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EVALUATING THE THERMAL PROPERTIES OF KNIT FABRIC MADE OF 100% CONVENTIONAL COTTON AND BCI COTTON

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Abstract:

The study discusses research findings on the thermal characteristics of BCI cotton, 100% conventional cotton, and blends with polyester and elastane. The investigation emphasises single-jersey, rib jersey, and single-jersey blend arrangements. The thermal properties of the recommended knitted material configuration were assessed. The results indicate that each fabric composition with a varied structure exhibits distinct thermal characteristics. BCI cotton fabrics have good uniformity and structure due to cultivation compliance, better thermal conductivity, air permeability, and thermal transmittance. They are eventually better for sportswear and summer apparel products. However, it is essential to consider that the other side of both rib and single jersey fabrics made of conventional cotton with less uniformity includes a more significant CLO and thermal resistance value than BCI cotton fabrics, giving a warmer feeling and being more fruitful for winter clothing with better-trapped air and heat. Thermo-physiological comfort is influenced by various factors such as fiber content, yarn quality, fabric finish, structure, and heat and water vapor resistance, which increase with material thickness and air entrapment in the fabric.

Keywords: knit fabric; thermal comfort; thermal resistance; thermal conductivity; air permeability.

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1. Introduction

The textile industry has been going through a major change in recent years, with a noticable shift towards acknowledging apparel's comfort and utilitarianism over its aesthetic appeal. This reflects the industry's persistent dedication to understanding and meeting consumers' ever-changing needs and preferences, emphasizing the critical role that consumer-centric research plays in shaping their approach. (Abhijit Majumdar et al., 2010; Jitendra Ajmeri, 2013).

Comfort, affordability, ease of production, variety of styles, and general appeal have all contributed to knitwear's meteoric popularity in recent years. Knit apparel can meet the standards for good thermal properties, which are increasingly vital in the apparel manufacturing industry. Knitted clothes provide good freedom of movement and marvellous stretching capabilities. They are also well known for their excellent air permeability and thermal conductivity (Çoruh, 2015). Knitted apparel can quickly disseminate the body's vapour, making it suitable for all sorts of apparel, from underwear and sportswear to casual wear. The adaptability and versatility of knitted apparel present an exciting area for exploration and advancement within the textile industry. (Athirah Mansor et al., 2016). A comprehensive study of these products' thermal characteristics is essential for further improving their comfort and performance. Wearable comfort is a complex concept encompassing psychological, sensory, and thermo-physiological elements, focusing on moisture management and thermoregulation (Mazedul Islam et al., 2014; Nilgün Özdil et al., 2006).

Extensive research on the thermal behaviour of textile materials has shown that fibre types, finishing techniques, and fabric structure significantly impact the fabric's thermal comfort properties. Consider the following: the quantity of air entrapped in the fabric structure, the kind of fibres, the yarn characteristics, the thickness of the fabrics, and the impact on heat transmission and moisture management. (Bedek et al., 2011; Nida Oglakcioglu, 2014; S.A. Hosseini Ravandi & Valizadeh, 2011).

With a focus on critical variables, such as thermal resistance, thermal conductivity, and moisture management, this study explores the thermal characteristics of knit clothing. The study was performed in several stages. At first, a comprehensive literature review was conducted to identify the key variables and their potential impact on the thermal performance of knit materials. Subsequently, standardised testing techniques were employed to examine knit fabric samples, encompassing single jersey, 2×2 Lycra rib, single jersey blend with polyester and Lycra constructions. The results obtained from these trials will offer significant knowledge of the impact of various knit structures, fibre compositions, and finishing procedures on the thermal efficiency of the materials. The fibre composition is mainly 100% conventional cotton, 100% BCI cotton, and a blend.

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Cotton cultivation techniques primarily fall into three categories: cultivation of cotton seeds using conventional, organic, and BCI (Better Cotton Initiative) methods. Traditional cotton farming incorporates cotton production using various fertilisers, pesticides, insecticides, herbicides, defoliants, and a significant amount of water. On the other hand, BCI cotton is an encompassing strategy for producing cotton that decisively addresses the three fundamental aspects of sustainability: social, economic, and environmental. BCI cotton offers a significant financial advantage with its potential for higher yields and reduced input costs. By facilitating the sharing of successful strategies, the system aims to inspire more widespread participation in communal initiatives. (Campos & Goyal, 2021; Pragnesh Shah et al., 2018).

Thermal conductivity denotes a fabric's ability to conduct heat through it. It measures how effectively a fabric can transfer heat from hot to cool areas. (Chen et al., 2018). The following equation can express it:

$$\lambda = \frac{h}{CLO\,Value \times 1000 \times 0.155}\ W/m{\cdot}K \tag{1}$$

Where λ = thermal conductivity, h = fabric thickness.

