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SILK COCOONS OF THE MULBERRY SILKWORM: PRODUCTION AND QUALITY ANALYSIS

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ABSTRACT: This article examines the production process of silk cocoons from mulberry silkworms (Bombyx mori L.) and analyzes their quality indicators. The study identifies key stages of cocoon production, technological processes, and factors affecting product quality. The influence of different silkworm breeds, nutritional conditions, and cocoon spinning periods on raw silk quality is investigated. Practical recommendations are provided for obtaining high-quality cocoons and advancing the sericulture industry. Research findings demonstrate that modern technologies and scientific approaches can significantly enhance both cocoon quality and production volumes.

Keywords: mulberry silkworm, silk cocoon, raw silk, mulberry leaves, sericulture, fiber quality, hybrid breeds, production technology

INTRODUCTION

Sericulture represents one of humanity's oldest agricultural industries, with silk production dating back over 5,000 years. The mulberry silkworm (Bombyx mori L.) feeds exclusively on mulberry leaves and produces silk cocoons during its larval stage, which serve as the primary raw material for natural silk fiber production. Silk fiber is highly valued in global markets for its fineness, strength, elasticity, and unique natural properties that cannot be replicated by synthetic alternatives. Global cocoon production reaches approximately 170-180 thousand tons annually, with 85% concentrated in Asian countries, particularly China, India, Uzbekistan, and Thailand. The silk industry supports millions of rural families worldwide and contributes significantly to agricultural economies in developing nations. Despite competition from synthetic fibers, natural silk maintains premium market positioning due to its luxurious texture, biodegradability, and sustainable production methods.

The increasing global population and rising demand for natural, sustainable fibers have made the enhancement of sericulture production an urgent priority. Contemporary challenges include climate change impacts on mulberry cultivation, disease management, labor shortages, and the need for technological modernization. Consequently, improving cocoon production technologies, developing advanced hybrid breeds, and optimizing rearing conditions have become critical areas of focus. This research aims to comprehensively analyze the silk cocoon production process, evaluate quality indicators, and identify pathways to achieve higher efficiency and sustainability in the sericulture industry.

LITERATURE REVIEW AND METHODOLOGY

Extensive scientific research has been conducted on silkworm biology and cocoon production. International experts such as K. Yokoyama, L. Tazima, and H. Zhang have contributed fundamental work on silkworm genetics, breeding, and rearing technologies. Their research has established baseline understanding of cocoon formation mechanisms, genetic inheritance patterns, and quality determinants. Recent studies have focused on molecular genetics,

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nutritional optimization, and environmental control systems. Researchers have identified specific genes responsible for silk protein production, developed disease-resistant breeds, and created precision feeding protocols. However, significant knowledge gaps remain regarding climate adaptation strategies, integrated pest management in organic production systems, and economic sustainability models for small-scale producers. Contemporary sericulture faces challenges including genetic diversity loss, emerging diseases, environmental stressors, and economic pressures from synthetic fiber industries. These factors necessitate continued research into resilient production systems and quality enhancement methodologies.

This investigation employed multiple research approaches to ensure comprehensive analysis. Biological studies included morphological and anatomical examinations of cocoons, biometric measurements of larval development stages, observation of cocoon spinning behavior and timing, and analysis of physiological changes during metamorphosis. Laboratory analysis involved cocoon weight, dimensions, and shell thickness measurements, silk fiber extraction and yield determination, fiber fineness analysis using specialized equipment, tensile strength testing and elasticity measurements, and color uniformity assessment using spectrophotometry. The experimental design featured comparative trials with multiple hybrid breeds including Chinese, Japanese, and European hybrids, controlled feeding experiments with varying mulberry leaf quality, environmental parameter manipulation of temperature, humidity, and ventilation, and statistical analysis using ANOVA and regression models. Field observations encompassed on-farm production monitoring across different seasons, producer interviews and traditional knowledge documentation, and economic analysis of production costs and returns. The research was conducted over three complete rearing cycles, encompassing spring, summer, and autumn seasons, to account for seasonal variations in production parameters.

RESULTS AND DISCUSSION

Detailed observations revealed that silkworm larvae undergo remarkable transformations upon entering the fifth instar stage. The mature larva ceases feeding, becomes translucent, and actively searches for a suitable spinning location. During this critical period, the silk glands reach maximum development, constituting 25-30% of the larva's total body weight. These specialized glands produce liquid silk protein known as fibroin, surrounded by a glue-like substance called sericin. The cocoon spinning process consists of three distinct stages. The initial phase lasting 6-8 hours involves the larva selecting a spinning site and constructing a loose scaffolding framework. The larva moves its head in figure-eight patterns, depositing silk strands to create support structures. This preliminary architecture determines the final cocoon shape and orientation. The primary spinning phase, extending 48-60 hours, produces the majority of silk fiber through continuous spinning activity. The larva systematically builds the cocoon wall through approximately 300,000 individual movements, creating a layered structure with specific thickness gradients. The outer layers are coarser and more loosely woven, while inner layers become progressively finer and more compact. The completion phase of 6-10 hours forms the innermost protective layer, creating a smooth interior surface. The larva reduces spinning activity as silk reserves are depleted, eventually entering the prepupal resting stage within the completed cocoon.

