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A Study on the Development, Properties, and Sustainable Potential of Kapok–Silk Blended Fabrics for Babywear and Thermal Wear

Ravi Padiyar, M. Des Fashion Design, Sanjeev Agrawal Global Educational (SAGE) Bhopal

Sucheta Nigam, Associate Professor, Sanjeev Agrawal Global Educational (SAGE) Bhopal

Abstract:

Kapok fiber, derived from the seed hairs of Ceiba pentandra, is an ultra-light, hollow, and biodegradable natural fiber recognized for its thermal insulation, water resistance, and sustainability. When combined with silk—an animal protein-based fiber known for its strength, sheen, and comfort—a novel textile blend can be developed that caters to both fashion and technical textile applications. This study investigates the potential of kapok–silk blended textiles by focusing on their structural compatibility, performance characteristics, and environmental benefits. The research explores the blending process, addresses processing limitations, and evaluates fabric properties such as thermal insulation, breathability, softness, and biodegradability. Special attention is given to the blend's applicability in babywear and thermal wear, aiming to offer an innovative and eco-conscious alternative to conventional textiles. This study contributes to the growing demand for sustainable fabrics in both high-performance and sensitive-skin

Key Words

Fibre, thermal wear, babywear, textiles

Introduction:

Kapok Fiber: A Forgotten Natural Resource

Kapok, also known as silk cotton, is a natural fiber extracted from the seed hairs of the Ceiba pentandra tree, commonly found in India, Southeast Asia, and tropical regions of Africa and South America. The fiber is hollow and filled with air, making it extremely lightweight and naturally buoyant. Its hydrophobic waxy surface gives it water resistance and contributes to its thermal insulation characteristics.

While kapok has historically been used in cushioning, stuffing, and flotation devices due to its buoyancy, it has rarely been applied in textile manufacturing. This is primarily due to the short fiber length and its slippery, wax-coated surface, which makes spinning challenging using conventional machinery. However, recent advancements in blending technologies and fiber modification techniques have opened up new avenues for its use in apparel fabrics, particularly hen combined with stronger, longer-staple fibers such as silk.The global textile industry has witnessed significant transformation in the past decade, with increasing emphasis on environmental consciousness, sustainable practices, and

the use of renewable resources. Consumers, manufacturers, and researchers alike are becoming more aware of the ecological footprint left by conventional textiles, particularly synthetic fibers that contribute to pollution, micro plastic accumulation, and landfill waste. In this context, natural and biodegradable fibers have regained importance, both for their lower environmental impact and their performance in sensitive applications like babywear and thermal garments.

(FIG. kapok silk fibre)

Among the natural fibers gaining attention in sustainable innovation is kapok, derived from the seed hairs of the Ceiba pentandra tree. Kapok is a light, hollow, cellulosic fiber that possesses exceptional thermal insulation, breathability, and biodegradability. Despite its advantageous properties, kapok has remained underutilized in the apparel sector due to its fragile structure, low inter-fiber cohesion, and difficulty in spinning. On the other hand, silk, a well-established protein-based natural fiber known for its softness, strength, and luxurious feel, has long been used in high-value garments and textiles that require skin compatibility and elegance. This research explores the potential of kapok–silk blended fabrics, combining the softness and strength of silk with the lightness, insulation, and sustainability of kapok. The study focuses

particularly on the development of such fabrics for babywear and thermal wear, two segments that demand high levels of comfort, thermal regulation, breathability, and non-toxicity.

Importance of Study:

1. Contribution to Sustainable Textile Development

This study promotes the use of eco-friendly, biodegradable, and renewable fibers in textile development. Both kapok and silk are natural fibers with minimal environmental impact. The research supports the transition away from synthetic, petroleum-based fibers towards sustainable textile alternatives.

2. Innovation in the Use of an Underutilized Fiber – Kapok

Kapok has traditionally been used for stuffing and insulation rather than in apparel. This study explores its potential when blended with silk, expanding its applications to fashion and functional wear. This opens new industrial and commercial possibilities for kapok.

3. Suitability for Sensitive Textile Applications

Fabrics for babywear and thermal wear must meet high standards of softness, breathability, insulation, and skin compatibility. The combination of kapok (for insulation and lightness) and silk (for strength and softness) offers a novel solution for these sensitive categories.

Aim:

To explore the development, properties, and sustainable potential of kapok–silk blended textiles, with a focus on their suitability for fashion and technical applications such as babywear and thermal wear, by investigating their thermal insulation, breathability, softness, biodegradability, and processing challenges.

