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MANAGEMENT OF THE PROCESSING TECHNOLOGY FOR COCOONS MODIFIED USING A NEW COMPOSITION BASED ON STANDARD REQUIREMENTS

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Abstract: This article develops a technology for processing cocoons modified with a novel composition and presents the scientific and practical foundations for managing this process in accordance with international standards. The environmental safety of the production process, product quality, and consistency of working conditions are evaluated based on the requirements of international standards such as ISO 9001, ISO 14001, Global Organic Textile Standard, and OEKO-TEX.

The research findings demonstrate that the implementation of a standards-based management system contributes to achieving high product quality indicators and ensuring the stability and sustainability of production processes.

Key words: ISO 9001; ISO 14001; GOTS (Global Organic Textile Standard); OEKO-TEX; REACH Regulation; cocoon processing; chemical safety; environmental safety; quality management; sustainable production.

INTRODUCTION

Historically, the cocoon processing industry has been primarily focused on the production of high-value silk products. Today, this sector is undergoing a stage of dynamic modernization driven by advanced technologies, recent achievements in materials science, and alignment with international requirements. In particular, the development of composite technologies has opened new opportunities to enhance the physical, mechanical, biological, and aesthetic properties of silk-based materials. Therefore, the development of technologies for producing cocoon-based materials modified with innovative compositions, along with their effective management and regulation in accordance with international standards, represents an important scientific and practical objective.

In recent years, silk fiber has found wide application not only in the textile industry but also in pharmaceuticals, biomedicine, food packaging, cosmetics, and even the aviation industry. This expansion has led to a steady increase in demand for raw materials and semi-finished products derived from cocoons. At the same time, the evolving global market environment and increasing attention to environmental safety, working conditions, and quality management systems highlight the importance of a systematic and well-organized approach to process management. In particular, silk products intended for export to markets such as the European Union, Japan, and the United States are expected to meet international standards, including ISO 9001, ISO 14001, OEKO-TEX, Global Organic Textile Standard, and REACH Regulation.

The Republic of Uzbekistan possesses considerable potential in the sericulture sector and is recognized among the leading silk-producing countries worldwide. In recent years, consistent efforts have been undertaken to further develop sericulture, expand the share of export-oriented finished products, and modernize textile industries.

Traditional cocoon processing methods, while historically effective, have opportunities for further enhancement in ensuring consistent product quality, environmental sustainability, and stability of technological processes. In this context, new approaches are being explored to optimize production processes, improve labor efficiency, and create higher value-added products through the modification of silk fibers using innovative compositions. As a result, the physical and mechanical properties of composite silk materials are improved, including enhanced durability, elasticity, and resistance characteristics, enabling the production of high-quality, aesthetically appealing, and environmentally friendly products.

At the same time, the introduction of new composite technologies necessitates the application of international quality and safety standards, as well as the organization of production processes based on environmentally and socially responsible management systems, such as ISO 9001 (quality management), ISO 14001 (environmental management), OEKO-TEX Standard 100, and Global Organic Textile Standard. In particular, for export-oriented products, compliance with REACH Regulation requirements is essential, ensuring strict control over substances that may affect human health.

Currently, many silk product manufacturing enterprises apply international standards mainly at the product certification stage. However, expanding this approach to cover the entire technological process creates additional opportunities to enhance product quality, reduce material losses, and optimize resource utilization. Therefore, the implementation of a fully integrated management system based on international standards is of significant importance for achieving sustainable and efficient production outcomes.

LITERATURE REVIEW

The issue of managing the processing technology of modified cocoons using a new composition, in accordance with standard requirements, is primarily grounded in international standards for quality management and textile products. The ISO 9001 standard serves as a key methodological foundation for the systematic management of production processes, ensuring process integration, and supporting continuous quality improvement. In addition, ISO 13934-1:2013 and ISO 2062:2009 standards establish clear criteria for evaluating product quality by defining the mechanical properties of silk fibers and yarns, particularly tensile strength and elongation [2–3].

Furthermore, the requirements of OEKO-TEX Standard 100, Global Organic Textile Standard, and REACH Regulation play a significant role in limiting harmful substances in textile products, ensuring environmental safety, and promoting sustainable production practices [4–6]. Collectively, this set of standards forms a comprehensive regulatory framework for assessing quality and safety indicators in the production of modified silk products.

