Investigation of Thermo-Physiological Comfort Characteristics of Knitted Fabrics Made from Regenerated Cellulose and Nylon Blended Mélange Yarn

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Abstract

This study investigates the comfort characteristics of mélange fabrics made from Tencel, Modal, Ecovero, and Bamboo fibers, each blended with 20% virgin nylon. The comfort properties of regenerated cellulosic fiber-blended mélange fabrics were evaluated by analyzing various parameters, including moisture management, breathability, hand feel, and thermal properties. Dimensional stability, spirality, pilling, and bursting strength were also examined to assess the physical performance of the fabrics. The experimental results revealed that Tencel-blended mélange fabric demonstrated superior comfort properties, offering better moisture management, breathability, hand feel, and thermal properties. Additionally, Tencel-blended mélange fabric showed higher bursting strength and optimal levels of dimensional stability and spirality compared to other regenerated cellulosic fiber-blended mélange fabrics. These findings underscore the suitability of Tencel-blended mélange fabrics for applications requiring excellent breathability, moisture management, and durability. The comprehensive analysis of various fabric blends provides valuable insights for optimizing fabric properties for specific end uses.

1. Introduction

Regenerated cellulosic fibers were created by dissolving cotton linters, wood pulp, or cellulose base material in various aqueous chemical solutions followed by wet-spinning and multi-roller drawing process [1][2]. The preparation of fiber making technique has three phases, namely Dope preparation (I), coagulation II, and post-treatment (III). Regenerating cellulose fiber is problematic due to environmental concerns. The viscose method, invented over a century ago, is the oldest technology for creating regenerated cellulose fibers like rayon. Alternative approaches have been developed over time to shorten processing processes and limit hazards. The N-methyl morpholine-N-oxide (NMMO) technique is preferred over the viscose process due to its safer byproducts [1]. Nowadays, 7% [3], of regenerated fibers are presently employed, indicating significant potential for textile garment applications. Regenerated cellulosic fibers including viscose Modal, Bamboo, and Tencel, are highly valued for their textile and environmental characteristics. Conventional viscose, Modal, Bamboo, and Tencel fibers have identical chemical makeup but differ in structure due to production procedures [4]. Even if the chemical composition of new lyocell, modal, and conventional viscose fibers is the same, their production conditions and methods result in variations in the fibers' structure and characteristics. The molecular (degree of polymerization, molecular mass) and supermolecular structure (crystallinity, amorphousness, dimensions) influence the mechanical properties of different regenerated cellulosic fibers [5].

Tencel is one of the most popular among them because it is very absorbent, with a distinct nano-fibril structure and smooth surface [6]. Tencel fibers offer exceptional comfort due to their nanostructure. The structural elements allow for high water absorptivity provide high heat capacity and balance impact for thermoregulation [7]. Another most demanding regenerated fiber is Modal. Modal is a modified viscose with improved wet strength, comfort, fine luster, smoothness, wicking, and performance properties such as strength and modulus. The fabric is soft, cool, and breathable, with a high gloss and moisture absorption. In addition, it has anti-UV and natural antibacterial properties [3]. Ecovero fiber varies from the other regenerated fiber. It might be connected to the special manufacturing method of Ecovero fibers [8]. Lensing AG, a leader in sustainable fiber manufacturing, manufactures EcoVeroTM from wood pulp-based fibers, which use less water and emit fewer emissions than generic viscose production [9]. Bamboo fiber is now being used in textile products. Bamboo fiber, a plentiful and inexpensive natural resource, is regenerated from the plant. Bamboo fiber is made from pulp collected from the Bamboo stem and leaves by wet spinning. The process involves hydrolysis, alkalization, and multi-phase bleaching, similar to viscose rayon fiber [10][11]. Regenerated Bamboo fibers exhibit higher tensile strength, UV protection, antibacterial and biodegradable qualities, high moisture absorption, softness, brightness, and flexibility under compressive loads. Regenerated Bamboo cellulose fiber is highly moisture-absorbing, breathable, and quick-drying, making it ideal for a variety of applications [12].

Vortex spinning is a new spinning technology that creates yarns with a characteristic layered structure, consisting of untwisted fibers in the middle and helically coiled fibers in the outer layer [13]. Vortex yarn and textiles have distinctive features that provide benefits over traditional yarn spinning processes, such as minimal hairiness and great performance features including superior moisture absorption and dispersion, rapid drying, and long-lasting performance [14][15]. Also, the yarn and fabric which is produced from Vortex well renowned for their outstanding pilling resistance, exterior look, and printability, opening up new product development possibilities in the fashion industry. The Murata MVS 810, the first vortex-spinning machine, was launched at the Osaka International Textile Machinery Show (OTEMAS'97). The machine has a delivery pace of up to 400 meters per minute. The MVS 81T machine is an enhanced version that produces twin vortex-spun yarn [16].

The fabric requires comfort properties which are primarily determined by its thermal qualities. Heavy actions cause the body to generate heat energy and raise its temperature. The body cools itself via perspiring fluids and vapor form. When sweat evaporates into the atmosphere, body temperature decreases. Garments should enable sweat to flow through for maximum comfort. Factors to consider for comfort properties are fiber type, spinning technology, yarn count, twist, hairiness, fabric thickness, cover factor, porosity, and finish [17]. Another important requirement is the breathability of the fabric. The air permeability of a cloth determines its capacity to transmit air effectively. Fiber characteristics, yarn hairiness, diameter, twist factor, linear density, knitting structure, course, and wale settings, and finishing treatments significantly impact airflow through the cloth. The fabric's high air permeability promotes breathability and comfort [18]. As also in a fabric's water vapor permeability also refers to its capacity to transport vapor from the body [11]. If the moisture resistance is too high to transmit heat by mass transport, and the thermal resistance of the textile layers evaluated by us is high, the stored heat in the body cannot be discharged, causing an unpleasant sensation [19]. Moisture control is crucial in athletics and uniforms to keep skin dry and comfortable. It refers to a fabric's capacity to move moisture from the skin to the outside surface of a garment in many dimensions. It is a crucial performance criterion for modern textiles used in a variety of applications [20]. Handle is another important parameter that affects the end product's appearance. Handle is affected by different types of parameters such as; raw material, yarn properties, fabric properties, etc. [21]. Fabric quality, including comfort, style, and look, is crucial for textile items. Handle qualities, including circular bending stiffness and friction coefficient, affect the cloth hand feel. The subjective handling test is also linked [22].

