

RECYCLING SILK SCRAPS INTO SUSTAINABLE FASHION TEXTILES UNDER THE CIRCULAR ECONOMY CONCEPT

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ABSTRACT

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This study aimed to investigate the utilization of Thai silk scraps in sustainable textile production. The objectives of this study were to examine approaches for reducing raw material use in the fashion textile industry and to design and develop sustainable fashion textiles from recycled silk scraps using the circular economy concept as a key framework. The research was conducted in two stages: (1) a preliminary study using literature review and focus group discussions with 10 participants, and (2) material development and prototype design evaluated by three textile experts. Research instruments included focus group guidelines and expert evaluation forms. The findings showed that the use of virgin raw materials in the fashion textile industry was significantly reduced by combining 20% recycled silk scraps with 50% virgin cotton and 30% recycled polyester fiber. Fibers made from recycled materials were strong, flexible, and suitable for spinning and weaving into fabrics, resulting in a significant reduction in resource utilization and waste generated during the manufacturing process. Furthermore, weaving the resulting fibers utilizing traditional Thai textile handicraft techniques together with contemporary design concepts resulted in woven fabrics with cultural value and styles in line with contemporary fashion trends. Expert involvement in both stages helped ensure the reliability and validity of the research process and outcomes. Ten fashion lifestyle product prototypes were developed from these materials, demonstrating the potential for commercial application of recycled materials and supporting the concept of sustainable fashion within the Thai cultural context and the broader creative industry.

Keywords: Recycling; silk fabric scraps; sustainable fashion textiles; circular economy concept

1. INTRODUCTION

Thai silk is a globally recognized cultural heritage, embodying Thai identity through complex, time-consuming weaving processes, and distinct patterns. Thai silk is internationally renowned for its rich cultural value, unique luster, and intricate designs, supported by organizations like SACIT (The SUPPORT Arts and Crafts International Centre of Thailand (Public Organization), 2018) that promote its craftsmanship. Thai silk production is a slow, intricate art form in which complex patterns take months or years

(Phrakhruphraphatsuthadham, 2017), which preserves traditional skills and cultural narratives, making each piece a unique, valuable artifact reflecting deep local wisdom and identity.

In recent years, the Thai government has been actively promoting policies to foster a creative economy aimed at boosting community income. The “Thai Fabrics, Fun to Wear” project is a government-backed initiative aimed at successfully modernizing traditional Thai textiles, making them appealing for daily use, enhancing their international appeal, and creating better economic prospects and income for local weaving communities by integrating heritage with contemporary fashion (Community Development Department, 2024).

However, the growth of the textile industry has led to the generation of fiber and fabric waste during manufacturing processes, resulting in environmental burdens and the loss of valuable raw materials. This problem becomes even more serious given that the fashion industry accounts for a significant share of the world’s greenhouse gas emissions and relies on water-intensive and energy-intensive manufacturing processes, especially in the dyeing and finishing stages (Quantis, 2018). Therefore, the development of environmentally friendly materials is an urgent challenge for the industry.

Additionally, interest in sustainable fashion has increased globally. According to a KPMG report, consumers in major cities such as London, Tokyo, and New York show strong support and a willingness to pay for eco-friendly and sustainable fashion items (Kwok-pan et al., 2019). In line with the circular economy concept, which emphasizes creating manufacturing processes that can be effectively reused, repaired, recycled, or recirculated, this trend is driving the textile sector to create new materials from waste materials (Ellen MacArthur Foundation, 2017).

Despite the increasing number of studies on sustainable textiles over the past decade, systematic work on recycling Thai silk scraps into fibers and fashion items is lacking. This is regarded as a substantial information gap concerning Thai textile innovation that has not yet been thoroughly investigated. Therefore, the objectives of this study are as follows:

- 1) To study the approaches for reducing raw material use in the fashion textile industry, and
- 2) To design and develop sustainable fashion textiles from recycled silk scraps.

2. LITERATURE REVIEW

2.1 Circular economy in fashion

The Circular Economy (CE) offers a sustainable alternative in response to resource depletion and the effects of linear economic systems that generate significant amounts of waste (Outmaster, 2019; Yarbpara, 2018). It emphasizes keeping products and materials in use for longer periods through reusing, repairing, recycling, and designing for durability and less waste (Bakker et al., 2021; Zhu et al., 2010).

The core principles of the CE include Durability, Renewability, Reuse, Repair, Replacement, Upgrade, Refurbishment, and Reduced Material Use, all of which aim to reduce greenhouse gas emissions and reduce the environmental load from the manufacturing sector (Outmaster, 2019).

According to Kalmykova et al. (2018), the CE functions as a “closed-loop” value chain in the industrial system, encompassing raw material sourcing, product design, production, distribution, consumption, collection, and disposal, as well as recovery and recycling, aimed at keeping resources in use by cycling them back into production.

The traditional fashion industry’s linear economic model, especially with fast fashion, consumes large quantities of virgin resources and creates massive pollution and textile waste. On the other hand, a circular manufacturing system is made possible through the application of CE, minimizing the need for virgin raw materials and repurposing waste materials into valuable inputs for new products, boosting sustainability and efficiency (Industrial Information Center, Thailand Textile Institute, 2023).