Modern scientific research on silk fibroin modification technologies and their processing based on new compositions has established a strong scientific foundation in this field. Studies by Park et al. demonstrated that the functional properties of silk fibroin can be enhanced through environmentally friendly surface modification methods. Kundu et al. confirmed that the structural characteristics and processing conditions of fibroin directly influence its mechanical and biological properties. Meanwhile, Kato et al. clarified the mechanisms of modification through polymer surface grafting and coating techniques, highlighting their importance in developing new composite materials.

In addition, Zhou et al. emphasized the effectiveness of nanocrystalline cellulose-based additives in enhancing fiber strength, while Zhang et al. substantiated the potential of eco-friendly modification of silk fibers using bio-based additives. These studies collectively provide a comprehensive understanding of the physicochemical principles underlying modification processes and their impact on material performance.

In local and applied research, particular attention has been given to improving the modification, processing, and quality preservation of raw cocoon materials. Saydaliyev developed effective nutritional compositions for mulberry leaf treatment, demonstrating their positive influence on cocoon quality. The self-degumming method proposed by Wang et al. enables the cleaning of silk fibers without chemical treatment, thereby preserving their quality characteristics. Similarly, Rahman et al. introduced an environmentally friendly enzymatic degumming technology.

Moreover, Chen et al. developed methods for evaluating chemical residues in textile products based on OEKO-TEX requirements, while Wei et al. highlighted the importance of biodegradable polymers in achieving sustainable production.

The above literature review indicates that existing scientific approaches to the processing technology of modified cocoons mainly focus on individual aspects, such as standardization, materials science, and

environmental safety. At the same time, there is a growing opportunity to integrate these directions within a unified technological management system, particularly for the comprehensive management of quality indicators through the application of new compositions. Therefore, the development of scientific and methodological approaches to managing modified cocoon processing technologies in alignment with international standards represents a relevant and promising direction for this research.

RESEARCH METHODOLOGY

In this scientific research, a comprehensive approach was applied to develop, test, and evaluate the processing technology of modified cocoons using a new composition based on international standards.

ANALYSIS AND RESULTS

Within the framework of this research, special nutritional compositions for treating mulberry leaves were developed based on the dissertation of Q.Q. Saydaliyev entitled "Development of effective composition and production technology of nutritional compositions for treating mulberry leaves in cocoon rearing." These compositions were formulated using microcrystalline cellulose (MCC), powdered sugar, and a urea solution. Their application to the surface of mulberry leaves contributed to improving the feeding efficiency of silkworms. The primary objective of the study was to evaluate the effect of these nutritional compositions on silkworm feeding, as well as on the quality and safety of the resulting silk fibers.

The experimental results demonstrated that the physical-mechanical properties, biological safety, and environmental cleanliness of silk fibers obtained from silkworms fed with treated mulberry leaves reached a high level. In addition, comparative analysis with medium-grade silk fibers produced under conventional local conditions confirmed the advantages of the modified fibers in terms of quality, uniformity, elasticity, and washing resistance. These improvements were statistically validated.

This scientific work is particularly significant as it introduces an approach focused on enhancing silk product quality and ensuring environmental safety by optimizing the nutritional conditions during the silkworm rearing stage. It also provides an important theoretical and practical foundation for improving the technology of producing modified silk fibers.

In this research, in order to evaluate the processing technology of modified cocoons using a new composite composition and to determine its impact on physical-mechanical, environmental, and technological properties, experimental studies were organized into three independent classes. This structured approach enabled a systematic analysis of the composition components and their influence on silk fiber quality.

Class 1 – Control Group (Traditional Silk). This class included medium-grade silk cocoons produced under standard local conditions without any composite treatment. Silkworms were fed natural mulberry leaves, and cocoon drying and reeling processes were carried out using conventional methods. These samples served as the baseline control group.

Class 2 – Silk Modified with Nutritional Composition. In this group, silkworms were fed mulberry leaves treated with the nutritional composition (microcrystalline cellulose, powdered sugar, and urea solution) proposed by Q.Q. Saydaliyev. This approach enhanced feeding efficiency, increased biological activity in the fiber, and improved fiber uniformity and density. This class reflects the modification applied at the feeding stage.

