proteins, carbohydrates, vitamins, enzymes and minerals are present in the honey in the form of bioactive compounds (Moniruzzaman *et al.*, 2014) [62]. Honey is also called as multifactorial food as it contains Metals (Co, Cr, Cu, Mn, Zn, and Fe), enzymes (Diastase, invertase, catalase, glucose oxidase, etc.), proteins, minerals, and vitamins (B and C). It is also called as natural sweetener made from plant nectar with the help of honey bees (Council, 2002) [15].

Post cocoon parameters like silk filament weight, silk filament length, non-broken filament length and decrease in renditta (to desirable level of 2.50 and 6.33) were obtained by fortification of mulberry leaves with 5% stingless bee honey (KA, 2024) besides it also increased larval weight, cocoon weight, shell weight, shell ratio. It also increased protein level across several parameters viz., silk gland protein (119.81 mg/g), haemolymph (9.81 mg/ml), fat body (51.01 mg/g) and fibroin content in cocoon (79.38%) when compared to the other experimental groups. Honey enhanced the silk protein synthesis at posterior segment of the silk gland by improved cocoon weight, shell weight, shell protein, pupal weight, raw silk weight, denier, renditta and less production of floss and floss protein i.e., 0.02 g and 5.42 mg/g, respectively, by fortification with 2% concentration. Inclusion of honey led to increase in glucose,

glycogen and trehalose in *B. mori* silkworm during the larval stage (Madhavi & Prasad, 2020) ^[58].

Other supplements

The nutritional and economic characteristics of the *B. mori* hybrid (Pure Mysore × CSR2) were enhanced by seri feed, a nutrient-enriched dietary supplement. It improved the amount of silk in the cocoon shell by increasing the synthesis of nucleic acid in silk gland cells (Kumar & Michael, 2011) ^[56]. Increase in the percentage of good cocoons (98.33%), no stained cocoons, negligible flimsy cocoons (0.66%), mountage-pressed cocoons (0.66%), and the least total defective cocoon through sericin fortification (1.33%) (Qadir *et al.*, 2022) ^[76]. Both larval and cocoon parameters were enhanced by bee pollen at a rate of 2% showed a low disease incidence (Sharma *et al.*, 2024). All post-cocoon characteristics, such as silk length, silk thread weight, denier, silk productivity, renditta (6.00 g), sericin (0.71 g), and fibroin (0.65 g), were improved by vermiwash fortified G4 mulberry leaves (KM *et al.*, 2024). With the maximum cocoon weight, shell weight, shell ratio, matured larval weight and recorded lowest larval duration in 20% albumin supplementation (Islam *et al.*, 2020) ^[39]. A significant increase in the weight of the silk gland, full-grown larva, female pupa, cocooning percentage, cocoon shell, weights of fresh cocoon, silk filament length, silk size, and silk weight was achieved by rearing silkworms on mulberry leaves enhanced with white hen's eggs (Helaly, 2018) ^[34]. Sodium butyrate (organic sodium salt) used as an additive or supplement for gut health often produced by the fermentation of the dietary fibre in the gut, it is used as supplementation in mulberry silkworm which enhanced the body growth by increasing feeding efficiency and influencing the juvenile hormone and ecdysteroid signaling pathways; moreover, it also promoted silk gland development through DNA replication in silk gland cells.

Pros of Supplementation in Silkworms

Improved growth rate

Nutritional supplements such as vitamins, amino acids, probiotics, and plant extracts enhance larval growth and reduce the larval duration (Jespa & Renuga, 2022) ^[46].

Enhanced silk yield and quality

Supplementation increases cocoon weight, shell weight, shell ratio, and filament length. Amino acids like methionine and lysine contribute to better fibroin and sericin synthesis (Hassan *et al.*, 2018; Hajam *et al.*, 2024) ^[32, 31].

Better disease resistance

Probiotics, herbal extracts, and micronutrients improve immunity against common silkworm diseases such as grasserie, flacherie, muscardine, and pebrine (Fometu *et al.*, 2022) ^[24].

Higher survival rate and stress tolerance

Nutritional enrichment reduces larval mortality, especially under stress conditions (temperature fluctuations, poor mulberry quality) helps larvae to tolerate environmental stressors (Aneesha & Kumar, 2022) ^[5] and also act as anti-oxidants (Felton & Summers, 1993) ^[22].

Improved feed utilization efficiency

Supplements enhance digestion and nutrient absorption, resulting in better conversion efficiency (Etebari, 2002; Etebari & fazilati, 2003) ^[18, 19].

Economic benefits

Increased cocoon yield and better-quality silk, lead to improved profitability for farmers (Bhuvana *et al.*, 2024) ^[12].

Cons of Supplementation in Silkworms

Increased cost of rearing

Commercial supplements may increase production costs, especially for small-scale farmers.

Risk of over supplementation

Excessive doses may cause toxicity, reduced feeding, or metabolic imbalance (Jiang *et al.*, 2020).

Lack of standardized dosage

Many studies vary in concentration and method of application, making field-level standardization difficult (Etebari, 2004) ^[20].

Potential residue or contamination issues

Improperly prepared supplements may introduce contaminants affecting larval health.

Variable results

Effectiveness may vary depending on silkworm breed, environmental conditions, and mulberry leaf quality.

Conclusion

Supplementation in silkworm rearing is a promising strategy to enhance larval growth, cocoon yield, silk quality, and disease resistance. Scientific evidence indicates that nutritional additives such as vitamins, amino acids, probiotics, enzymes, and plant-based extracts can significantly improve economic traits in sericulture. However, supplementation must be applied judiciously. Proper dosage, timing, and method of application are critical to avoid adverse effects. Standardization of protocols and cost-effective supplementation strategies are essential for large-scale adoption, particularly for small and marginal farmers.

Overall, supplementation should be considered as a supportive strategy rather than a substitute for good mulberry cultivation and hygienic rearing practices. Future research should focus on optimizing formulations, evaluating long-term impacts, and developing low-cost, eco-friendly supplementation approaches for sustainable sericulture.

Disclaimer (Artificial intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Mode (Chat GPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

Competing interests

Authors have declared that no competing interests exist.

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