This study aims to determine the comfort characteristics of regenerated cellulosic fiber blended mélange fabrics made from Tencel, Modal, Ecovero, and Bamboo fibers, each blended with 20% virgin nylon fiber.

2. Materials and Methods

2.1 Materials

This study used Tencel, Modal, Ecovero, and Bamboo fibers from Birla Jingwei Fibre Co Ltd, China, as host fibers, while 100% virgin nylon from PT. Indorama Polychem, Indonesia, served as the mélange fiber. As outlined in Table 1, the fiber properties include linear density indicating fineness, tenacity showing breaking strength, and cut length representing staple length of the fibers. Ensuring proper blending, both fiber types were selected with the same fineness and staple length. Figure 1 depicts the various regenerated cellulosic fibers used in this research, providing a visual context for their characteristics and aiding in understanding their blending behavior.

Table 1
Fiber specifications

Parameters	Tencel	Modal	Ecovero	Bamboo
Linear density (dtex)	1.2	1.2	1.2	1.2
Tenacity (cN/tex) [23]	36	35	30	21
Cut length (mm)	38	38	38	38
Fiber density (gm/cm^3)	140	149	144	143
Moisture regain (%) [24]	13	11	11	11
Elongation (%)	8.7 ± 1.6	10.4 ± 1.8	9.6 ± 1.7	10.5 ± 1.5

2.2 Methodology

2.2.1 Blow-room mixing

The production process of mélange yarn in this study involved several key steps. Initially, a fiber blend consisting of 80% regenerated cellulosic fiber and 20% colored nylon fiber was prepared, with a total of 20 kg of fiber used for each mixing. To ensure uniform fiber distribution, the fibers were thoroughly mixed in a clean environment before being fed into a manual bale opener. The manual bale opener enhanced the blending process, preparing the fibers for the subsequent carding machine.

Table 2
Blow-room mixing plan

Parameters	Blend Ratio (Regenerated cellulose + Nylon)							
Fiber	Tencel	Nylon	Modal	Nylon	Ecovero	Nylon	Bamboo	Nylon
Fiber percentage	80%	20%	80%	20%	80%	20%	80%	20%
Total Mixing	100%		100%		100%		100%	

2.2.2 Manufacturing of mélange yarn

The blended fibers were then processed through a series of machines. The blend was first carded using a Trützschler TC 11 carding machine from Germany to produce card sliver. Following carding, Rieter SB D 15 and Rieter RSB D 45 were used to produce a uniform drawn sliver. The finished drawn sliver was directed to a Muratec Vortex 870 machine from Japan to produce mélange yarn.

After spinning, the yarn underwent stabilization by conditioning it in a controlled environment using a yarn conditioning chamber set to a temperature of 45°C and a vacuum of 90% for 45 minutes. This conditioning process eliminated residual stresses in the yarn and stabilized the twist, resulting in improved tensile strength, enhanced evenness, and reduced hairiness.

Table 3
Types of machinery, parameters, and set value

Machine Parameters	Carding	Breaker Draw Frame	Finisher Draw Frame	Vortex Machine
Brand name	Trützschler TC 11	Rieter SB D 15	Rieter RSB D 45	Muratec Vortex 870
Country of origin	Germany	Switzerland	Switzerland	Japan
Roller gauge mm	---	44 × 48	44 × 48	---
Doubling/ Input sliver	---	6	5	60 gr/yd.
Sliver Grain/ Count	80 gr/yd.	80 gr/yd.	60 gr/yd.	30 Ne
T.D.R.	---	---	---	191
Spindle type	---	---	---	Medium(M)
Nozzle pressure	---	---	---	0.50 MPa
Speed	50 Kg/hr.	700 m/min	550 m/min	450 m/min

2.2.3 Manufacturing of fabric

The mélange yarn was then used to knit single jersey fabric on a Mayer & Cie single jersey knitting machine. The machine model, MV 4-3.2 II from Germany, featured a 610 mm cylinder diameter, operated at 20 rpm, contained 1800 needles (Gauge 24), and had 78 feeders. Following knitting, the fabrics underwent a standard wash in a spun oil washing machine with mild detergents. The final step involved a finishing treatment using 60 g/l of Tubingal 9270 hydrophilic softening agent at 130°C for 20 minutes at a speed of 16 m/min on a starter machine. All washing and finishing agents were sourced from CHT Bangladesh Pvt. Ltd.

2.3 Characterization of yarn and fabric testing of methods

Maintaining a consistent ambient temperature is vital for yarn production, as it significantly affects the quality of the final product. Throughout this study, temperature and relative humidity (RH%) were meticulously controlled at all stages to ensure optimal yarn formation, as detailed in Table 4.8. Before testing, all samples were conditioned according to ISO 139 standards. The tests were then performed in a laboratory environment with standard testing conditions of 65 ± 2% relative humidity and 20 ± 2°C temperature.

Following the ASTM D1425 (2020) standard, the Uster® Tester 6 from Uster Technologies in Switzerland was used to measure the coefficient of mass variation (CVm%), thick places, thin places, and hairiness of the mélange yarns at a testing speed of 400 m/min. For data analysis, the sensitivity thresholds for thick places (+ 50%) and thin places (-50%) per 1000 m of yarn were applied. The tensile properties of the mélange yarns, produced by all regenerated cellulosic fibers, were measured using the TENSOLAB-4 from MesdanLab Strength Tester in Italy. This testing was conducted with a constant rate of extension principle according to EN ISO 2062:2009, utilizing a 50 N load cell, a sample length of 500 mm, and a clamp speed of 500 mm/min.