The application of Circular Economy (CE) in fashion involves three key dimensions:

- 1) Provision of textile waste (scraps, used fibers) for integration into new products via circular design and recycling technology, extending material life beyond traditional downcycling.
- 2) Circular business models which shift consumers from mere “buyers” to engaged “resource holders” via rental, resale, and take-back systems, turning waste into valuable material inputs for manufacturers.
- 3) A strong sustainability vision that assists businesses in addressing resource limitations and minimizing their long-term environmental impact (Wongsaravit, 2018)

In the fashion industry, CE generally seeks to integrate design, materials, production, reuse, and recycling activities into a single loop in order to improve resource efficiency, cut waste, and lessen environmental impact over the course of a product’s life cycle.

2.2 Textile industry and recycling

Driven by fast fashion's overconsumption, the textile industry significantly harms the environment through massive resource use and waste. In response, the fashion industry has committed to ambitious sustainability targets, including reducing greenhouse gas emissions by at least 50% by 2030 and promoting the transition to low-impact, circular material use (United Nations Framework Convention on Climate Change, 2021).

Textile recycling categorizes waste as pre-consumer (factory scraps) or post-consumer (used clothing and items). The recycling process ranges from sorting to the production of new fibers (Hawley, 2006).

Due to sophisticated technology and sorting, clothes manufactured from recycled fibers are generally expensive, but costs are decreasing as major brands invest in better systems in response to increased consumer demand for environmentally friendly solutions (Post Today, 2023).

The main textile recycling technologies include:

1) Mechanical recycling, which uses physical processes like cutting and grinding to break down fibers for reuse, keeping costs low but reducing original quality.

2) Chemical recycling, which involves breaking down textile waste into its basic components using solvents or chemicals, allowing for the creation of high-quality, virgin-like fibers suitable for new blends (Fashion for Good, n.d.).

The fast fashion industry is a major polluter that generates a massive amount of textile waste, with over 80% ending up in landfills and only about 15–20% being recycled, causing significant environmental problems (Gupta et al., 2022; Shamsuzzaman et al., 2023).

While brands use recycled inputs (such as recycling plastic bottles into polyester), complex garments (blended fibers, dyes, trims) are difficult to recycle, creating a circularity gap where materials get downcycled or landfilled, highlighting the need for better design for disassembly (Katchwattana, 2023). As a result, comprehensive textile recycling remains a major challenge for the industry.

Nonetheless, 54–77% of consumers in many parts of the world show a greater preference for garments made from recycled materials, indicating a substantial growth in demand for sustainable items (McKinsey & Company, 2022; European Commission, 2020). As a result, there is now a greater push for recycling innovations like chemical and mechanical recycling, as well as new business opportunities, such as the sale of used clothing, returning products for recycling, and the creation of renewable fibers to reduce the use of virgin raw materials.

2.3 Properties and potential of silk scraps

Silk is a natural protein fiber primarily composed of fibroin (70–80%) and sericin (20–30%). Fibroin is the strong, insoluble protein core of silk fiber, providing its strength, durability, and structure. Sericin is the natural, water-soluble glue (adhesive protein) that binds silk fibroin fibers together in a cocoon, and is removed during bleaching (degumming) (Yuan et al., 2024). Silk also contains fats, waxes, natural dyes, and minerals, which affect its natural color and sheen. Silk possesses physical properties such as high toughness and elasticity, good shape retention, lightweight feel, good moisture absorption, and thermal insulation. While silk is vulnerable to strong alkalis, oxidizing agents, and UV light (sunlight), it shows strong resistance against common microorganisms (Al Nassaj, 2023).

Silk's luxurious qualities include its sheen, breathability, lightness, and dye absorption, earning it the title of "The Queen of Fibers", and it is especially relevant in Thai culture, where it's prized for handicrafts (The SUPPORT Arts and Crafts International Centre of Thailand (Public Organization), 2018). However, silk's delicate nature, especially its vulnerability to harsh chemicals like strong alkalis, makes it a high-maintenance fiber, leading to its use primarily for luxury and formal wear rather than everyday, easy-care clothing, despite its natural beauty and feel. Silk scraps are valuable textile waste from the weaving and tailoring processes that can be upcycled into high-value products through design processes or by blending with other fibers to produce new materials, such as blended fabrics or recycled fibers, reducing waste and creating commercial opportunities. Research strongly supports that textile scraps can become high-value products that meet market demand for sustainable goods when strategically designed with local identity and innovative techniques.

The potential of silk scraps is also connected to global market trends that emphasize sustainability, culture, and handicrafts, offering substantial opportunities for regional woven goods, especially when combining innovation, modern design, and the concept of Value Creation to produce unique products that are difficult to replicate.

2.4 Sustainable fashion textiles

2.4.1 Guidelines for sustainable fashion design and production

Sustainable fashion design (or Eco Design) is a holistic approach integrating environmental, social, and economic aspects across a garment's life cycle (from raw material to disposal) aimed at minimizing

resource consumption and waste. Concepts like Green Design, Eco Design, and Design for the Environment are closely related, focusing on minimizing negative environmental impacts across a product's lifecycle by reducing resource use, energy, and waste, while also prioritizing reuse, recyclability, and sustainable materials to create a circular economy (Cimatti et al., 2017).

Fashion designers are central to sustainability by using techniques like circular design, selecting recycled/sustainable materials, and creating durable items, which minimize waste, reduce environmental impact, and create economic value of the products (ARCH Team, 2024).