Thermal resistance measures a fabric's ability to restrict heat flow through it. (Mishra et al., 2019). It indicates how difficult it is for heat to pass through a fabric. The following equation can express it:

$$R_t = \frac{h}{\lambda}\ \frac{m^2{\cdot}K}{W} \tag{2}$$

R_t = thermal resistance, h = fabric thickness in meters, λ = thermal conductivity.

CLO value is a measure of fabric's thermal insulation property. It refers to the required amount of insulation for keeping a resting person comfortable at 21°C (70°F) temperature in an ordinarily active state. (Collins & Hoinville, 1980). The following equation can express it:

$$CLO\,Value = \frac{R_t}{0.155}\ \frac{m^2{\cdot}K}{W} \tag{3}$$

Where R_t = thermal resistance.

Thermal transmittance refers to the volume of heat that passes through a one-square-meter area in a stable heat transfer condition in one second. (Buzatu et al., 2017). The following equation can express it:

$$U = \frac{1}{R_t}\ \frac{W}{m^2{\cdot}K} \tag{4}$$

Where U = thermal transmittance, R_t = thermal resistance.

Our investigation reflects a broader scope rather than only comprehending knit apparel's thermal performance. Our goal is to spark creativity and give practical advice to designers and manufacturers by creating explicit connections between physical attributes and the thermal performance of knit apparel. So, our primary focus is to assess the comfort and functionality of knitted apparel in response to the increasing customer need for high-performing, thermally efficient clothes for different climate conditions.

Thermal properties of knit fabrics (single jersey, rib, interlock) have been studied over the years. Initial studies focused on the principle of heat transfer in textiles. J.R. Philip and Daniel developed the theory of combined moisture and heat transfer in porous media in the mid-1950s (Vries, 1987). The influence of thermal properties of clothing on the thermoregulatory responses of humans has been studied since the 1980s (Pascoe et al., 1994), which further strengthens the evidence of clothing's importance in maintaining thermal balance.

The introduction of sophisticated testing and measuring techniques has driven the research on the thermal properties of fabrics. A brief exploration of the thermal insulation properties of fabrics made from natural and artificial fibres was consequently conducted (1, 2, 14, 15). The initiation of sustainability practices and the increasing demand for green factories have inspired and necessitated using regenerated fibres over cotton, given their environment-friendly and better performance properties. This has culminated in a recent study on cellulose-based knitted fabric's thermal properties, aiming to enhance comfort properties (16). Then, the focus shifted towards finding specific thermal properties in knit fabrics for particular climates and situations, such as finding fabrics for cold weather, hot weather, sportswear, etc. Various studies tried to find out the impact of fabric structure (single jersey, rib, interlock), yarn properties (fibre type, yarn count, twist), and knitting parameters (tightness) on the thermal comfort properties. (Abhijit Majumdar et al., 2010; Oglakcioglu & Marmaralı, 2007). Adjusting these parameters can enhance the thermal properties of fabrics.

Fabrics protect the human body from heat and cold, maintaining thermal comfort and decreasing temperature variations. It provides a thermal balance between the body and the environment, benefiting consumers and emergency service personnel (Gu et al., 2017). Heat transfer from the body through fabrics is highly related to the surface characteristics of yarns, capillary structure, and air volume distribution within the fabrics (Stanković et al., 2008). Increased wind or air movement can enhance convective heat loss, reducing the thermal insulation provided by the knit fabric. This is particularly significant for looser-knit structures that allow more air permeability (Das et al., 2007). Higher humidity levels lead to increased thermal conductivity and decreased thermal resistance. It is essential because it impacts the insulation performance of knit fabric (Mishra et al., 2021). During intense physical activity, the fabric absorbs sweat, increasing moisture content and altering thermal resistance by displacing enclosed air with water (Kanat et al., 2014). As knit apparel has effective moisture-wicking properties, it helps to prevent overheating during physical activities and ensures comfort (Li, 2001). The enhanced moisture management capabilities make rib knits more suitable for activewear, as they can keep the wearer dry and comfortable by quickly wicking away sweat (Das et al., 2007). The human body maintains

thermal balance with its environment when heat loss and production are equal. This relationship can be expressed using the following equation:

Heat generation = Heat loss

Or,

$$M - W = C_v + C_k + R + E_{sk} + E_{res} + C_{res} \quad (5)$$

Here, M represents metabolic rate (W/m^2). W stands for external work (W/m^2). C_v, C_k, & R denote heat loss through convection, conduction and radiation (W/m^2). E_{sk} represents heat loss through the skin via evaporation (W/m^2), and E_{res} represents the evaporative heat loss due to respiration (W/m^2). Finally, C_{res} is the sensible heat loss associated with respiration (W/m^2).