Table 4
Ambient condition of different spinning sections

Ambient Condition	Blow-room	Carding	Draw frame	Vortex
Temperature °C	30	32	34	28
RH%	52	50	50	65

Before performing all the tests, the samples were conditioned in a controlled setting with a temperature of 20 ± 2°C and a relative humidity of 65 ± 2%, following the specifications of ASTM D 1776 (2004).

The fabric's wicking properties were evaluated using the strip test method according to TM 9 standards, with samples sized 20 × 2.5 cm, and the results were measured in centimeters of wicking height. The fabric's water vapor evaporation rate was determined following TM 10 standards. Initially, the fabric was conditioned at 20 degrees Celsius and 65% relative humidity (RH) for 16 hours to achieve standardized moisture content. To begin the test, a fabric sample measuring 100 cm^2 was carefully cut and weighed (W_1). Then, 1 ml of distilled water was added to the sample, and the sample was reweighed (W_2) to determine the initial moisture content. The sample was subsequently subjected to drying conditions at 20 degrees Celsius and 65% RH for 30 minutes. After the drying process, the sample was weighed again (W_3) to determine the residual moisture content. By comparing the initial and final sample weights, the fabric's water vapor evaporation rate was calculated. using Equation iii.

Evaporation rate (%) = $\frac{W_2 - W_3}{W_2 - W_1} \times 100$ .... (iii)

Water absorbency was assessed following the methodology outlined by Mukhopadhyay et al. [25].

The fabric's air permeability was assessed using the FX 3300 LabAir IV from Switzerland following ASTM D737 standards. The water vapor transmission rate (WVTR) via the Cup Method was determined following the guidelines outlined in the ASTM E96 Standard. To evaluate the fabric's hand feel, including compression, bending, and friction, the Fabric Touch Tester DW 262 from China was utilized. It's important to note that there is currently no universally established standard for this evaluation. Hence, the test was conducted based on the instructions provided by the supplier. Fabric samples measuring 50 × 5 cm were cut along the wale, course, and diagonal (45° angle) directions. These samples were then positioned beneath the measuring head of the instrument for evaluation. Fabric thermal properties were assessed following the ASTM D1518 standard using the Thermal Guarded Hot Plate YG606D machine.

Dimensional Stability was evaluated according to the ISO 6330:2021 standard, Spirality was assessed following the ISO 16322-2:2021 standard, pilling resistance was determined using the ISO 12945-2:2000 standard, GSM (Grams per Square Meter) was measured in accordance with the BS EN 12127:1998 standard, and Bursting strength was tested using the James Heal TruBurst Bursting Strength Tester, following the ISO 13938-2:1999 standard.

Wales per centimeter and courses per centimeter were measured following ASTM D-3887 standards, along with stitch density and stitch length according to TS EN 14970 (2006). Areal density measurements adhered to ASTM D 3776 standards. Fabric thickness was assessed using an SDL digital thickness gauge in compliance with ISO 5084 standards. Table 4.7 contains detailed fabric specifications. Before measuring the structural properties, the finished fabric was conditioned for 24 hours in an environment maintained at 20 ± 2°C and 65 ± 2% relative humidity, as per ASTM D 1776 (2004).

Equations (I and ii) [26] were used to calculate the tightness factor and porosity of the fabric, respectively.

Tightness factor (K) = $\frac{\sqrt{tex}}{l}$ .... (i)

Where l is the stitch length in cm.

Porosity (%) = $[1 - \frac{\text{Density of fabric}(g/cm^3)}{\text{Density of fibre}(g/cm^3)}] \times 100$ .... (ii)

Where the density of fabric (g/cm^3) = $\frac{\text{Fabric weight } (g/cm^2)}{\text{Fabric thickness(cm)}}$

Table 5
Specification of the fabrics

Parameters	TNMF	MNMF	ENMF	BNMF
Wales/cm	14.2	14.8	14.4	14.8
Course/cm	20.4	19.8	20	19.4
Stitch density (cm^2)	289.68	293.04	288	287.12
Stitch length (mm)	2.69	2.674	2.66	2.67
Tightness factor	16.494	16.592	16.680	16.617
Areal density (gm/cm^2)	0.014	0.0149	0.0144	0.0143
Fabric thickness (cm)	0.0371	0.0405	0.0398	0.0389
Porosity (%)	99.730	99.753	99.749	99.743

3 Results and Discussion

3.1 Yarn properties analysis

The coefficient of variation (CV%), thin places, thick places, neps, hairiness, and count strength product (CSP) are significantly influenced by the inherent characteristics of the fibers used in this study, namely Tencel, Modal, Ecovero, and Bamboo. Tencel fibers, exhibited high strength, contributing to higher CSP values in Tencel blended mélange yarn. Additionally, Tencel blended mélange yarn demonstrated a lower coefficient of variation, fewer thick and thin places, fewer neps, and reduced hairiness compared to other regenerated cellulosic fiber blended mélange yarns, as shown in Table 6. These findings indicate that Tencel-blended mélange yarn exhibits superior yarn quality.

Table 6
Properties of yarn

Parameters	TNMY	MNMY	ENMY	BNMY
Coefficient of Variation (CV%)	13.09	13.09	14.69	15.48
Thin place − 50%	5.0	8.0	25.0	33.0
Thick place + 50%	11.0	20.0	51.0	88.0
Neps + 200%	25.0	30.0	25.0	47.0
Hairiness	2.60	2.76	2.63	3.05
Count Strength Product (CSP)	2760	2755	2130	1950

Figure 1 presents an optical image of regenerated cellulose blended mélange fabric. Figure 1 (a) shows that the colored nylon fiber content is higher than in all other regenerated cellulose blended mélange fabrics studied in the research. This increased presence of colored nylon fibers enhances the mélange appearance of the fabric, and also indicating superior interaction between Tencel and nylon fibers.

3.2 Moisture management analysis

Moisture management properties refer to a material's ability to absorb, wick, and release moisture, ensuring the wearer stays dry and comfortable by effectively regulating sweat and humidity [27]. These properties are crucial for comfort, especially in active or warm environments.