2.4.2 Market needs and business opportunities

Fashion trends from 2025 highlight conscious consumerism, emphasizing value, quality, and longevity over fast fashion, driving growth in sustainable materials, even amid economic volatility (McKinsey & Company, 2025).

Many fashion entrepreneurs leverage the circular economy and sustainable clothing production to gain a competitive edge, boost brand image, and increase product value by meeting consumer demand for eco-friendly, longer-lasting goods, aligning perfectly with research into creating innovative sustainable textiles from recycled silk scraps.

3. RESEARCH METHOD

3.1 Sample groups

The sample groups in this study were selected using purposive sampling to obtain in-depth information from participants with relevant knowledge, experience, and interest in sustainable textile development and fashion product design in the context of the circular economy.

3.1.1 Population and sample

To assess the potential of recycled materials and product design directions within the context of a circular economy, the study population comprised individuals working in the textile and fashion industry, as well as consumers interested in sustainable textile and fashion products. The sample was selected using purposive sampling to obtain in-depth information from participants with relevant knowledge, experience, and interest in sustainable textile development and design.

3.1.2 Expert group

The expert group, consisting of three fashion textile specialists, including textile designers, fashion textile industry entrepreneurs, and fashion professors, with over 10 years of experience, assessed the suitability of the product sketches and prototypes using purposive sampling to gain in-depth information from experts with knowledge of recycled silk fibers, design development, and commercial potential. The evaluation results provided a reliable foundation for the successful development of sustainable fashion product prototypes.

3.1.3 Focus group

The focus group of 10 participants, including academics, textile experts, and consumers interested in sustainable fashion, was purposely selected to reflect in-depth viewpoints on consumer behavior, design trends, and market needs. The selection followed predefined inclusion criteria: (1) a demonstrated interest in sustainable fashion products, (2) professional experience or familiarity with the textile industry, and (3) a willingness to contribute to the qualitative discussion. Participants were recruited through academic networks and professional contacts within the textile and fashion sectors. The number of participants was appropriate for the Focus Group Discussion (FGD), yielding qualitative data covering materials, product functions, and market opportunities.

3.2 Variables

3.2.1 Independent variables

Independent variables included the percentage of recycled silk fibers to other fiber mixes used in yarn production, specific weaving patterns (e.g., plain overshoot, twill, and block overshoot), yarn sizes, and design concepts based on sustainable fashion and circular economy principles.

3.2.2 Dependent variables

Dependent variables included fiber properties, the structural quality and technical integrity of the woven fabrics, usability and durability, as well as the suitability level of the sustainable fashion product prototypes, assessed by aesthetic, identity reflection, commercial feasibility, and satisfaction of experts in the fashion textile industry.

3.3 Research procedure

Phase 1: Preliminary study and knowledge synthesis (R1)

The first phase involved the study of the fundamentals of Thai silk and its production process based on local wisdom, including surveying the types, quantities, and characteristics of silk fibers and silk scraps generated during the production and tailoring processes in order to assess their potential for reuse.

A literature review and study on textile fiber recycling, sustainable fashion materials, and circular economy concepts were carried out in order to synthesize a database for material and product development. Ten textile experts, fashion entrepreneurs, and consumers interested in sustainable fashion were chosen through purposive sampling to participate in a focus group discussion aimed at improving the insights. The participants' opinions were gathered on design directions, market demand, the viability of using recycled materials, and concepts that preserve and align with Thai wisdom. All data were synthesized into a product design conceptual framework that would serve as a guide for the subsequent stage of material and prototype development.

Phase 2: Material development and design construction (D1)

Textile materials were developed from waste silk fibers and silk scraps produced during manufacturing and sewing processes, by putting these waste materials through a mechanical recycling process that involved sorting, shredding, and restoring the fibers to obtain recycled silk fibers that can be effectively reused in the production of new yarn.

The standard steps of the yarn production process, including mixing, carding, drawing, spinning, winding and twisting, were followed in order to produce yarn of appropriate quality for further development (Figure 1).

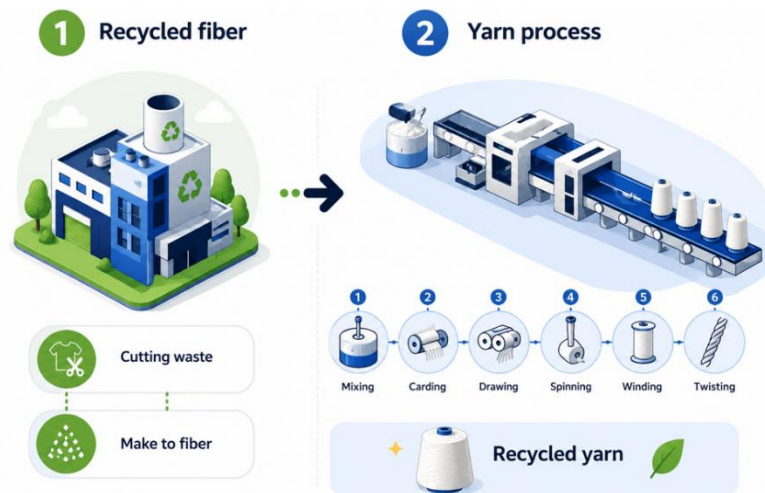


Figure 1: Recycled fiber processing

Source: Created by Naddawadee Boonyadacho using ChatGPT (GPT-5, OpenAI) with its integrated DALL-E image generation capability and subsequently reviewed and edited by the author.

