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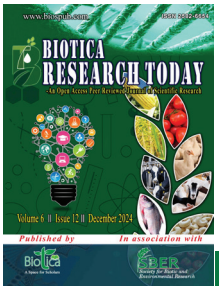

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Probiotic-Enriched Leaves: A Natural Strategy for Boosting Growth and Silk Quality of Silkworm (*Bombyx mori* L.)

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Abstract

Probiotics have shown promising tool in improving the health, well-being and productivity of various organisms, including silkworms (*Bombyx mori* L). By using probiotic-enriched mulberry (*Morus alba*) leaves improves silkworm gut health, gland development, enhances nutrient absorption and strengthens disease resistance, growth rate, cocoon size, leading to improved quality and higher silk yield. This sustainable and eco-friendly approach enhances sericulture while providing both economic and environmental benefits.

Keywords: Mulberry, Probiotics, Silkworms, Sustainable

Introduction

Sericulture is a process has been improved upon over centuries, originating in antiquity to maximize quality and productivity. Despite development in sericulture techniques, challenges such as silkworm diseases, nutrition, inefficient digestion and suboptimal growth remain key barriers to achieving higher productivity. Both cocoon production and larval growth and development are significantly due to the nutrient value of mulberry leaves. In order to improve silkworm health and increase silk production it requires innovative and sustainable solutions. Using probiotic rich leaves is a viable and promising way addresses these issues. Probiotics are products containing "live microbes, when given in adequate amounts; for gut health, growth and development of silkworms. The maximum number of probiotics bioaccumulated in silkworms through the consumption of mulberry leaves, which serves as an ideal medium for delivering probiotic microorganisms. Microbial population in the intestinal zones of the *Bombyx mori* includes *Bacillus cereus*, *B. subtilis*, *B. amyloliquefaciens*, *Lactobacillus casei* and *L. plantarum*, *Bifidobacteria* sp. and Yeast (Shruti *et al*., 2019). When silkworms consume probiotic-infused leaves, these beneficial microbes colonize the gut, improves digestion and nutrient absorption, thus supporting the overall growth and development. The presence and attachment of beneficial probiotic bacteria to the intestinal mucous membrane create a robust natural biological barrier against many pathogens and acts as competitors for nutrients which results in starving off pathogens. Studies on the effects and practicability of probiotics on different growth parameters, silk yield and cocoon formation and to better understand how this natural intervention can able to transform the sericultural practises and increases its profitability and sustainability by providing an alternative to synthetic growth (Bhuvana *et al*., 2024).

Characteristics of Probiotics

To be recognized as a probiotic, a microbial strain must fulfil specific properties.

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A good strain is an easily, inexpensively reproducible, multiply rapidly, robust during processing and storage, capable of large-scale production, possessing strong stability and viability within the product while stored (Figure 1). This must not result in off flavours or textures after being added to foods (Bhuvana *et al*., 2024).

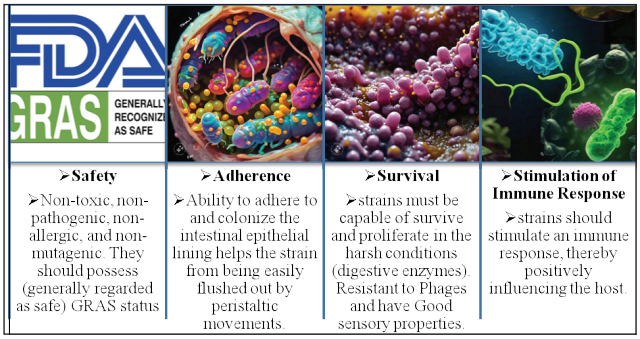

Figure 1: Characteristics of probiotics with specific properties (Bhuvana *et al*., 2024)

Impact of Probiotics on Silkworm Health

Probiotics serve a vital function in enhancing the health and productivity of silkworms, particularly in sericulture, where maximizing growth and economic traits is the key. Here's an elaboration on their multifaceted benefits:

1. Improving Nutrition and Food Conversion Efficiency

Probiotics improves the intestinal gut microbiota of silkworms, there by facilitating better digestion and nutrients absorption. Due to better food conversion efficiency silkworms can be able to metabolize feed into body mass and there by produce silk more effectively (Suraporn *et al*., 2015).

2. Strength and Integrity of the Intestinal Epithelial Barrier

Probiotics strengthens the intestinal barrier by binding to the intestinal epithelium acts as a frontline of defence for the silkworm forming a protective biological shield. Additionally, promote the health of the epithelial junctions which ensures the gut stays intact and resistant to infections; it increases the production of mucin, a glycoprotein that is an essential component of the mucous layer there by inhibiting pathogen attachment.

3. Reduced Pathogen Colonization and Better Intestinal Mucosa Attachment

Probiotics mainly LABs cling strongly to the intestinal mucosa cells, preventing pathogens from attaching to intestinal cells by colonizing it. The capability of LABs to stick to intestinal mucosa is crucial thereby it enables them to out-compete dangerous bacteria by occupying receptor sites, thereby preventing pathogen adhesion and colonization (Figure 2). Additionally, this also promotes mucin production there by strengthening the mucosal barrier and inhibits harmful bacteria. Lactase enzyme produced by it aids in the breakdown of milk sugar (lactose) which readily absorbed by digestive system, lactic acid produced by it acts as muscle fuel, controls harmful bacteria and increases mineral absorption (Esaivani *et al*., 2014).