The impact of different fiber compositions on drying characteristics was examined in Fig. 2 (a). The results reveal that fabrics made from Tencel-blended mélange yarn exhibit a lower drying rate compared to mélange fabrics blended with Modal, Ecovero, and Bamboo. The variation in fabric drying rate is attributed to the moisture regain percentages of the regenerated cellulosic fibers. Tencel fiber has a higher moisture regain compared to other regenerated fibers, resulting in a longer evaporation time [28]. Furthermore, Fig. 2 (b) shows that the water absorbency of all four types of regenerated cellulosic fiber-blended mélange fabrics is similar. Additionally, Fig. 2 (c) illustrates that Tencel-blended mélange fabric exhibits a higher wicking height in the course-wise direction compared to mélange fabrics blended with Modal, Ecovero, and Bamboo. However, the study found that the wicking height in the wale-wise direction was consistent across all four fabric types. This is attributed to the physical structure of the regenerated cellulosic yarn. Tencel-blended mélange yarn exhibits a more even surface, as shown in Table 6, allowing for less interrupted capillary action compared to other regenerated cellulosic blend fabrics [29]. The error bars in the above figures represent the standard deviation of the results.

3.3 Breathability analysis

Breathability analysis determines a fabric's ability to facilitate the movement of air and moisture through its structure, thereby assessing its capacity to maintain comfort and regulate temperature [30].

Figure 3 (a) illustrates that the Tencel-blended mélange fabric exhibits significantly higher air permeability than the other mélange fabrics blended with Modal, Ecovero, and Bamboo. This increased air permeability suggests that the Tencel blend mélange fabrics allow more air to pass through the fabric, enhancing breathability and comfort. This distinction is attributed to the contrasting physical structures of the fabrics. Specifically, Table 5 indicates that the Tencel-blended mélange fabric has a lower tightness factor and reduced fabric thickness, likely contributing to this result. Furthermore, Fig. 3 (b) demonstrates that the water vapor transmission rate (WVTR) remains relatively consistent across all four regenerated fiber-blended mélange fabrics. This consistency implies that, despite variations in air permeability, these fabrics exhibit almost similar capabilities in allowing moisture vapor to pass through, ensuring effective moisture management and comfort [31][32]. It is important to note that the error bars in Fig. 3 were derived from the standard deviation, providing a measure of variability and reliability in the data.

3.4 Hand feel analysis

Hand feel is the tactile sensation or touch experienced when fabric comes into contact with the skin, encompassing various sensory perceptions such as bending, compression, friction, and tension [33]. The Fabric Touch Tester DW262 (China) was employed to evaluate the fabric's compression average rigidity (CAR), bending average rigidity (BAR), and surface friction coefficient (SFC). This assessment provided indices for softness (SF), stiffness (ST), and smoothness (SM), each rated on a five-point scale.

In this study, Fig. 4 (a) demonstrates that the compression average rigidity (CAR) of Tencel-blended mélange fabrics is lower, and Fig. 5 shows that the softness (SF) index is higher compared to other mélange fabrics blended with Modal, Ecovero, and Bamboo. This indicates that Tencel-blended mélange fabrics are more compressible and have a softer hand feel than other regenerated cellulosic fiber blended, mélange fabrics, this is attributed to their lower thickness.

Additionally, Figs. 4 (b) and 5 reveals that the bending average rigidity (BAR) and stiffness (ST) index of Bamboo-blended mélange fabrics are lower compared to those blended with Tencel, Modal, and Ecovero. This suggests that Bamboo-blended mélange fabrics are more pliable and conform better to the body, due to the inherently lower stiffness of Bamboo fibers, which is directly reflected in the fabric's properties. Furthermore, fabrics made from Tencel-blended mélange yarn exhibit a lower surface friction coefficient (SFC) and a higher smoothness (SM) index, as represented in Figs. 4 (c) and 5, compared to fabrics produced from other regenerated cellulosic fiber blended yarns. This indicates that Tencel-blended mélange fabric has a smoother hand feel, attributed to the lower coefficient of variation (CV%), minimal thick and thin places, lower neps percentages, and reduced hairiness of the yarn. Error bars in the figures were determined based on the standard deviation of the results.

3.5 Thermal properties analysis

Thermal properties refer to the characteristics of a material that determine how it responds to heat, including its ability to conduct, retain, and dissipate heat. These properties influence a material's insulation capabilities, heat resistance, and thermal comfort [34].

Figure 6 illustrates that Tencel-blended mélange fabrics exhibit lower insulating capacity compared to those made from other regenerated cellulosic fiber blended mélange fabrics. This is evident from the lower thermal resistance shown in Fig. 6 (a) and the lower CLO value in Fig. 6 (b). Fabrics with lower insulating capacity are advantageous in warm climates, for active wear, and in scenarios where breathability, moisture management, and temperature regulation are essential for comfort and performance. Furthermore, Fig. 6 also demonstrates that Tencel-blended mélange fabrics exhibit higher heat transfer capacity compared to other regenerated cellulosic fiber blended mélange fabrics. This is shown by both the higher thermal conductivity in Fig. 6 (a) and the higher thermal transmittance value in Fig. 6 (b). Fabrics with higher heat transfer capacity offer benefits in cooling, moisture management, thermal comfort, health and safety, and performance. They are particularly useful in active wear, hot climates, and layered clothing systems, where maintaining a comfortable and stable body temperature is crucial. This difference can be attributed to the distinct physical structures of fabrics. The lower tightness factor and reduced fabric thickness of Tencel-blended mélange fabrics are responsible for their lower insulating capacity and higher heat transfer capacity compared to other regenerated cellulosic fiber blended mélange fabrics[3][35]. The error bars in Fig. 6 were derived from the standard deviation.