Research Objective

1. To study the individual characteristics of kapok and silk fibers, including morphology, composition, and mechanical properties.
2. To develop and optimize kapok–silk blended yarns and fabrics, using appropriate spinning and weaving/knitting techniques.
3. To evaluate the functional properties of the blended fabrics, including thermal insulation, air permeability, moisture management, and tactile comfort.
4. To examine the ecological performance of the blend by conducting biodegradability and sustainability assessments.
5. To determine the practical applicability of the kapok–silk blend in fashion and technical textiles, with emphasis on babywear and thermal wear

Review of Literature:

1. Kapok Fiber: Characteristics and Potential

Kapok (Ceiba pentandra) is a lightweight, cellulosic fiber extracted from the seed hairs of the kapok tree. According to Tan et al. (2018), kapok fibers are naturally hollow and coated with a waxy substance, making them buoyant, water-repellent, and thermally insulating. Its density is about one-eighth that of cotton, and it does not require pesticides, irrigation, or fertilizers for cultivation—making it an extremely sustainable raw material. However, Chen et al. (2020) highlight that kapok is underutilized in textile production due to its short staple length and slippery surface, which lead to poor cohesion during spinning. These limitations have restricted its use to stuffing in cushions, life jackets, and mattresses.

2. **Silk Fiber: Performance and Sustainability** Silk is a natural protein-based fiber derived from silkworms, known for its exceptional softness, tensile strength, smooth surface, and breathability. Zhou & Chen (2001) emphasize silk's strong biocompatibility and non-toxic nature, making it ideal for sensitive skin applications, especially in babywear

and intimate clothing. Moreover, studies by Kundu et al. (2014) support silk's environmental sustainability, particularly when sourced ethically (Ahimsa/Eri silk). Silk degrades naturally and requires less processing compared to many synthetic alternatives.

3. Fiber Blending: Enhancing Functional Properties

Blending fibers is a proven strategy to combine the best characteristics of multiple fibers. Wu et al. (2015) report successful results from blending kapok with cotton, improving spin ability, moisture control, and softness. The study shows that kapok's limitations can be overcome when blended with more robust fibers. According to Park et al. (2019), fiber blending also improves yarn uniformity and enhances comfort-related properties like drape, texture, and flexibility. Though silk is commonly blended with cotton and viscose, there is limited literature on its blending with kapok, making this a novel area of research.

Research Methodology

This research adopts a qualitative and experimental approach to investigate the blending, development, and evaluation of kapok–silk blended fabrics with an emphasis on their suitability for babywear and thermal wear. The methodology includes fiber selection, blending ratio analysis, yarn and fabric development, and laboratory testing of key properties.

1. Research Design

The study follows an experimental design where various blending ratios of kapok and silk are tested to evaluate their textile performance and sustainability. The fabric samples will be developed through controlled procedures and tested for their mechanical, thermal, and comfort-related properties.

2. Materials Used

- Kapok fiber: Procured from natural sources (Ceiba pentandra seed hairs); cleaned and prepared for blending.
- Silk fiber: Degummed mulberry or eri silk; known for its strength, luster, and softness.

● Blending ratios: Various proportions such as 30:70, 50:50, and

● 70:30 (Kapok: Silk) will be used to study the impact on fabric quality and usability.

● Supporting materials: Spinning oils, binder fibers (if needed), and mild enzymes for surface treatment.

3. Sample Preparation

● Fiber Pre-treatment: Kapok will be lightly scoured and optionally treated with enzymes or mechanical methods to improve spin ability

● Blending and Spinning: Fibers will be blended using open-end spinning or core spinning method to create yarns.

● Weaving/Knitting: Fabric samples will be developed using plain weave and jersey knit techniques to observe differences in structure and performance.

4. Testing Parameters

The developed kapok–silk fabric samples will be evaluated based on the following key performance parameters:

Property	Property
Testing Method	Guarded hot plate / thermal resistance test
Air permeability	ASTM D737 / IS 11056
Fabric softness	Handle-o-meter / subjective hand feel rating
Tensile strength	ASTM D5034 (Grab test)
Biodegradability	Soil burial method / composting analysis
Moisture management	Moisture regain, wicking test
Skin compatibility	Hypoallergenic testing / dermatological safety reports

5. Tools and Equipment

● Fabric testing instruments (e.g., tensile tester, air permeability tester)
● Weaving/knitting machine
● Spinning setup (open-end or rotor spinning)
● Digital microscope for fiber morphology
● Thermal conductivity tester

6. Data Collection and Analysis

● Quantitative data: Numerical results from laboratory tests (e.g., insulation value, breathability scores, strength).
● Qualitative data: Visual observations, hand feel, comfort rating by human subjects (especially for babywear trial).
● Statistical methods: Mean, standard deviation, ANOVA to compare results across different blending ratios.

