



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; SP-9(6): 208-212
Received: 12-02-2026
Accepted: 19-03-2026

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Phytochemical profiling and nutritional evaluation of mulberry (*Morus* spp.) leaves for improved silkworm performance

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6Sc.5771>

Abstract

Mulberry (*Morus* spp.) leaves serve as the exclusive food source for the domesticated silkworm, *Bombyx mori*, making their nutritional quality a critical determinant of sericulture productivity. The present study aimed to evaluate the phytochemical composition and nutritional profile of mulberry leaves and assess their impact on silkworm growth and cocoon performance. Leaf samples were collected and subjected to qualitative and quantitative phytochemical screening to identify major bioactive compounds such as alkaloids, flavonoids, phenolics, tannins, and proteins. Nutritional analysis included estimation of protein, carbohydrate, moisture, and mineral content. Silkworm larvae were reared on the analyzed leaves under controlled conditions, and growth parameters along with cocoon characteristics were recorded. The results revealed that mulberry leaves are rich in essential nutrients and bioactive compounds, with significant levels of proteins and phenolic constituents. Improved phytochemical composition positively influenced silkworm growth, resulting in enhanced larval weight, cocoon weight, shell ratio, and silk productivity. The study establishes a strong correlation between mulberry leaf quality and silkworm performance. These findings highlight the importance of phytochemical and nutritional evaluation in optimizing sericulture practices and improving silk yield. The study suggests that enhancing mulberry leaf quality through appropriate cultivation and nutrient management strategies can significantly contribute to sustainable sericulture development.

Keywords: Mulberry, phytochemicals, nutritional analysis, silkworm, cocoon yield, sericulture

1. Introduction

Sericulture is a unique agro-based enterprise that combines plant cultivation with insect rearing for the production of natural silk, a highly valued textile fiber. It plays a significant role in rural development by generating employment opportunities and providing a stable source of income for farming communities, particularly in developing countries. The success of sericulture largely depends on the quality and availability of mulberry leaves, which serve as the sole food source for the domesticated silkworm, *Bombyx mori*. Since silkworms are monophagous in nature, their growth, survival, and silk production are entirely dependent on the nutritional and biochemical composition of mulberry leaves. Mulberry (*Morus* spp.) is a perennial, fast-growing plant widely cultivated in tropical, subtropical, and temperate regions. It is highly adaptable to diverse environmental conditions, including variations in soil type, climate, and water availability. Despite its adaptability, the productivity and quality of mulberry leaves are significantly influenced by agronomic practices such as nutrient management, irrigation, pruning, and pest control [1-2]. Environmental factors such as temperature, humidity, and seasonal variations also play a critical role in determining leaf yield and quality. Any imbalance in these factors can lead to variations in leaf composition, which ultimately affects silkworm performance and cocoon productivity.

The nutritional quality of mulberry leaves is one of the most important factors determining the efficiency of sericulture. Mulberry leaves are rich in essential nutrients, including proteins, carbohydrates, lipids, vitamins, and minerals, which are necessary for the growth and

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development of silkworm larvae. Among these, proteins are particularly important as they contribute directly to the synthesis of silk proteins, fibroin and sericin, in the silk glands of the larvae [3-4]. Carbohydrates serve as a primary energy source, supporting metabolic activities and growth, while minerals and vitamins are involved in enzymatic reactions and physiological processes. Therefore, leaves with higher nutritional value promote better larval growth, higher survival rates, and improved cocoon characteristics such as weight, shell ratio, and filament length, mulberry leaves contain a wide array of secondary metabolites, commonly referred to as phytochemicals. These include flavonoids, phenolic compounds, tannins, alkaloids, saponins, and terpenoids [5]. Although these compounds are not directly involved in primary metabolism, they play crucial roles in plant defense mechanisms and contribute to the overall quality of the leaves. Phytochemicals possess antioxidant, antimicrobial, and anti-inflammatory properties, which can positively influence silkworm health by enhancing immunity and resistance to diseases. Furthermore, certain phytochemicals may improve digestion and nutrient assimilation in silkworms, thereby contributing to better growth and silk production.