Table 7
Physical properties of fabrics

Parameters	**80% Tencel, 20% Nylon**			**80% Modal, 20% Nylon**			**80% Ecovero Viscose, 20% Nylon**			**80% Bamboo viscose, 20% Nylon**		
Dimensional Stability, %	1st wash	3rd wash	5th wash	1st wash	3rd wash	5th wash	1st wash	3rd wash	5th wash	1st wash	3rd wash	5th wash
	L: -10.5 W: -5.7	L: -10.7 W: -5.8	L: -11 W: -6	L: -9.5 W: -2	L: -9.7 W: -2.7	L: -10 W: -3	L: -10.5 W: -5.5	L: -10.7 W: -5.8	L: -11 W: -6	L: -11.5 W: -4.5	L: -11.7 W: -4.7	L: -12 W: -5
Spirality (%)	0.5	0.7	1	2.8	2.7	3	0	0	0	0	0	0.5
Pilling	4–5			4–5			4–5			4–5		
GSM	140			149			144			143		
Bursting Strength	464.5			379.2			356.6			335.2		

The fabric properties in this study were derived from blends of Tencel, Modal, Ecovero, and Bamboo fibers with 20% virgin nylon. Dimensional stability after washing is a crucial parameter for fabric performance properties. Among the blends, Modal-blended mélange fabric exhibited the lowest shrinkage values in both length and width directions, as well as the highest spirality, as shown in Table 7. These findings indicate that Modal-blended fabric maintains better dimensional stability while demonstrating more spirality compared to other regenerated cellulosic blends [36]. Pilling resistance was consistently rated across all fabric types, with a pilling grade of 4–5, indicating good resistance to pilling for all blends. The fabric areal density and thickness are significantly influenced by the fiber density and yarn properties. Among the blends, Modal-blended mélange fabrics exhibited the highest areal density. This is attributed to the higher fiber density of Modal-blended mélange fabrics compared to other regenerated cellulosic fiber-blended mélange fabrics. Evaluating the bursting strength is essential for determining the strength and durability of knitted fabrics [37]. In this study, Tencel-blended mélange fabric exhibited the highest bursting strength compared to other regenerated fiber-blended mélange fabrics, as shown in Table 7. This superior performance is attributed to the high strength of the Tencel-blended mélange yarn (Table 1), which directly enhances the overall fabric strength. Furthermore, Fig. 1 indicates that Tencel-blended mélange fabric contains a higher proportion of nylon fiber, which also contributes to the higher bursting strength of the Tencel-blended mélange fabric.

4 Conclusion

This research comprehensively evaluated the comfort and performance characteristics of mélange fabrics made from Tencel, Modal, Ecovero, and Bamboo fibers, each blended with 20% virgin nylon. The study's findings indicate that Tencel-blended mélange fabrics exhibit superior comfort properties, including enhanced moisture management, breathability, hand feel, and thermal performance. These fabrics also demonstrated almost 23% higher bursting strength, optimal dimensional stability, and spirality compared to other regenerated cellulosic fiber-blended mélange fabrics. These insights highlight the potential of Tencel-blended mélange fabrics for applications where breathability, moisture management, and durability are critical. The findings also provide valuable guidelines for optimizing fabric properties for specific end uses, thereby advancing the development of high-performance textile products.

Declarations

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Ethical Approval

Not applicable: this article does not contain any studies with human participants or animals performed by any of the authors.

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Author Contributions

Md. Fazley Elahi: Conceived and designed the experiments, and performed the experiments.

Md Anwar Hossain: Conceptualization, writing the original draft and writing the paper, methodology, analysis, and interpreted the data.

Mohammed Rafin Bhuiyan: Visualization, investigation, and writing the paper.

Habibur Rahman: Visualization, investigation, and writing the paper.

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Mohammad Rafiqur Rashid: Visualization, investigation, writing review & editing, and supervision.

All authors read and approved the final manuscript.

Availability of data and materials

For inquiries or requests related to the data and materials, please contact with the corresponding author.