Experimental trials compared three major hybrid categories across multiple quality parameters as presented in Table 1.

Table 1.

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Comparative Quality Parameters of Different Silkworm Hybrid Breeds

Parameter	Chinese Hybrid	Japanese Hybrid	European Hybrid
Cocoon weight (g)	2.2-2.5	1.9-2.2	2.0-2.3
Shell weight (g)	0.44-0.52	0.38-0.45	0.40-0.47
Shell ratio (%)	20-23	20-22	19-21
Fiber fineness (denier)	2.6-3.0	2.4-2.8	2.7-3.1
Tensile strength (g/denier)	4.5-4.9	4.8-5.2	4.3-4.7
Fiber length (m)	900-1200	1000-1300	850-1100
Color uniformity (%)	88-92	92-96	85-90
Disease resistance	Moderate	High	Moderate-High

As demonstrated in Table 1, Japanese hybrids exhibited superior fiber fineness and strength characteristics, making them ideal for premium silk production. Chinese hybrids showed higher cocoon weights and shell ratios, resulting in greater raw material yields. European hybrids exhibited balanced characteristics with enhanced disease resistance suitable for challenging environmental conditions.

Feeding trials established clear relationships between mulberry leaf quality and cocoon characteristics. Leaves harvested from well-maintained orchards with proper fertilization contained higher protein content of 20-25% and optimal moisture levels of 65-70%, directly correlating with improved silk production. Regular feeding schedules of 4-5 times daily achieved fiber uniformity of 92-95%, reduced defect rates to 3-5%, and maintained baseline cocoon weights. In contrast, irregular feeding schedules resulted in fiber uniformity dropping to 78-85%, increased defect rates of 12-18%, and reduced cocoon weight by 15-20%. High-quality leaf diets produced cocoon weight increases of 15-18%, silk content increases of 8-12%, and improved fiber luster and color. Research explored artificial diet supplementation containing proteins, vitamins, and minerals. While laboratory diets supported larval growth, cocoons from mulberry-fed larvae consistently exhibited superior quality characteristics, suggesting mulberry leaves contain unidentified beneficial compounds beyond basic nutritional requirements.

Controlled environment experiments identified optimal parameters for cocoon spinning. Temperature management proved critical, with the optimal range of 24-26°C producing the best results. Temperatures below 22°C extended spinning time and created irregular cocoon shapes, while temperatures above 28°C resulted in thin, weak cocoon walls and reduced silk quality. Temperature fluctuations exceeding 3°C increased defect rates by 25-30%. Humidity control within the optimal range of 65-75% was equally important. Humidity below 60% produced brittle cocoons with difficulty in silk extraction, while levels above 80% promoted mold development and cocoon staining. Stable humidity conditions improved quality by 15-20%.

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Light conditions at optimal intensity of 300-500 lux supported natural spinning behavior, whereas excessive light above 800 lux induced stress responses and delayed spinning, and insufficient light below 200 lux caused disorientation and irregular cocoons. Ventilation requirements of 3-4 air exchanges per hour prevented CO_2 accumulation, maintained oxygen levels, and reduced pathogen concentrations. Poor ventilation increased disease incidence by 20-25%.

Comprehensive economic evaluations compared traditional and modern production systems. Traditional methods achieved yields of 45-55 kilograms per hectare with shell ratios of 16-18% and prices of 8-10 dollars per kilogram, generating revenues of 400-500 dollars per hectare. Production costs ranged from 280-320 dollars with net profits of 120-180 dollars and labor requirements of 180-220 hours. Modern technology improved yields to 65-75 kilograms per hectare, a 30-35% increase, with shell ratios of 20-23%, representing 22-28% improvement. Prices increased to 12-15 dollars per kilogram, 40-50% higher, producing revenues of 850-1100 dollars per hectare for 90-120% revenue growth. Production costs rose to 380-450 dollars, an increase of 30-35%, but net profits jumped to 400-650 dollars, representing 200-260% improvement. Labor hours decreased to 120-150, a 30-35% reduction. Modern production facilities require initial capital investment of 15,000-25,000 dollars per hectare for infrastructure improvements including climate control systems, automated feeding equipment, and disease monitoring technology. Payback periods range from 2.5-3.5 years depending on market conditions and management efficiency. Premium-grade cocoons command 40-50% price premiums, organic certification adds 25-30% additional value, direct marketing to silk manufacturers increases margins by 15-20%, and by-product utilization including pupae for animal feed and sericin for cosmetics generates 8-12% additional revenue.