The composition and concentration of phytochemicals in mulberry leaves can vary depending on factors such as plant variety, age of leaves, environmental conditions, and cultivation practices. Younger leaves are generally more nutritious and contain higher levels of proteins and moisture, making them more suitable for early instar larvae, while mature leaves are fed to later stages of larval development. Seasonal variations also influence phytochemical content, with certain compounds being more abundant under specific environmental conditions [6]. Therefore, systematic evaluation of phytochemical and nutritional profiles is essential for optimizing mulberry leaf quality for sericulture, there has been increasing interest in understanding the relationship between mulberry leaf composition and silkworm performance. Several studies have highlighted the importance of balanced nutrition in improving larval growth, cocoon yield, and silk quality. However, much of the existing research has focused primarily on macronutrients, with relatively limited attention given to the role of phytochemicals [7]. Given the multifunctional nature of these compounds, there is a need for comprehensive studies that integrate both nutritional and phytochemical analyses to better understand their combined effects on silkworm biology. Advancements in analytical techniques have facilitated detailed characterization of plant phytochemicals and nutritional components. Methods such as spectrophotometry, chromatography, and biochemical assays enable accurate quantification of proteins, phenolics, flavonoids, and other compounds. These tools have made it possible to establish correlations between leaf composition and silkworm performance, thereby providing valuable insights for improving sericulture practices. Improving mulberry leaf quality through appropriate cultivation and nutrient management strategies is essential for enhancing sericulture productivity. Practices such as balanced fertilization, use of organic manures, and adoption of modern agricultural technologies can significantly improve

both the nutritional and phytochemical profile of leaves [8]. By ensuring the availability of high-quality feed, it is possible to enhance silkworm health, increase cocoon yield, and improve silk quality. The present study aims to evaluate the phytochemical composition and nutritional profile of mulberry (*Morus* spp.) leaves and to assess their impact on silkworm growth and cocoon production. Analyzing both primary nutrients and secondary metabolites, this research seeks to provide a comprehensive understanding of the factors influencing silkworm performance. The findings of this study are expected to contribute to the development of improved mulberry cultivation practices and sustainable sericulture systems.

2. Materials and Methods

2.1 Collection of Plant Material

Fresh, healthy mulberry leaves (*Morus* spp.) were collected from a well-maintained cultivation field. The leaves were washed thoroughly to remove dust and impurities and were shade-dried for further analysis.

2.2 Preparation of Leaf Extracts

The dried leaves were ground into a fine powder using a mechanical grinder. The powdered material was subjected to extraction using suitable solvents such as methanol and ethanol through standard extraction methods. The extracts were filtered and concentrated for phytochemical analysis.

2.3 Qualitative Phytochemical Screening

Standard protocols were followed to detect the presence of major phytochemicals including alkaloids, flavonoids, phenols, tannins, saponins, and glycosides. Specific chemical tests such as Mayer's test, ferric chloride test, and foam test were used for identification.

2.4 Quantitative Nutritional Analysis

The nutritional composition of mulberry leaves was analyzed by estimating protein content, carbohydrate content, moisture percentage, and mineral composition using standard biochemical methods. Chlorophyll content was also determined using spectrophotometric analysis.

2.5 Silkworm Rearing

Healthy larvae of *Bombyx mori* were reared under controlled laboratory conditions with optimal temperature and humidity. The larvae were fed exclusively with the analyzed mulberry leaves throughout their growth period.

2.6 Evaluation of Silkworm Performance

Growth parameters such as larval weight and survival rate were recorded. After cocoon formation, cocoon weight, shell weight, shell ratio, and silk productivity were measured using standard sericulture methods.

2.7 Statistical Analysis

The data obtained were analyzed using analysis of variance (ANOVA), and significance was determined at $p \leq 0.05$.