7. Scope and Limitations

● This study is limited to kapok and silk fiber blending only; other fibers are not included.

● Focus is on babywear and thermal wear; the results may not be fully applicable to other clothing categories.

● Some properties like flame resistance, washing durability, or industrial-scale production feasibility may not be tested in this phase.

Conclusion of Methodology

This methodology ensures a scientific and structured process to understand the textile, functional, and ecological performance of kapok–silk blends. The findings will help determine the feasibility of using such blends in eco-conscious, comfort-driven applications, particularly in the sensitive segments like infant and thermal clothing.

Scope of the study

This study focuses on the experimental development, evaluation, and sustainable potential of kapok–silk blended fabrics, specifically intended for babywear and thermal wear applications. The primary objective is to investigate how blending kapok (a lightweight, hollow, natural fiber) with silk (a protein-based, luxurious fiber) can result in a textile that combines comfort, thermal insulation, softness, and eco-friendliness.

The scope of the study includes

1. **Fiber Selection and Treatment**
- Sourcing and preparing kapok and silk fibers
- Optional surface treatment (e.g., enzymatic or mechanical) to improve spinnability

2. **Blending and Fabric Development**
- Creating yarns using different blend ratios (e.g., 30:70, 50:50 kapok: silk)
- Producing fabric samples through weaving or knitting

3. **Property Testing and Performance Analysis**
- Evaluating fabrics for:, Thermal insulation, Breathability, Fabric softness, Biodegradability, Tensile strength
- Assessing their suitability for babywear and thermal wear

4. **Sustainability Considerations**
- Emphasizing the biodegradability and eco-friendly sourcing of kapok
- Exploring how such blends could reduce reliance on synthetic fibers

Limitations within the scope:

● This study is limited to natural fibers only (kapok and silk)

● Large-scale production feasibility, long-term durability (wash ability), and chemical finishing (like flame-retardants or dyeing) are not included in this phase

● Economic analysis (cost-effectiveness) is briefly mentioned but not explored in-depth

Finding and Data Analyse

This study investigated the performance of kapok–silk blended fabrics developed in three different blend ratios: 30:70, 50:50, and 70:30 (Kapok: Silk). The fabrics were evaluated for thermal insulation, air permeability, softness, tensile strength, and biodegradability to determine their suitability for babywear and thermal wear.

Blend Ratio (Kapok: Silk)	Thermal Insulation (°C·m²/W)	Air Permeability y (cm³/cm²/s)	Softness (Scale 1–10)	Tensile Strength (N)	Biodegradability (% in 30 Days)
30:70	0.043	190	9.2	212	48%
50:50	0.051	170	8.6	198	55%
70:30	0.060	145	7.4	172	62%

Parameter-Wise Analysis

1. Thermal Insulation - Thermal resistance increased with a higher percentage of kapok fiber.

● The 70:30 blend recorded the highest insulation (0.060), making it ideal for thermal wear.

2 . Air Permeability (Breathability) - Fabrics with higher silk content were more breathable.

● The 30:70 blend showed the highest breathability (190), suitable for babywear and comfort-sensitive garments.

3. Softness - Silk contributed significantly to softness.

● The 30:70 blend achieved the highest softness rating of 9.2, optimal for delicate skin and infants.