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Figures

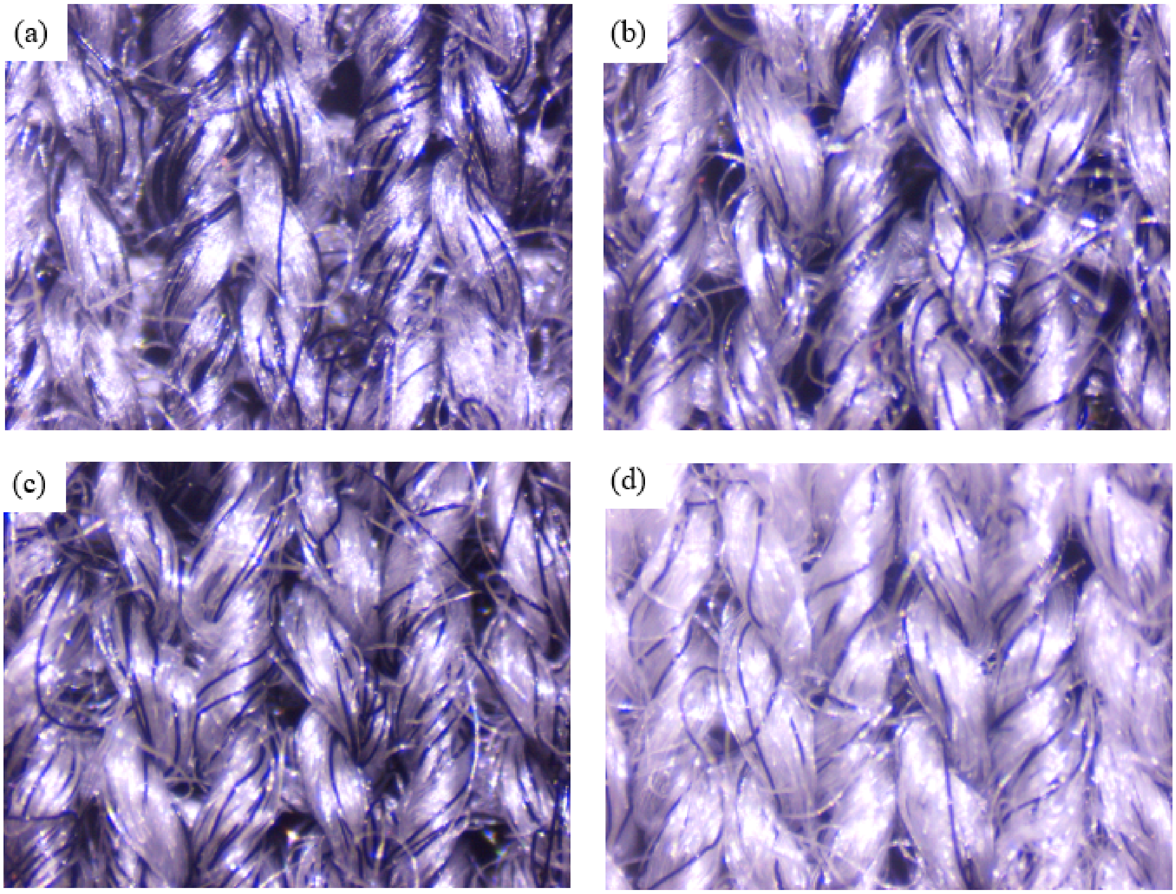

Figure 1

Optical microscopic views (5.5X): (a) Tencel-blended mélange fabric, (b) Modal-blended mélange fabric, (c) Ecovero-blended mélange fabric, and (d) Bamboo-blended mélange fabric

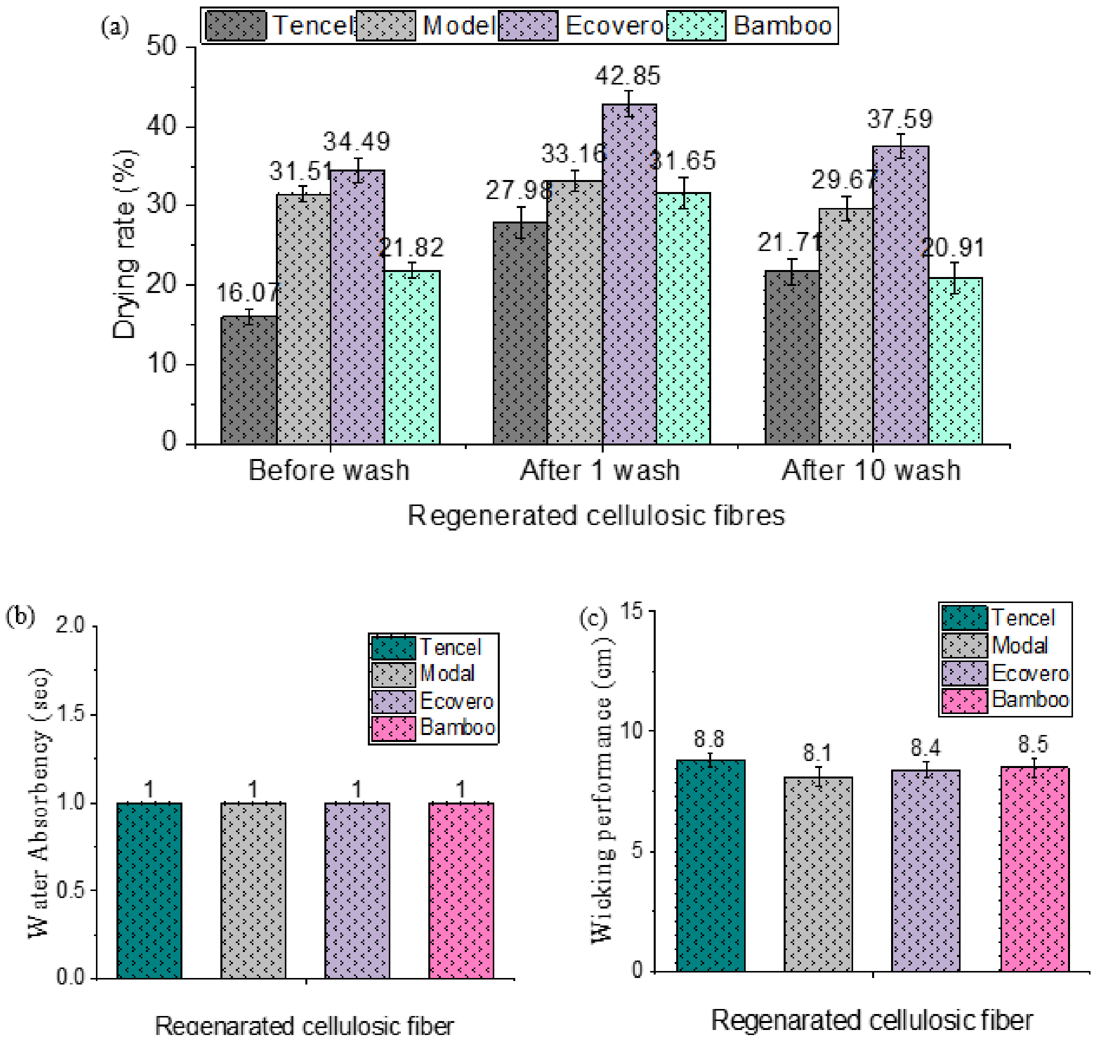

Figure 2

Moisture management analysis of the knitted fabric produced from regenerated cellulose and nylon blended mélange yarn.: (a) drying rate (%), (b) water absorbency (sec), and (c) wicking performance (cm)