4. Competitive Pathogen Exclusion

It is the best way by which probiotics protects the silkworm gut from infectious pathogens. This process involves,

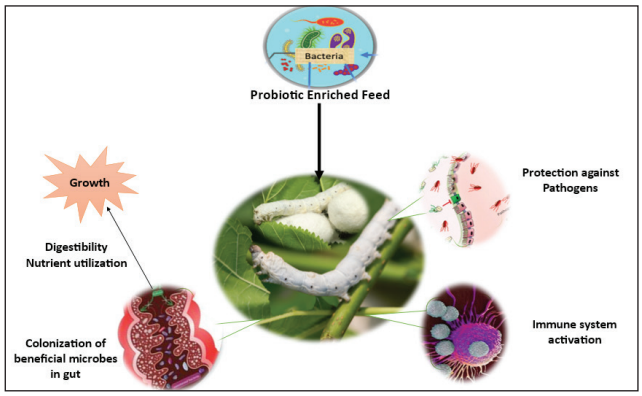

Figure 2: Role of probiotic enriched mulberry feed on *Bombyx mori* L. (Shruti *et al*., 2019)

Blocking the receptor sites: in the intestine, making them unavailable to pathogens;

Competition for nutrients: probiotic bacteria reduce the availability of nutrients to harmful pathogens in the gut.

5. Production of Antimicrobial Substances

Probiotics secrete anti-microbial substances like short chain fatty acids (lactic and acetic acid), which lower the gut pH making unfavourable conditions for other harmful pathogens. Bacteriocins produced by probiotics include Lactacin and Plantaricin inhibit the other harmful bacteria.

6. Modulation of Immune System

The immunomodulatory activities of probiotics are one of the most significant impacts on silkworm health. These actions by means of interactions with these cells including macrophages, dendritic and epithelial cells help in regulating immune responses.

7. Anti-Inflammatory Response

Anti-inflammatory molecules produced by probiotics in the intestine decrease the inflammatory response; otherwise these can decrease the immunity in silkworm.

Immunity boosting: Antibodies secreted by probiotics reduce the infection proneness and immediate response against pathogens. The cumulative action of all these mechanisms leads to enhanced health, growth, decreased disease incidence and higher silk yield.

Some Promising Probiotic Strains in Silkworm Rearing

No commercial probiotics are designed for sericulture despite being available for human consumption. Table 1 represents the various researches on probiotic use to enhance silkworm growth and development.

At, Central Sericultural Research & Training Institute (CSRTI), Mysuru has identified probiotic bacteria like *Lactobacillus*, *Bacillus* and *Enterococcus*, in the gut of mulberry silkworms that enhance nutrient absorption, disease resistance and growth. Metagenomic studies revealed that different silkworm strains host distinct gut bacteria: the Pure Mysore strain has predominantly *Enterococcus* and *Bacillus*, while the CSR2 strain mainly harbors *Lactobacillus* (Yeruva *et al*., 2020).

Table 1: Research on probiotic use to enhance silkworm growth and development

Sl. No.	Probiotics used for mulberry fortification	Result	References
1	*Saccharomyces cerevisiae* on enzymatic and the quantitative economic parameters.	Amylase and invertase rise in the digestive juice of the probiotic treated worms with increased silk production.	Esaivani *et al*. (2014)
3	*Lactobacillus acidophilus* on quality parameters of strains of Thai silkworm.	Improvement in survival rate, pupation ratio, cocooning ratio and cocoon weight.	Suraporn *et al*. (2015)
4	Spirulina, Azolla, Yeast and Soy milk on cross breed, PM × CSR-2, quality parameters.	Azolla was good for an effective rearing rate, cocoon weight followed by soy milk and yeast.	Shruti *et al*. (2019)
5	*Staphylococcus gallinarum strain* SWGB-7 and *S. arlettae strain* SWGB-16 on economic parameters of silkworm bivoltine double hybrid.	*S. gallinarum* recorded maximum larval,cocoon, shell, pupal weight, weight, fine denier and effective raterearing besides reduced larval mortality.	Shruti *et al*. (2019)
6	Probiotic feed on the economic parameters of the double hybrid silkworm by using *L. rhamnosus, S. boulardii* and *Bifidobacterium longum*.	Enhanced growth rates, increased cocoon weight and improved silk quality along with reduced mortality rates and feed conversion costs, making sericulture more profitable.	Bhuvana *et al*. (2024)

Conclusion

The application of probiotics in silkworm rearing aligns with growing trends toward natural and resilient sericulture practices worldwide, providing both environmental and economic benefits. Probiotic-enriched leaves represent a low-cost, accessible solution for sericulturists, particularly in resource-limited areas, where enhancing productivity is essential for livelihood sustainability by enhanced growth rates, improved nutrient absorption, increased resistance to diseases and superior silk yield and quality. This approach not only promotes silkworm health but also offers an eco-friendly alternative to synthetic growth enhancers and chemical additives traditionally used in sericulture.

Future Perspectives

So many studies have declared that probiotics like *Bacillus subtilis* and *Lactobacillus* strains positively affect silkworm health when introduced into their diet. The leaf itself can serve as a medium for these microbes, or probiotic supplements can be sprayed onto the mulberry leaves before feeding them to silkworms. Further research trials would help to determine the best probiotic strains, concentrations, large scale production on cheap substrates and a-ready-to-use product formulation and delivery methods to optimize silkworm yield through leaf-based probiotics which hold a key position in disease management, growth promotion and overall health of silkworms.

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