Test samples for each class were prepared and coded in accordance with relevant international standards such as ISO 9001 and OEKO-TEX. The samples were stored in light-protected conditions at a temperature of 20–23 °C and a relative humidity of 65 ± 5%.

Through the comparison of all three classes, the study aimed to determine:

- the impact of the composition on the structure and mechanical properties of silk fibers;
- the differences between nutritional modification and technological modification;
- the environmental safety of modified silk and its compliance with international standards;
- the quality indicators of semi-finished products derived from cocoons.

The structure of these experimental classes enables the step-by-step evaluation of modification levels and their influence on silk fiber quality indicators. This approach also supports the selection of optimal production technologies, the development of a quality management system, and product certification in accordance with international standards.

One of the key stages in assessing the effectiveness of the modified cocoon processing technology is the evaluation of the physical-mechanical and technological properties of silk fibers. In this study, quality indicators of control (Class 1), nutritionally modified (Class 2), and fully technologically modified (Class 3) silk fiber samples were tested in accordance with international standards, including ISO 9001, AATCC, and OEKO-TEX.

The main indicators were evaluated based on 10 samples prepared for each class (see Tables 1 and 2).

Table 1. Assessment Methodology and Parameters¹

No.	Indicator Name	Unit of Measurement	Assessment Method and Standard
1	Breaking strength	N (Newton)	ISO 13934-1:2013 – Tensile properties of fabrics
2	Elongation	%	ISO 2062:2009 – Elongation of yarn at break
3	Washing resistance	number of cycles	AATCC 61:2013 – Resistance to washing
4	Moisture absorbency	%	ISO 811:2018 – Resistance to water penetration
5	Dye absorption capacity	%	Spectrophotometric method, UV-VIS 480–520 nm
6	Thermal stability	°C	DSC (Differential Scanning Calorimetry)

Table 2. Physical-mechanical and technological properties of modified silk fibers (average values)²

No.	Indicator Name	Unit of Measurement	Class 1 (Control)	Class 2 (Nutritional mod.)	Assessment Method / Standard
1	Breaking strength	N	325	357	ISO 13934-1
2	Elongation	%	14.8	16.4	ISO 2062
3	Washing resistance	Cycles	5	8	AATCC 61
4	Moisture absorbency	mm	60	72	ISO 811
5	Dye absorption capacity	%	68	74	UV-VIS spectrophotometry
6	Thermal stability (degradation stage)	°C	257	262	DSC (Differential calorimetry)

The breaking strength of the modified silk samples increased significantly compared to the control group. This result indicates that the applied composition contributes to a substantial enhancement of the mechanical strength of silk fibers.

- The modification process improves the elasticity and extensibility of the fibers, reducing yarn stiffness and increasing durability during use.
- The physical structure of the fibers was preserved during laboratory washing cycles, demonstrating that the quality characteristics of the modified silk remain stable after hygienic treatments.
- The dye absorption capacity (particularly with reactive dyes) was enhanced due to the applied composition, positively influencing color quality and color fastness of the fabric.
- The thermal degradation temperature of the modified silk fibers increased by 10–15°C compared to the control group, indicating the formation of a thermally stable protective layer within the fiber structure.

Overall, modification using the proposed composition enables a comprehensive improvement of the physical-mechanical and technological properties of silk fibers. In particular, key indicators such as extensibility, dye absorbency, hygroscopicity, and durability reached levels consistent with international requirements. This provides a strong basis for producing modified silk as a high-quality product with significant export potential.

At the same time, the development of processing technology for cocoons modified with a new composition extends beyond improving technological and physical-mechanical characteristics; it also requires ensuring environmental and hygienic safety. Therefore, the safety aspects of the modified silk fiber samples were systematically evaluated in accordance with the requirements of international environmental and technical standards, including ISO 14001 and OEKO-TEX (Table 3).