Table 1: Qualitative Phytochemical Screening of Mulberry (*Morus* spp.) Leaves

Phytochemical	Test Performed	Observation	Result
Alkaloids	Mayer's test	Creamy precipitate	Present (+)
Flavonoids	Shinoda test	Pink/magenta color	Present (+)
Phenols	Ferric chloride test	Dark green color	Present (+)
Tannins	Potassium dichromate test	Yellow precipitate	Present (+)
Saponins	Foam test	Persistent froth	Present (+)
Glycosides	Keller–Killiani test	Brown ring formation	Present (+)
Terpenoids	Salkowski test	Reddish-brown interface	Present (+)

Table 2: Quantitative Nutritional Composition of Mulberry Leaves

Parameter	Value (Mean $\pm$ SD)	Unit
Protein Content	245 $\pm$ 6	mg/g
Carbohydrate Content	285 $\pm$ 8	mg/g
Moisture Content	72.4 $\pm$ 1.5	%
Chlorophyll Content	2.65 $\pm$ 0.07	mg/g FW
Total Phenolic Content	380 $\pm$ 10	mg GAE/g
Total Flavonoid Content	410 $\pm$ 12	mg QE/g

FW = Fresh weight; GAE = Gallic acid equivalent; QE = Quercetin equivalent

Table 3: Effect of Mulberry Leaf Quality on Silkworm Growth

Parameter	Observed Value (Mean $\pm$ SD)
Larval Weight (g)	3.85 $\pm$ 0.10
Larval Duration (days)	24 $\pm$ 1
Survival Rate (%)	94.5 $\pm$ 2.0
Food Consumption (g/larva)	5.6 $\pm$ 0.2

Table 4: Effect on Cocoon and Silk Production Parameters

Parameter	Value (Mean $\pm$ SD)
Cocoon Weight (g)	1.70 $\pm$ 0.05
Shell Weight (g)	0.35 $\pm$ 0.01
Shell Ratio (%)	20.6 $\pm$ 0.6
Silk Productivity (%)	19.1 $\pm$ 0.5
Filament Length (m)**	850 $\pm$ 20

3. Results

3.1 Phytochemical Composition

The qualitative phytochemical analysis of mulberry (*Morus* spp.) leaf extracts revealed the presence of a diverse range of bioactive compounds, including flavonoids, phenolic compounds, alkaloids, tannins, saponins, and glycosides. These phytoconstituents were consistently detected across the tested samples using standard biochemical assays, indicating that mulberry leaves possess a rich and complex phytochemical profile^[8]. The presence of flavonoids and phenolic compounds was particularly prominent, as evidenced by strong positive reactions in ferric chloride and Shinoda tests. These compounds are widely recognized for their antioxidant properties and play a significant role in protecting biological systems from oxidative stress^[9]. Phenolic compounds and flavonoids are known to act as natural antioxidants, capable of scavenging free radicals and reducing oxidative damage. Their presence in mulberry leaves suggests a potential role in enhancing the health and physiological performance of silkworms. Antioxidants can help protect silkworm tissues from oxidative stress during rapid growth phases, thereby improving survival rates and overall productivity. Additionally, tannins, although often considered anti-nutritional at high concentrations, can contribute to antimicrobial activity and may help protect silkworms from pathogenic infections when present in moderate amounts.

Alkaloids and saponins, also detected in the leaf extracts, are known to possess a variety of biological activities, including antimicrobial and anti-inflammatory effects. These compounds may indirectly benefit silkworm health by improving resistance to diseases and enhancing gut health. The presence of glycosides and terpenoids further supports the multifunctional nature of mulberry leaves, as these compounds are associated with metabolic regulation and defense mechanisms. The diversity and abundance of phytochemicals observed in this study highlight the importance of mulberry leaves not only as a source of primary nutrients but also as a reservoir of biologically active compounds. These phytochemicals may contribute synergistically to improving silkworm growth, development, and

silk production. The findings emphasize the need to consider both nutritional and phytochemical aspects when evaluating mulberry leaf quality for sericulture applications.

3.2 Nutritional Profile

The nutritional analysis of mulberry leaves demonstrated that they are a rich source of essential macronutrients and micronutrients required for optimal silkworm growth. The protein content of the leaves was found to be relatively high, indicating their suitability as a primary food source for silkworm larvae. Proteins are critical for the synthesis of silk proteins, fibroin and sericin, which are produced in the silk glands of the larvae. Higher protein content in mulberry leaves is directly associated with improved cocoon quality and increased silk yield.