In order to maintain the “identity of local wisdom” while utilizing contemporary materials, the recycled yarns were woven into prototype fabrics employing Thai textile craftsmanship techniques. The prototype materials reflected cultural refinement while including a sustainable aspect in the manufacturing process, through the use of local looms and weaving techniques. The development of this prototype fabric was also essential for assessing the viability of the recycled yarns for practical applications, including tensile strength, fabric structural consistency, and aesthetic qualities.

Data from developed materials, market needs, and industry experts were synthesized into lifestyle fashion product design concepts. The design mock-ups were created and presented for assessment based on their aesthetic appeal, usability, cultural value, commercial feasibility, and consistency with the concept of sustainable fashion under the circular economy. The highest-rated design for creating a product prototype was chosen based on the assessment.

After the recycled silk fibers were obtained, natural dyes were used to produce hues in accordance with the design concept. Three natural materials were used in the dyeing process: *Maclura cochinchinensis* (Lour.) Corner heartwood (for yellow), indigo (for blue), and double dyeing with both *Maclura cochinchinensis* (Lour.) Corner heartwood and indigo (for green). The standard procedures for protein fiber dyeing were followed with controlled mordant and temperature parameters to produce stable colors suitable for weaving.

1) Dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood for yellow

The recycled silk fibers showed a light gray hue, a result of the blending of different shades of fibers during the recycling process. The silk fibers appeared darker yellow rather than bright yellow after being dyed with *Maclura cochinchinensis* (Lour.) Corner heartwood in the dyeing pot since the original color was derived from the fibers' gray hue (Figure 2). Longer-lasting color was produced by using alum and limewater to encourage pigment binding. The quality of the recycled material was evident, even though the final color shade was not as bright as that of pure silk fibers.



Figure 2: Dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood
Source: Photograph by Naddawadee Boonyadacho

2) Dyeing with indigo for blue

The fibers displayed a grayish blue shade following dyeing with indigo, which was consistent the original color of recycled fibers. The silk fibers retained their softness after dyeing, while the indigo dye permeated the silk threads unevenly, giving them a natural color dimension (Figure 3). This distinctive quality is considered an aesthetic value of recycled material that cannot be achieved from new, uniform fibers.



Figure 3: Dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood and indigo for blue
Source: Photograph by Naddawadee Boonyadacho

3) Double dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood and indigo for green

The green shade was obtained by double-dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood for yellow and then indigo, resulting in a deep and translucent green from the overlap of dull yellow and grayish blue. The resulting green was muted and not overly vivid, reflecting the characteristics of the recycled fibers as shown in Figure 4.



Figure 4: Fibers dyeing with *Maclura cochinchinensis* (Lour.) Corner heartwood and indigo for green
Source: Photograph by Naddawadee Boonyadacho

Phase 3: Prototype development and expert evaluation (R2)

The product prototype was developed using woven fabric from recycled silk fibers. The prototype production process focused on usability and reflection of Thai wisdom through weaving techniques. Following the development of the prototype, its quality in key areas, including woven fabric properties and material strength, design quality and aesthetics, usability, degree of reflection of Thai handicraft identity, commercial potential, and consistency with sustainable fashion, was evaluated by textile and fashion experts.

The remaining woven fabrics from the prototype production were sent to the Thailand Textile Institute for physical and mechanical property testing to scientifically verify the quality of the recycled materials and to inform further product development.

Phase 4: Synthesis, conclusion, and dissemination (D2)

The data from all processes—including fiber development, weaving, product design, prototyping, and expert assessments—were gathered and examined in order to draw academic conclusions about the potential of recycled silk scraps in the sustainable fashion industry.

4. RESULTS AND DISCUSSION

4.1 Insights from focus group discussions and analysis of the potential of silk scraps in the context of Thai handicrafts

The focus group discussions emphasized the potential of recycled silk scraps as a material for the creation of sustainable fashion textiles, in terms of their material qualities, commercial potential, and connection to Thai handicraft wisdom. According to experts, “uneven shades, color spots, and different textures” of waste fibers are not defects but rather distinctive qualities that highlight the material’s natural character. This aligns with the global sustainable fashion concept, which places a high value on material authenticity and transparency in the production of sustainable products.

According to experts, silk scraps held significant potential for material aesthetics, especially given the distinctive texture and sheen of traditional Thai silk. Although recycled fibers were not ideal for high-concentration applications due to their shorter length and greater brittleness compared to pure silk, they might greatly increase their value (upcycling) when added to acceptable yarn formulations. Although experts recommended a 50–60% ratio to maintain the “Thai silk” character, the actual production process showed that such a high ratio was not supported by the mechanical properties. To preserve yarn strength, suitability for weaving, and utility in creating sustainable fashion products, the percentage of recycled silk must be reduced to 20–30%.

Experts also stressed the importance of minimizing or avoiding bleaching because it accelerates the deterioration of silk fibers. Reducing environmental effects and maintaining the distinctiveness of Thai silk in handicrafts are two benefits of preserving natural shades or colors from waste materials.