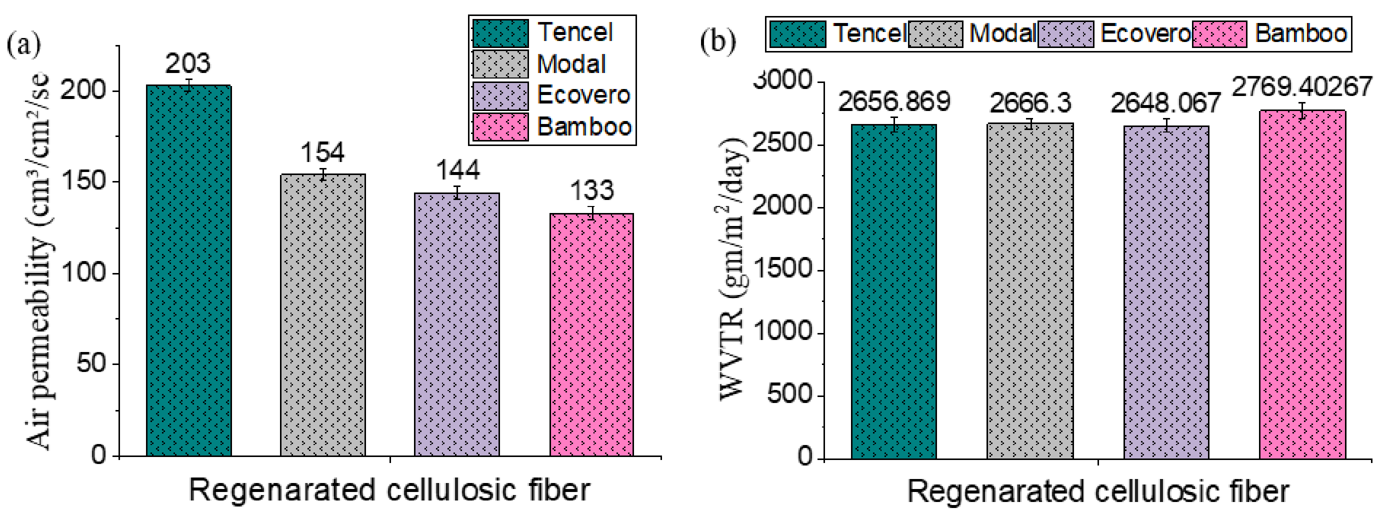

Figure 3

Breathability analysis of the knitted fabric produced from regenerated cellulose and nylon blended mélange yarn.: (a) air permeability values and (b) water vapor transmission rate (WVTR)

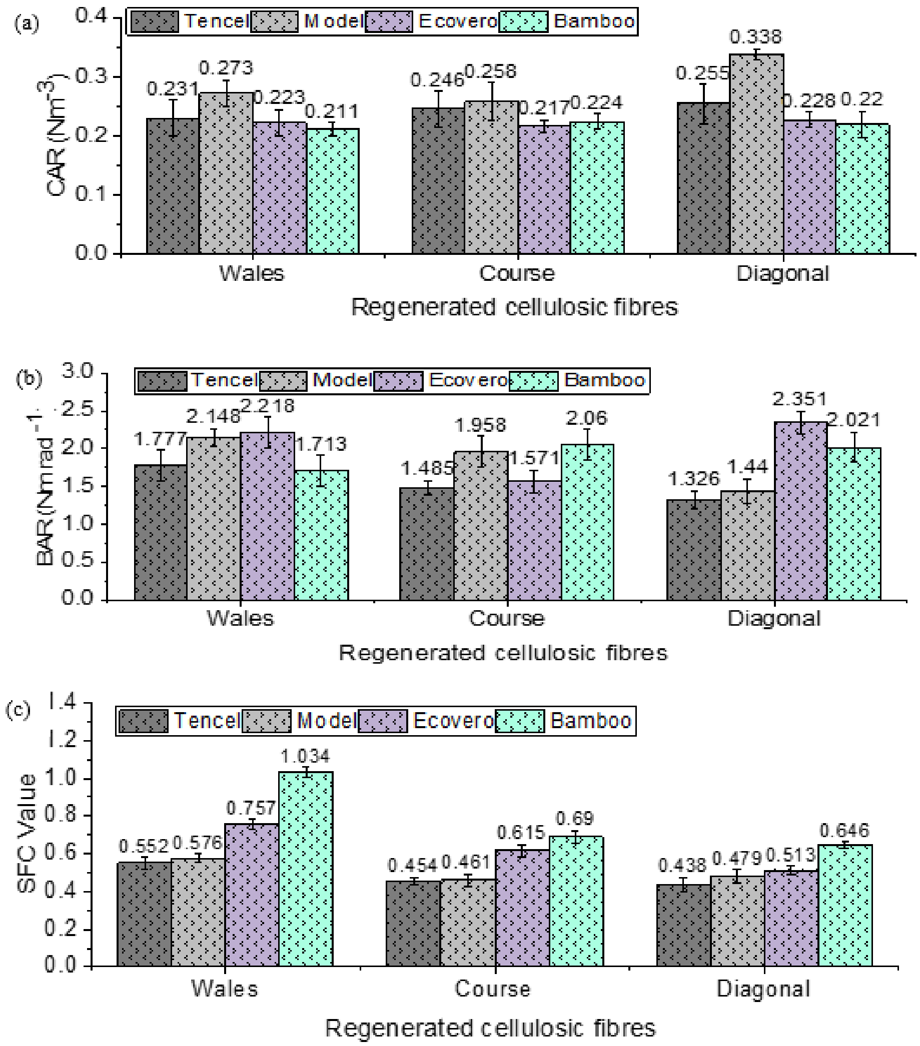

Figure 4

Hand feels analysis of the knitted fabric produced from regenerated cellulose and nylon blended mélange yarn: (a) compression average rigidity, (b) bending average rigidity, and (c) surface friction coefficient