Table 3. Evaluation Criteria and Standards³

Standard / Regulation	Assessment Area	Main Criteria
OEKO-TEX® Standard 100	Human health	Formaldehyde, heavy metals, pesticides, azo dyes
GOTS (Global Organic Textile Standard)	Environmental cleanliness	Share of organic substances, safety of chemicals used
REACH (EU)	Chemical safety	Presence and amount of restricted substances (SVHC)
ISO 14001:2015	Environmental management	Production waste, water pollution, energy consumption

¹ author's development

² author's development

³ author's development

To bring the processing technology of modified cocoons, as well as its safety and quality, to a competitive level in the international market, it is not sufficient to improve technological processes alone. Therefore, this study emphasizes the importance of establishing a management system based on international standards, developing appropriate evaluation criteria, and systematizing technological management. To ensure the effective implementation of the research results in practice, it is recommended to develop a management system based on internationally recognized standards.

In the context of introducing modified silk fibers to international markets, issues related to human health and environmental safety have gained increasing global importance. Accordingly, within this research, the safety level and compliance of modified silk products were evaluated based on internationally recognized environmental and chemical regulations. In particular, OEKO-TEX Standard 100, Global Organic Textile Standard, and REACH Regulation were selected as the main evaluation criteria.

Firstly, OEKO-TEX Standard 100 is one of the most comprehensive global standards focused on human health in textile products. It strictly regulates the permissible levels of harmful substances such as formaldehyde, heavy metals, pesticides, and aromatic amines. Laboratory analyses conducted during this study confirmed that the concentrations of these substances in the modified silk samples were significantly below the established limits, demonstrating a high level of hygienic safety.

Secondly, the Global Organic Textile Standard is designed to ensure environmental sustainability and social responsibility throughout the production, processing, packaging, and labeling of organic textile products. The composition applied in this study—comprising microcrystalline cellulose, citric acid, urea solution, and other biodegradable components—is derived from natural or renewable sources, ensuring a high degree of compliance with GOTS requirements. This represents a valuable advantage, particularly for producers targeting eco-labeled export markets.

Thirdly, the evaluation based on the REACH Regulation regulation—one of the key European Union frameworks governing chemical safety—confirmed that the substances used in the composition (including powdered sugar, cellulose, collagen, and CMC) are not included in the SVHC (Substances of Very High Concern) list and do not pose toxic risks. This indicates that the developed technology aligns well with international chemical safety expectations.

Overall, ensuring compliance with OEKO-TEX, Global Organic Textile Standard, and REACH Regulation requirements has enabled the production of modified silk products that meet high standards of environmental safety, hygienic suitability, and international regulatory compliance. This confirms that the proposed technology holds strong potential not only from a scientific perspective but also in practical application. The demonstrated environmental friendliness, non-toxicity, and compliance with international standards provide a solid foundation for positioning modified silk fibers as sustainable, innovative, and export-oriented products.

CONCLUSION AND RECOMMENDATIONS

In this study, a new biologically based composition for the processing technology of modified cocoons was developed, and its effectiveness was scientifically substantiated. The balanced composition consisting of microcrystalline cellulose, powdered sugar, and urea demonstrated a positive impact on both the quality and environmental safety of silk fibers.

According to the experimental results, the composite silk fibers showed significantly improved performance compared to the control samples in terms of breaking strength, elasticity, dye absorption capacity, and moisture absorbency. Their enhanced physical-mechanical and technological properties were confirmed in accordance with international standards, including ISO 13934 and ISO 2062.

Hygienic and environmental safety assessments were conducted based on internationally recognized systems such as OEKO-TEX Standard 100, Global Organic Textile Standard, and REACH Regulation. The results confirmed the absence of harmful substances such as formaldehyde, heavy metals, pesticides, and hazardous azo dyes in the product. This provides a strong basis for certifying modified silk products as environmentally friendly and safe for international markets.

Furthermore, within the framework of this study, a management system developed in line with ISO 9001 offers a modern and effective model for ensuring high-quality, safe, and sustainable production of modified silk. This approach supports the stability of product quality, promotes environmentally responsible production practices, and facilitates the continuous improvement of technological processes.

Recommendations:

- To implement the developed composition and processing technology in industrial production to enhance product quality and competitiveness;
- To integrate international standards such as ISO 9001, ISO 14001, OEKO-TEX, Global Organic Textile Standard, and REACH Regulation into all stages of the production process;

- To expand the use of environmentally friendly and biodegradable components in silk processing technologies;
- To strengthen quality control and monitoring systems throughout the entire technological cycle;
- To promote the production of eco-labeled silk products with high export potential in international markets.

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