Focus group discussions revealed that blended yarn formulas containing 20–30% recycled silk scraps could actually satisfy research objective (1) by lowering the consumption of new raw materials in the textile industry. Additionally, they reduce the reliance on expensive pure silk, cut down on waste from the fashion industry, and reduce energy and water consumption in the new fiber production process. This approach is in line with the “Fashion Circularity” movement, which emphasizes long-term usage of raw materials without diminishing their significance in Thai culture. Experts stressed that recycled silk fibers are especially appropriate for creating community-based weaving systems, which are at the core of Thai textile knowledge in many areas, when integrating this with the knowledge of Thai weaving craftsmanship. Recycling yarn for local weavers fosters creativity that builds on traditional expertise, allowing modern woven fabrics to showcase both the Thai cultural identity visible through the new value of recycled resources and weaving processes.

Experts believe that such development will result in the distribution of income and the strengthening of the grassroots economy, the continuation of Thai weaving knowledge to fit into the context of contemporary fashion, and the production of products with material storytelling that connects the past and the future.

Experts recommended weaving tests on three different types of fabrics to assess the potential of recycled silk fibers in real-world situations:

- 1) Using 100% recycled silk fibers for both warp and weft in order to test the potential of the recycled material as a whole fabric structure, including uniformity, strength, and continuity of the fibers during the actual weaving process.

- 2) Using 100% pure silk for the warp threads and recycled silk fibers for the weft. Because the warp threads must withstand greater strain throughout the weaving process, this method improves the fabric’s strength. This approach is suitable for testing the durability of recycled silk in areas with lower tensile forces.

3) Using 100% pure silk for the weft threads and recycled silk fibers for the warp. This technique clearly illustrates the strength and stability limitations of recycled materials and aids in the analysis of the durability of recycled fibers when they serve as the primary tension strands of the fabric structure.

Experts believe that fashion clothing is the best category for this material in terms of design and marketing since customers can easily identify the fabric's identity, color, texture, and story, and it also aligns with current fashion trends that place an emphasis on sustainability and cultural values.

4.2 Yarn composition analysis and recycled fiber production process

In keeping with the goal of developing sustainable fashion materials, the technical experiment results show that it is possible to reuse silk waste and silk scraps from the fashion industry as components of blended yarns, while retaining appropriate properties for weaving and reducing the textile industry's reliance on virgin raw materials.

4.2.1 Yarn composition

The recycled silk fibers were provided by the Queen Sirikit Department of Sericulture, sourced from industrial waste threads at Chul Thai Silk Co., Ltd. These non-standard by-products, originating from reeling and dyeing processes, initially appeared as tangled threads of varying lengths and colors. The blended yarn formula used in the experiments consisted of three types of fibers.

- 50% Virgin Cotton: This type of cotton is created entirely of natural fibers from the cotton plant that have never been recycled or repurposed. Its exceptional qualities include being light, breathable, soft, and non-irritating to the skin. Therefore, it has long been a popular material in the textile industry. In addition to improving wearing comfort, using virgin cotton in blended yarns enhances the product's perceived environmental and consumer friendliness.

- 30% Recycled Polyester Fiber (R-PET): R-PET fiber is a strong, durable, lightweight synthetic material from recycled polyethylene terephthalate (PET) plastic bottles, made by cleaning, shredding bottles into flakes, melting, and spinning them into yarn for textiles. Using R-PET fibers significantly cuts plastic waste, energy consumption, reduces reliance on fossil fuels, and promotes the circular economy by turning waste into valuable textiles, making it a key sustainable trend in global fashion.

- 20% Recycled Silk Fibers derived from waste materials (15% in light colors like white and cream and 5% in varied colors). Waste silk fibers are leftovers from the fashion industry's manufacturing or stitching processes. They are typically discarded as waste. To enable their reuse in the yarn production process, these fibers were sorted, shredded, and reprocessed in this study. A special quality of silk fibers is their sheen, softness, and moderate strength. By upcycling waste materials, incorporating waste silk fibers into blended yarns improves material aesthetics and adds value to the whole fashion industry.

The 50:30:20 ratio was determined through preliminary weaving trials to balance the recycled silk's appearance with the yarn's strength. Trials showed that using more than 20% silk made the yarn uneven and prone to breakage during weaving. Therefore, 50% virgin cotton was used to provide a solid base and softness, while 30% R-PET was added to increase the yarn's durability. This combination allows for smooth weaving while keeping the unique texture and color spots of the recycled silk.

A combination of various shades of silk scraps and unbleached fibers produced a light grey mélange when these three types of fibers were spun into actual yarn. This outcome is in line with the approach of minimizing chemical reactions, conserving water, and maintaining the characteristics of recycled materials, especially the color spots and irregularities that distinctly show the "natural character of the material".

4.2.2 Yarn number for weaving

To determine the optimal yarn count for traditional Thai weaving, which requires yarn strong enough to withstand breakage during weaving, two yarn counts were evaluated (Figure 5).

- Formula 1: 10/2 yarn, which provides thickness and durability, ideal for fabrics requiring heavier weight and structure.

- Formula 2: 20/2 yarn, which is a fine, lightweight yarn, perfect for contemporary fashion.

20/2 yarn was chosen as the primary material because it strikes a balance among strength, softness, and comfort, and can be easily incorporated into Thai weaving handicrafts in both fabric structure and aesthetic qualities.