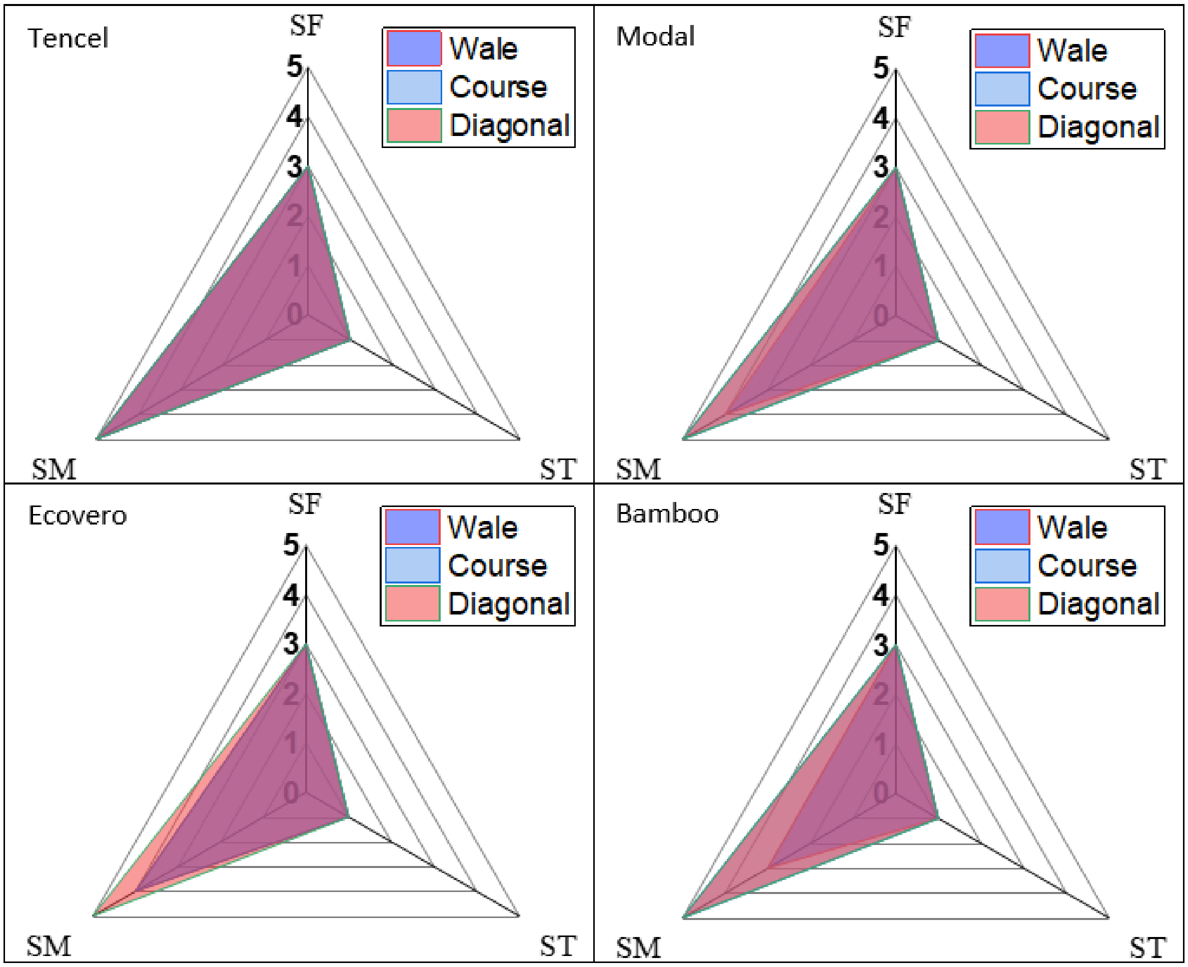

Figure 5

Softness (SF), Stiffness (ST), and, Smoothness (SM) analysis of regenerated cellulose and nylon blended mélange yarn made knitted fabric obtained from Fabric Touch Tester, DW262

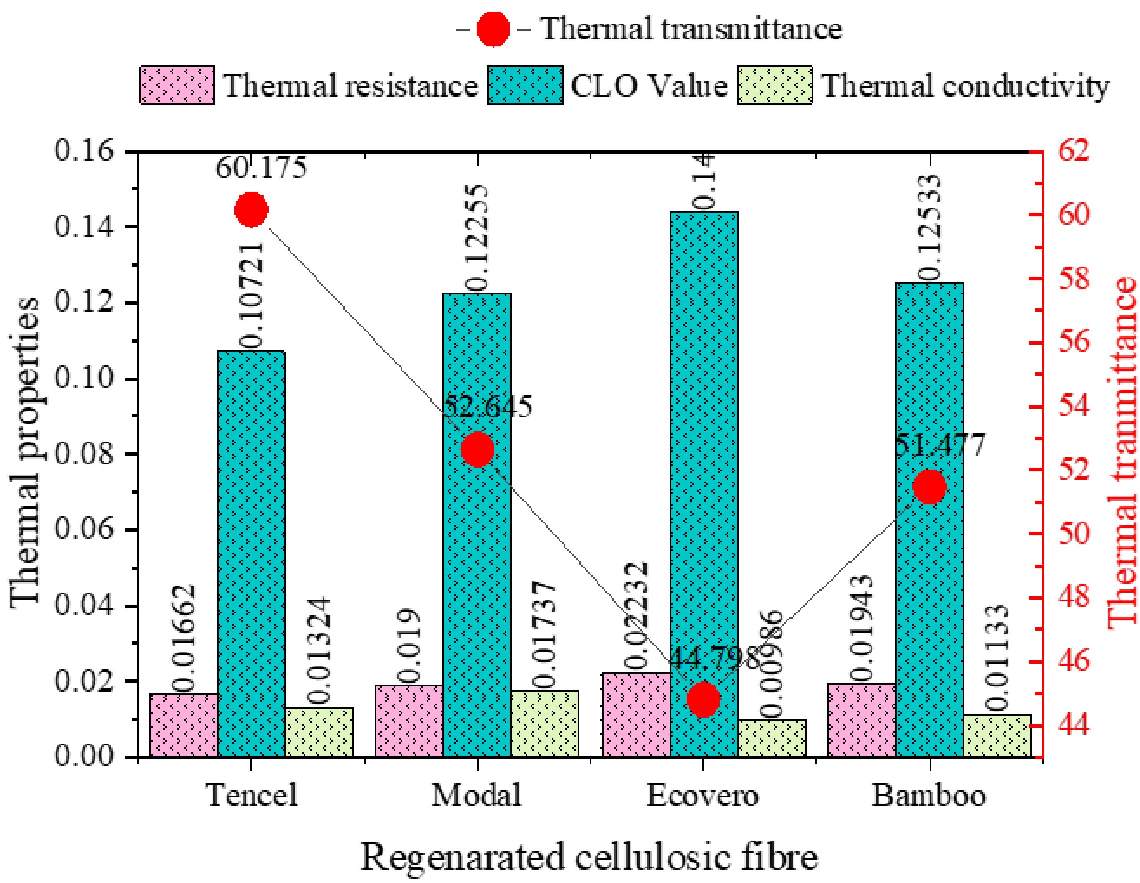

Figure 6

Thermal properties of the knitted fabric produced from regenerated cellulose and nylon blended mélange yarn