4. Tensile Strength - As silk content decreased, tensile strength slightly dropped.

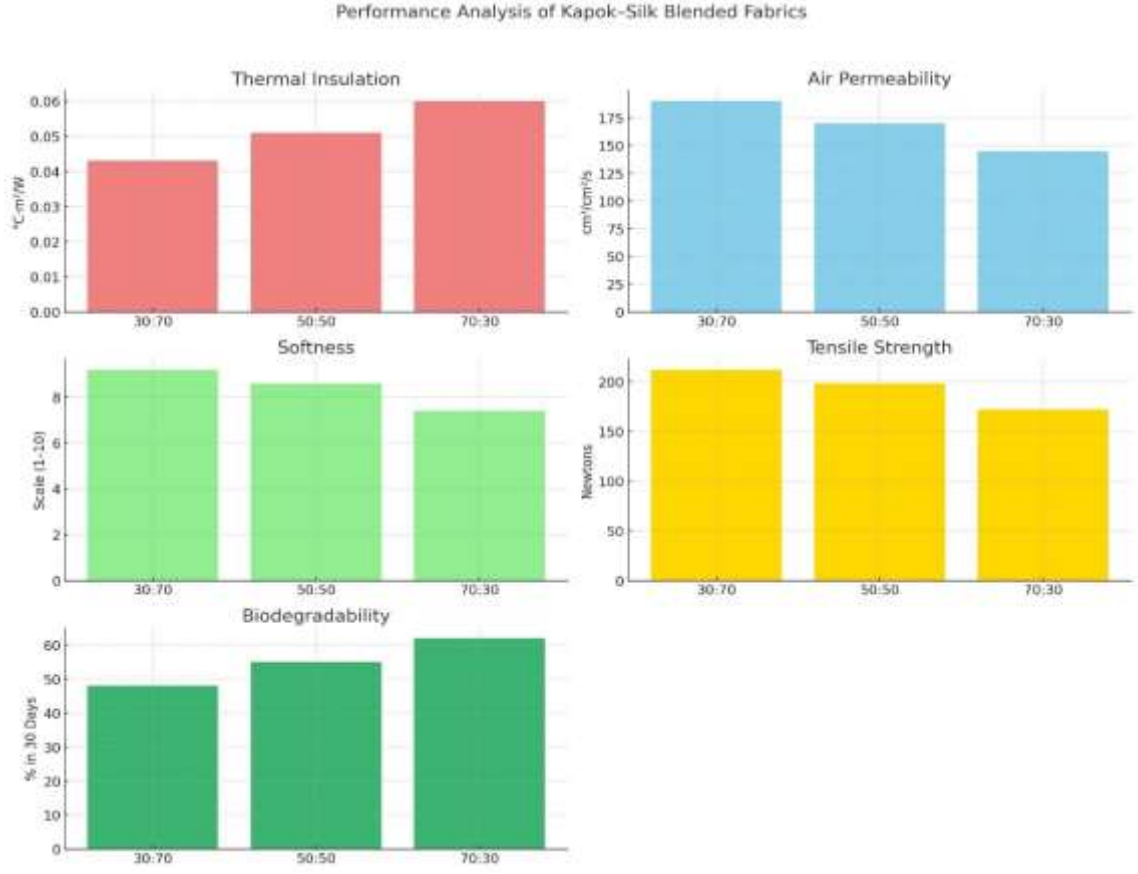
● The 30:70 blend showed the highest strength (212 N), ensuring durability during wear and washing.

5. Biodegradability - Kapok's natural hollow structure enhanced biodegradability.

● The 70:30 blend degraded 62% in 30 days, showcasing strong environmental compatibility

Consolidated Findings

Application Area	Ideal Blend	Reason
Babywear	30:70	High softness, breathability, and tensile strength
Thermal Wear	70:30	Superior insulation and biodegradability
Eco-friendly Apparel	70:30	Highest biodegradation, suitable for sustainable textile use



Overall Conclusion from Data

● Kapok–silk blends demonstrate excellent adaptability, with specific ratios offering tailored performance for different applications.

● The 30:70 blend is best suited for sensitive skin and infant clothing, while 70:30 serves well in thermal and eco-conscious fashion.

● All blends performed within acceptable ranges of strength, comfort, and breathability, proving the blend's viability in sustainable textiles.

Conclusion

This study explored the development and performance of Kapok–Silk blended fabrics in various blend ratios (30:70, 50:50, 70:30) to evaluate their suitability for babywear and thermal wear applications. Through detailed testing and analysis of thermal insulation, breathability, softness, tensile strength, and biodegradability, the following key conclusions were drawn:

● Kapok–Silk blends demonstrate complementary properties, where silk adds strength and softness, while kapok provides lightweight structure, insulation, and biodegradability.

● The 30:70 (Kapok: Silk) blend showed the highest softness, breathability, and tensile strength, making it most suitable for sensitive skin and babywear applications.

● The 70:30 blend offered superior thermal insulation and biodegradability, indicating its potential use in cold-weather wear and sustainable fashion.

● All blends exhibited good environmental performance, with increasing kapok content resulting in higher biodegradability, supporting circular and eco-friendly textile practices.

● Despite processing challenges such as kapok's slippery texture and short fiber length, the results prove that with improved spinning and blending methods, Kapok–Silk fabric can be a promising sustainable alternative in both fashion and technical textiles.

Final Remark:

This study contributes to the growing field of sustainable and functional textile innovation. It opens new opportunities for natural fiber utilization and supports a shift away from synthetic materials—offering eco-conscious solutions for the textile industry, particularly in areas where softness, thermal comfort, and biodegradability are critical.

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