Figure 5: Recycled yarn, yarn numbers 10/2 and 20/2
Source: Photograph by Naddawadee Boonyadacho

4.3 Contemporary Thai weaving with recycled silk

The findings of the weaving experiments conducted using recycled silk yarns showed that the most appropriate technique for the fiber qualities was the plain-weave and shaft-weave loom structures, especially the four-shuttle configuration (Figure 6, Table 1). This was because they supported a range of pattern-making techniques, dispersed tensile forces, and reduced yarn breakage. Structural analysis also revealed that, when paired with traditional Thai weaving techniques, the variations in size, length, and color of the recycled silk fibers became a “highlight” in the fabric design, providing dimension, texture, and individuality to the patterns.



Figure 6: Weaving techniques applied in this study, including twill, plain overshoot, block overshoot, cross inlay, and brick inlay
Source: Photograph by Naddawadee Boonyadacho

Table 1: Weaving techniques for patterns

Twill	Plain overshoot	Block overshoot	Cross inlay	Brick inlay
Use 100% pure silk for the warp and recycled silk fibers for the weft.	Use recycled silk fibers for both warp and weft.	Use 100% pure silk for the weft and recycled silk fibers for the warp. Block Overshot is used to create dimensional textures.	Use recycled silk fibers for both warp and weft. Cross Inlay is used to create dimensional textures.	Use 100% pure silk for the weft and recycled silk fibers for the warp. Brick Inlay is used to create dimensional textures.

Based on the data and weaving experiments, the characteristics of patterns and techniques suitable for recycled silk are as follows:

1) Twill: Using the 4-shuttle technique in weaving, where two shuttles are lifted at a time for diagonal patterns. The warp threads were made of virgin silk fibers and the weft threads were made of recycled silk fibers.

2) Plain Overshot: Using the 4-shuttle technique in weaving by stringing the shuttles in a waffle pattern. The weft threads were made of recycled silk fibers. In the pattern where the weft crossed the most over the fabric pattern, recycled silk fibers were combined to make the threads larger, creating a prominent, raised pattern.

3) Block Overshot: Weaving with the 4-shuttle technique is similar to making a honeycomb pattern. To give the cloth a raised texture, the weft threads were woven across the warp threads at a distance of around two cm. One side showed white weft threads woven using a cocoon shell, while the other side showed weft threads combined with leftover silk fibers.

4) Cross Inlay: Using the 4-shuttle technique to weave large recycled silk threads in a herringbone pattern at regular intervals that alternate with regular over-one-under-one segments to make a textured, segmented fabric that resembles herring bones.

5) Brick Inlay: Weaving in rows with a cross-hatched pattern using the 4-shuttle technique, inserting square-shaped weaving techniques at regular intervals, and then weaving diagonally in the subsequent row to continue weaving.

4.4 Development of fashion collections and expert evaluation

Recycled materials can be further developed into contemporary products in a number of ways, including form, pattern, and material aesthetics, as shown by the development of fashion collections based on recycled silk fibers. Three collections were developed by three designers, reflecting different interpretations of recycled silk, including the preservation of Thai identity, the application of local wisdom, and a response to international textile trends.



Figure 7: Collection 1

Source: Photograph by Pawarut Saengseethong

Collection 1 (Figure 7) focuses on contemporary elegance through modern minimalism, combining the intricate construction and precise tailoring, or what experts call finishing finesse. The fabrics in this collection highlight the intricate patterns of houndstooth and waffle weave structures, as well as the inherent beauty of recycled silk, which may be found in light grey shades, making them elegant, simple yet sophisticated, suitable for a variety of occasions.



Figure 8: Collection 2

Source: Photograph by Panupong Khamdee

Collection 2 (Figure 8) reflects the power of “ancestral textiles” through the reinterpretation of traditional Thai weaving techniques such as Koh Lueng, honeycomb, and block overshoot in a contemporary way. A rich, multifaceted texture is achieved by weaving recycled silk strands with pure silk, making Thai weaving more accessible to new customers. This collection shows how Thai fabrics can be used to create modern fashion items that seamlessly blend the past and present, rather than only in their traditional settings.

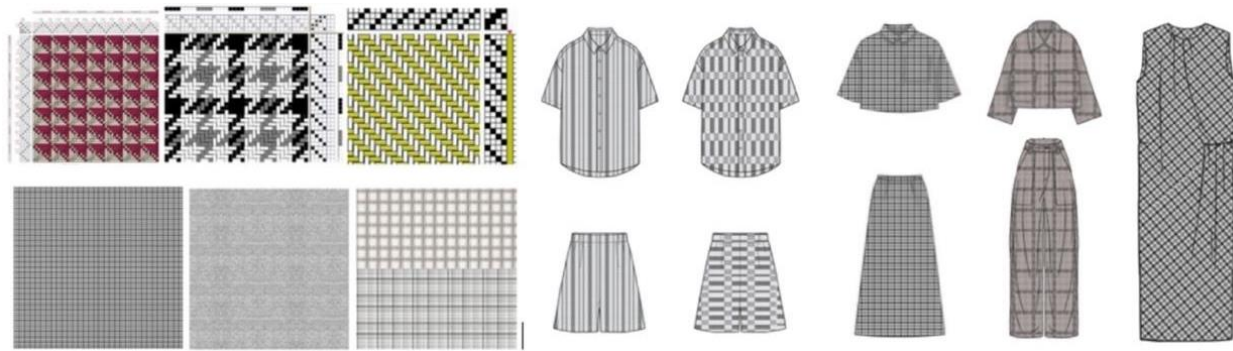


Figure 9: Collection 3

Source: Photograph by Sasicha Srijanchom

Collection 3 (Figure 9) was developed from a textile trend that emphasized bold fabric patterns such as stripes, checks, twill and corduroy. With an emphasis on oversized, straight silhouettes popular among the young and working fashion market, these bold patterns made it possible to present recycled silk in a more contemporary dimension. This collection appeals to customers seeking fashion that is both sustainable and aligned with international trends, as it combines structured patterns with the natural tones of recycled fabrics.