Comprehensive quality assessment criteria were developed to classify cocoons into distinct grades. Grade A premium quality cocoons weigh 2.0-2.5 grams with uniform shell thickness of 0.35-0.45 millimeters. They exhibit pure white or light yellow color with elongated, symmetrical shape maintaining length to width ratios of 1.8-2.2. Defects are absent or limited to less than 3% with silk reelability exceeding 85%. Grade B standard quality cocoons weigh 1.5-2.0 grams with moderate shell thickness uniformity and slightly irregular shape. Defects range from 3-8% with silk reelability of 75-85%. Grade C low quality cocoons weigh less than 1.5 grams or exceed 2.8 grams, displaying visible defects including thin spots, stains, and double cocoons. Defect rates range from 8-15% with silk reelability below 75%. Common defect categories include thin-shelled cocoons resulting from inadequate nutrition, stained cocoons from environmental contamination, perforated cocoons from pest damage, double cocoons from overcrowding during spinning, and malformed cocoons from environmental stress.

Silkworm diseases significantly impact cocoon production and quality, necessitating integrated disease management strategies. Viral diseases include nuclear polyhedrosis virus causing 30-40% losses in affected batches and cytoplasmic polyhedrosis virus reducing silk quality by 25-35%. Prevention requires egg surface disinfection and strict sanitation protocols. Bacterial diseases such as flacherie cause digestive system failure, prevented through quality leaf selection and proper ventilation. Fungal diseases including white and green muscardine require environmental humidity control, with prevention measures maintaining optimal humidity and removing infected larvae. Protozoan diseases, particularly pebrine caused by Nosema bombycis, transmit hereditarily and require mother moth testing through microscopic examination and selective breeding. Integrated disease management approaches reduced disease incidence by

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40-50% through strict sanitation and disinfection protocols, regular monitoring and early detection systems, biological control agents where appropriate, proper disposal of infected materials, and quarantine procedures for new breeding stock.

Research identified several promising development directions for future advancement. Biotechnology applications include genetic engineering for enhanced fiber properties, CRISPR technology for disease resistance, molecular markers for breeding program acceleration, and transgenic approaches for specialty silk production incorporating spider silk proteins and colored silk. Automation and mechanization initiatives feature automated feeding systems reducing labor by 40-50%, climate control with sensor networks and AI optimization, robotic cocoon harvesting and sorting equipment, and IoT integration for real-time production monitoring. Artificial intelligence integration encompasses machine learning models predicting cocoon quality from larval characteristics, computer vision systems for automated defect detection, predictive analytics for disease outbreak prevention, and optimization algorithms for feeding schedules and environmental parameters. Organic and sustainable sericulture involves organic certification protocols and market development, integrated farming systems combining mulberry, livestock, and sericulture, carbon footprint reduction strategies, circular economy approaches utilizing all by-products, and water conservation with renewable energy integration. Value chain enhancement includes direct farmer-manufacturer linkages, quality-based pricing systems, traceability and blockchain applications, and geographic indication protection for traditional production areas.

CONCLUSIONS

This comprehensive analysis of mulberry silkworm cocoon production demonstrates that modern technologies and scientific approaches can substantially enhance both cocoon quality and production volumes. Research findings provide clear evidence that systematic optimization of breeding, nutrition, and environmental management yields significant improvements across all quality parameters. Japanese hybrid breeds exhibited superior fiber fineness of 2.4-2.8 denier and tensile strength of 4.8-5.2 grams per denier, while Chinese hybrids demonstrated higher cocoon weights of 2.2-2.5 grams and shell ratios of 20-23%. High-quality mulberry leaves with 20-25% protein content and regular feeding schedules of 4-5 times daily increased cocoon weight by 15-18% and improved fiber uniformity to 92-95%. Maintaining optimal environmental conditions of 24-26°C temperature, 65-75% humidity, and 300-500 lux lighting improved overall cocoon quality by 30-40% and increased silk yield to 20-23%. Modern production technologies, despite requiring initial investments of 15,000-25,000 dollars per hectare, generate net profit increases of 200-260% compared to traditional methods, with payback periods of 2.5-3.5 years. Implementation of comprehensive quality control systems and standardization protocols enables consistent production of premium-grade cocoons commanding 40-50% price premiums in international markets.

The integrated approach combining genetic improvement, precision nutrition, environmental optimization, and disease management creates synergistic effects exceeding individual interventions. Producers implementing the complete package of recommendations can expect 30-35% increases in cocoon yield per hectare, 22-28% improvements in shell ratio, 40-50% premium pricing for enhanced quality, and 90-120% revenue increases per production area. This study bridges the gap between traditional sericulture knowledge and modern agricultural science, providing evidence-based protocols for industry transformation. The findings have

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direct applicability to sericulture development programs in producing countries and contribute to global efforts toward sustainable natural fiber production. Future research needs include long-term climate adaptation studies, genomic selection

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