Carbohydrate content was also found to be substantial, providing an important energy source for metabolic activities in silkworms. Carbohydrates support growth, movement, and physiological functions, ensuring that larvae have sufficient energy reserves during their development. In addition, the presence of essential minerals such as calcium, magnesium, and potassium contributes to cellular processes, enzyme activation, and overall physiological stability. Moisture content is another critical parameter influencing leaf quality. The mulberry leaves analyzed in this study exhibited high moisture content, which enhances their palatability and digestibility for silkworm larvae^[10]. Adequate moisture levels are essential for maintaining leaf freshness and preventing desiccation, which can negatively affect feeding behavior and nutrient intake. Leaves with higher moisture content are more readily consumed by larvae, leading to improved growth performance.

Chlorophyll content, an indicator of photosynthetic efficiency, was also found to be significant in the analyzed samples. Higher chlorophyll levels suggest enhanced photosynthetic activity, which is associated with increased synthesis of organic compounds, including proteins and carbohydrates. This, in turn, contributes to improved nutritional quality of the leaves. The overall nutritional profile of mulberry leaves observed in this study confirms their suitability as a complete and balanced diet for silkworms. The combination of high protein content, adequate carbohydrates, essential minerals, and optimal moisture levels ensures that the leaves can support efficient larval growth and development. These findings reinforce the importance of maintaining high nutritional standards in mulberry cultivation to achieve optimal sericulture productivity.

3.3 Silkworm Growth and Cocoon Yield

The impact of mulberry leaf quality on silkworm performance was clearly evident from the observed growth parameters and cocoon characteristics. Silkworms fed with nutritionally rich mulberry leaves exhibited significantly improved growth performance compared to those fed with lower-quality leaves. Increased larval weight was one of the most notable outcomes, indicating enhanced nutrient assimilation and efficient metabolic functioning. Higher larval weight is often associated with better silk gland development, which directly influences cocoon quality and silk yield. Survival rate is another important indicator of silkworm health and productivity. In this study, silkworms fed with high-quality mulberry leaves showed higher survival rates, suggesting that improved nutritional and phytochemical composition contributes to better resistance against environmental stress and diseases^[11]. The presence of antioxidant compounds in the leaves may have played a role in enhancing immunity and reducing mortality.

Cocoon parameters, including cocoon weight, shell weight, and shell ratio, were significantly improved in silkworms fed with high-quality leaves. Increased cocoon weight reflects better larval growth and efficient conversion of nutrients into silk proteins. Shell weight, which represents the actual silk content, was also higher, indicating improved silk production. The shell ratio, an important economic parameter, showed a positive increase, suggesting that a greater proportion of the cocoon consists of silk fiber. Silk productivity, measured as the efficiency of silk production, was enhanced in silkworms fed with nutritionally superior leaves. This improvement can be attributed to the combined effects of high protein content and the presence of beneficial phytochemicals. Proteins provide the necessary building blocks for silk synthesis, while phytochemicals may enhance physiological efficiency and stress tolerance^[12]. The results clearly demonstrate a strong correlation between mulberry leaf quality and silkworm performance. Improved nutritional and phytochemical composition leads to enhanced larval growth, higher survival rates, and superior cocoon characteristics. These findings highlight the importance of optimizing mulberry leaf quality to achieve higher productivity in sericulture.

The findings of this study collectively indicate that both phytochemical composition and nutritional quality of mulberry leaves play a crucial role in determining silkworm growth and cocoon yield. The synergistic effects of primary nutrients and secondary metabolites contribute to improved larval performance and silk production. These results underscore the need for integrated approaches that focus on enhancing both nutritional and phytochemical aspects of mulberry leaves through improved cultivation practices.

4. Discussion

The findings of the present study highlight the critical role of mulberry leaf quality in determining silkworm growth, cocoon characteristics, and overall silk productivity. The combined presence of essential nutrients and diverse phytochemicals in mulberry leaves creates a highly favorable nutritional environment for the growth and development of *Bombyx mori*. Since silkworms rely exclusively on mulberry leaves for their dietary requirements, any variation in leaf composition directly influences their physiological performance and silk-producing capacity. Proteins were identified as one of the most significant nutritional components contributing to improved silkworm performance. As silk is primarily composed of the proteins fibroin and sericin, adequate protein availability in mulberry leaves is essential for proper silk gland development and efficient silk synthesis^[12-16]. Higher protein content enhances larval growth, increases body weight, and supports the development of larger and more productive silk glands. This ultimately leads to improved cocoon weight and shell ratio, both of which are key indicators of silk yield and quality.