Table 2: Expert evaluation scores of three draft fashion collections using recycled silk fibers

Evaluation criteria	Collection 1 (Mean $\pm$ SD)	Collection 2 (Mean $\pm$ SD)	Collection 3 (Mean $\pm$ SD)
1. Appropriateness of design composition	4.00 $\pm$ 0.82	4.00 $\pm$ 0.82	4.00 $\pm$ 0.82
2. Creativity and innovativeness	4.00 $\pm$ 0.82	4.33 $\pm$ 0.47	4.00 $\pm$ 0.82
3. Distinctiveness and identity	3.67 $\pm$ 0.94	4.00 $\pm$ 0.82	4.33 $\pm$ 0.47
4. Material suitability	4.00 $\pm$ 0.82	4.33 $\pm$ 0.47	4.33 $\pm$ 0.47
5. Versatility and functionality	4.00 $\pm$ 0.82	4.00 $\pm$ 0.82	3.67 $\pm$ 0.94
6. Ability to enhance product value through recycled materials	4.33 $\pm$ 0.47	4.33 $\pm$ 0.47	4.67 $\pm$ 0.47
7. Environmental friendliness	4.00 $\pm$ 0.82	4.00 $\pm$ 0.82	4.67 $\pm$ 0.47
8. Market relevance in sustainable fashion	4.33 $\pm$ 0.47	4.33 $\pm$ 0.47	4.33 $\pm$ 0.47
9. Potential to attract designers and businesses	4.67 $\pm$ 0.47	4.67 $\pm$ 0.47	4.67 $\pm$ 0.47
Overall satisfaction	4.00 $\pm$ 0.82	4.67 $\pm$ 0.47	4.67 $\pm$ 0.47

A comparative analysis of the three collections (Table 2) showed that, despite the fact that each concept is unique, they all have one important characteristic in common: the designs are centered around the natural textures and hues of recycled silk strands. The aesthetic value of fashion is not diminished by the use of renewable materials; rather, it enriches the product's distinctive individuality, as demonstrated by all three collections. Furthermore, the diverse designs demonstrate the potential of recycled silk fibers to reach various fashion market segments, from the sophisticated and craft-minded to the contemporary, trend-driven global fashion market.

Combining the ideas from Collections 2 and 3 is the most practical design strategy in terms of aesthetics, utility, and production, according to an analysis of the three collection drafts and suggestions from textile and fashion experts. This is due to the fact that both collections showcase the possibilities of recycled silk fibers in distinct yet complementary ways. Collection 2 focuses on a detailed depiction of Thai handicraft wisdom, while Collection 3 aligns with global textile trends such as stripes, checks, and twills, expanding the product's market reach and attracting a new customer base.

The integration of the two collections' concepts creates a design framework that is "contemporary yet culturally grounded" through the development of textures and patterns from traditional weaving techniques that allow for a clear material depth and the incorporation of leftover silk fibers to create new patterns that add uniqueness and dimension to the fabric.

4.5 Design and development of product prototypes from recycled silk fibers

Ten prototypes of fashion products were produced. The prototype collection, depicted in Figure 10, is the result of integrating material data, contemporary Thai weaving techniques, and the circular economy concept to develop useful, everyday fashion items from "recovered silk scraps". The collection combines the textured characteristics of recycled silk fibers with simple silhouettes in keeping with the concept of modern craft wear, a significant trend in sustainable fashion today.



Figure 10: Prototypes of fashion products
Source: Photograph by Naddawadee Boonyadacho

Table 3: Weaving techniques for patterns

Evaluation list	Mean	SD	Satisfaction level
Design and aesthetics			
1. The design elements are appropriate and beautiful.	4.33	0.47	High
2. The design is outstanding and unique.	4.00	0.00	High
3. The design is consistent with sustainable textile production.	4.33	0.47	High
Quality and usability			
4. Fabric durability	4.33	0.47	High
5. Fabric properties are suitable for the intended use.	4.33	0.47	High
6. The fabric prototype is appropriate for practical use.	4.67	0.47	Highest
Sustainability and circular economy			
7. Utilization of recycled silk fibers adds value to fashion textile products.	4.67	0.47	Highest
8. The production process is environmentally friendly.	4.33	0.47	High
Market feasibility			
9. The design is in line with the needs of the sustainable fashion market.	4.33	0.47	High
10. The price is reasonable.	4.00	0.00	High
11. Possibility of generating entrepreneurial interest	4.67	0.47	Highest
12. Reflection of technology and innovation in textile production	4.33	0.47	High
13. Satisfaction with the overall fashion textile prototype	4.33	0.47	High

According to expert evaluations (Table 3), the recycled silk fashion textile product prototypes received high to very high satisfactory scores across all dimensions, indicating their suitability in terms of design aesthetics, fabric properties, durability, sustainability potential, and market viability. The items with the highest scores included the fabric prototype being appropriate for practical use, the utilization of recycled silk fibers adding value to fashion textile products, and the possibility of generating entrepreneurial interest. This indicates that the development of fabrics from silk scraps and the prototype design fully address functional, aesthetic, and sustainability challenges, while also being ready for future commercial production.

Table 4: Test results of fabrics made from recycled silk fibers (3 samples)

Fabrics made from recycled silk fibers.	Recycled silk fibers for the weft + 100% pure silk for warp	100% pure silk for the weft + recycled silk fibers for the warp	Recycled silk fibers for the weft + recycled silk fibers for the warp
Dimensional changes after washing (ISO 5077 / ISO 6330)	Warp-1.5%, Weft-4.0%	Warp-0.5%, Weft-7.0%	Warp-0.5%, Weft-2.0%
Tensile strength (ISO 13934-2)	Warp 220 N, Weft 440 N	Warp 130 N, Weft 640 N	Warp 140 N, Weft 220 N
Color fastness to washing (ISO 105-C10)	Color Change 4–5, Bleeding 4–5	Color Change 4–5, Bleeding 3–5	Color Change 4, Bleeding 2–5
Color fastness to light (ISO 105-B02)	> 4	> 4	> 4

The results in Table 4 showed that all three woven fabric samples made from recycled silk fibers had physical properties that satisfied international standards and could be developed into fashion textiles for clothing and apparel. All samples showed acceptable shrinkage rates in both warp and weft directions after washing, indicating their ability to retain their shape after use and maintenance.

The tensile strength of fabric made with 100% pure silk for either the warp or the weft was higher than that of fabric made with recycled silk fibers for both the warp and the weft, which had a slightly lower tensile strength but was still adequate for use in clothing and other fashion items.

4.6 Discussion of main results

The findings indicate that silk waste may be effectively reused to make yarn and fabric, minimizing the need for virgin raw materials and promoting the circular economy's maximization of resource value (Ellen MacArthur Foundation, 2017). Despite the fact that recycled fibers are inherently weaker than short fibers, blending them at a ratio of 20% offers the best balance for spinning and weaving, which is in line with research showing that yarn stability depends on blending recycled and new fibers.

The design concept of integrating recycled materials with cultural heritage is supported by the development of woven patterns using contemporary Thai techniques such as twill, overshot, and inlay, which create a distinctive surface character and reflect local wisdom in a contemporary way (Phrakhruphrapatsuthadham, 2017; Community Development Department, 2024). This is consistent with the idea that “material storytelling” increases the perceived value of sustainable fashion products.

The expert evaluation showed that the prototype collection was highly suitable in terms of creativity, materials, and commercial potential. This is in line with the behavior of sustainable fashion consumers who place a high value on recycled materials and transparent production methods (Jair_NBS, 2023; Kwok-pan et al., 2019). Thus, a design guideline that satisfies the demands of the modern market was created by combining highlights from Collection 2 and Collection 3.

In conclusion, the findings demonstrated that silk scraps may be transformed into valuable design materials and easily integrated into Thai handicrafts. This is consistent with the regenerative textile systems framework, which prioritizes the regeneration of local economies and values.

5. CONCLUSION AND FUTURE WORK

This study showed that silk scraps can be recycled into fibers and transformed into eco-friendly, sustainable fashion products. The ideal blended yarn formula was 50% cotton, 30% R-PET, and 20% silk waste, as it could maintain the distinctive character of Thai silk while providing sufficient strength for industrial production. Contemporary Thai weaving techniques gave recycled materials a new significance and improved their aesthetic value. Meanwhile, the resulting collection design was highly satisfactory and shows strong potential for commercialization, especially the incorporation of ideas from Collections 2 and 3, which effectively convey sustainability through materials and craftsmanship.

In order to encourage the industrial application of this material, future research should focus on these three areas: (1) physical properties testing in accordance with international standards to confirm the material's availability; (2) development of fiber modification technologies to increase the proportion of recycled silk; and (3) design of a community-based supply chain system that connects fiber producers, weavers, and entrepreneurs in order to create a sustainable circular economy and expand the use of recycled materials in the whole Thai fashion industry.

In the current experimental prototype stage, the production cost per unit is approximately 30–50% higher than conventional materials. This increase is primarily due to the additional processing costs required to transform industrial silk waste into high-quality recycled fibers before they can be woven into new textiles. Furthermore, the limited production volume during this stage limits the benefits of economies of scale. However, these costs are expected to decrease significantly as processing technologies become more efficient and production scales up to industrial levels. Despite the higher initial cost, this material offers greater economic value by creating high-value upcycled products while delivering long-term sustainability benefits for the fashion industry.

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DECLARATION

1. Conflict of interest

The authors declare no conflict of interest.

2. Generative AI and AI-assisted technologies in the writing process

Generative AI and AI-assisted technologies were used in a limited capacity to support language editing and clarity improvements during manuscript preparation. The authors reviewed, revised, and finalized all content, taking full responsibility for the accuracy, integrity, and originality of the work.

3. Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. All datasets have been anonymized to ensure that no identifying information of participants is disclosed.

4. Ethics statement

This study was approved by the Srinakharinwirot University Human Research Ethics Committee (Approval No. SWUEC-672647). All participants provided written informed consent before participating in the study.

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6. Contributor Role Taxonomy (CRediT)

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