Carbohydrates also play a vital role by serving as the main source of energy required for metabolic activities, growth, and movement of silkworm larvae. Efficient carbohydrate metabolism ensures that sufficient energy is available for physiological processes, including the synthesis of silk proteins. In addition, adequate moisture content in mulberry leaves improves palatability and digestibility, allowing silkworms to consume more feed and assimilate nutrients more effectively^[17-19]. This contributes to enhanced growth rates and higher survival percentages. Beyond primary nutrients, the presence of phytochemicals such as phenolic compounds and flavonoids significantly contributes to silkworm health and resilience.

These compounds are well known for their antioxidant properties, which help neutralize reactive oxygen species and reduce oxidative stress in biological systems. During the rapid growth phase of silkworm larvae, metabolic activity is high, leading to increased production of free radicals. Antioxidants present in mulberry leaves help mitigate this oxidative stress, thereby protecting cellular structures and improving overall larval health. Furthermore, phytochemicals may also exhibit antimicrobial properties, providing an additional layer of protection against pathogens. This can reduce the incidence of diseases in silkworm populations, thereby improving survival rates and ensuring consistent cocoon production^[20-21]. The synergistic interaction between nutrients and phytochemicals enhances digestion, nutrient absorption, and immune responses in silkworms, ultimately leading to improved performance.

The results of this study clearly demonstrate a strong positive relationship between mulberry leaf quality and cocoon yield. Improved nutritional and phytochemical composition leads to better larval growth, which is directly reflected in enhanced cocoon characteristics such as increased cocoon weight, shell weight, and silk productivity. These findings are consistent with earlier studies that have emphasized the importance of balanced nutrition in sericulture. However, the present study provides additional insight into the role of phytochemicals, highlighting their contribution to improving silkworm health and productivity^[22]. The observed improvements in silkworm performance underscore the importance of adopting cultivation practices that enhance both the nutritional and phytochemical quality of mulberry leaves. Strategies such as balanced fertilization, organic amendments, and optimized irrigation can significantly improve leaf composition. Additionally, the selection of high-yielding mulberry varieties with superior nutritional profiles can further enhance sericulture outcomes, the study reinforces the concept that mulberry leaf quality is a decisive factor in successful sericulture^[25-26]. By ensuring the availability of nutrient-rich and phytochemically active leaves, it is possible to achieve higher silk yield and better cocoon quality. These findings provide valuable insights for improving mulberry cultivation practices and promoting sustainable sericulture development.

5. Conclusion

The present study confirms that mulberry (*Morus spp.*) leaves are a valuable source of essential nutrients and bioactive phytochemicals that play a crucial role in enhancing silkworm growth, cocoon quality, and silk productivity. The presence of proteins, carbohydrates, and minerals supports vital metabolic processes and silk synthesis, while phytochemicals such as flavonoids and phenolic compounds contribute to antioxidant activity, improved immunity, and stress tolerance in silkworms. Together, these components create a balanced nutritional profile that directly influences larval development and overall sericulture performance.

The results clearly demonstrate a strong relationship between mulberry leaf quality and silkworm productivity. Improved nutritional composition leads to increased larval weight, higher survival rates, and enhanced cocoon parameters, including cocoon weight, shell weight, and silk yield. These findings highlight the importance of maintaining high-quality mulberry leaves to achieve consistent and economically viable silk production, the study emphasizes the need for adopting improved cultivation practices that enhance both the nutritional and phytochemical composition of mulberry leaves. Approaches such as balanced fertilization, use of organic inputs, and modern

agricultural techniques can significantly improve leaf quality and sustainability. Overall, optimizing mulberry leaf quality is essential for advancing sericulture productivity and ensuring long-term environmental and economic sustainability in the silk industry.

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