In the knit fabric, when the moisture content increases, the ability of the knit fabric's insulating power decreases, resulting in lower thermal resistance. Moisture reduces the thermal insulation value of cloth and alters its moisture characteristics, ultimately impacting fabric comfort. (Garg et al., 2022). The thermal insulation properties of fabrics directly affect the ability to protect against heat (Puszkarz et al., 2020). Moist generated by the body is mostly absorbed by clothes, which in turn increases their weight, making them uncomfortable and negatively impacting human comfort and work (Onofrei et al., 2011). High moisture retention causes discomfort in warm weather as moisture increases fabric weight and causes a clammy feeling in the skin (Slater, 1986). The perception of heat is primarily influenced by perspiration rather than skin surface temperature, as sweating's evaporative cooling effect helps the skin maintain a comfortable temperature. (Bedek et al., 2011).

Single jersey, rib, and interlock - these are the three predominantly used fabric structures for knit fabric. Due to their structures, these three types have distinctive properties. Primarily, the variations in thickness and density of single jersey, rib and interlock fabric structures are responsible for these differences. (Gunesoglu et al., 2005). A study showed the thermal resistance and thermal conductivity values of single jersey fabrics are notably lower than 1×1 rib fabrics and interlock fabrics. On the contrary, interlock fabrics have higher thermal conductivity values than 1×1 rib structures. (Oglakcioglu & Marmaralı, 2007).

Several studies have shown that with an increased knit fabric (single jersey, rib or blend) density, thermal conductivity tends to increase due to reduced air gap. (Gurarda et al., 2018). It was determined that the fabric thickness, the quantity of still air trapped within the fabric structure, and the movement of external air are the primary factors that influence heat transfer through the fabric. (Nawaz et al., 2011). Knitted rib fabric can offer better insulation due to increased air-trapping capability. (Oglakcioglu & Marmaralı, 2007). Variations in yarn twist and ply significantly influence the thermal properties of knit fabrics. Generally, increased yarn twist improves the fabric's density, which further leads to improved thermal insulation because of reduced air permeability. (Hassan et al., 2024). Variations in ply can alter the fabric's structure and surface area, which impacts the thermal conductivity. (Stankovic et al., 2019; Stanković et al., 2022). Fabrics with higher ply counts tend to show better insulation properties, as they trap more air within the yarn structure. (Salopek Čubrić et al., 2022). However, excessive twisting or ply can lead to stiffness, which reduces comfort and wearability.

Double-layer fabrics provide better thermal insulation properties because of the entrapped air between the layers. (Kabir et al., 2023). In contrast, single-layer fabrics normally provide greater breathability and moisture management properties. (Yang et al., 2023). Studies show that a double-layer knit fabric can provide improved comfort by reducing skin-to-fabric contact, which minimises heat buildup. (Maurya et al., 2024). However, the increased insulation may cause overheating during high-activity scenarios. (Subburaayasaran et al., 2022). Similarly, multilayer textile materials exhibit better thermal insulation properties than single-layer ones, depending on the composition and configuration of each layer. (Matusiak, 2006). Types of yarn and the linear density of outer and inner layers affect thermal properties. (Jhanji et al., 2015). The middle layer heavily influences the thermal insulation properties. (Venkataraman et al., 2017). Adding reflective nano-fibrous interlayers with multilayer structures can significantly improve thermal insulation in cold protective clothing. (Sun et al., 2013).

Material type and repeated laundering significantly impact fabrics' thermal properties. Repeated laundering generally increases fabric thickness and thermal resistance while decreasing air permeability. (Demiryürek et al., 2019).

Thermal properties and their values are greatly influenced by the fibre composition of knit fabric. With a single jersey structure, thermal conductivity and thermal resistance of cotton-spandex blended fabrics show a 17% and 47% increase, respectively, when compared to 100% cotton fabrics. (Khalil et al., 2021). In the case of fabrics made from cotton-bamboo blended yarns, as the proportion of bamboo fibres increases, the thermal conductivity of knit fabrics reduces in general. (Abhijit Majumdar et al., 2010). On the other hand, fabrics made with 50% organic cotton and 50% recycled polyester fibres showed thermal resistance and air permeability that is up to par (Marmaralı & Sevgi, 2023). Recycled and eco-friendly cotton decreases air permeability value, provides effective clothing insulation for knit fabrics, and increases the thermal resistance of fabrics. (Necef et al., 2023).

Hollow and crimped fibres give better insulation properties because of their ability to trap more air. On the other hand, round and smooth fibres tend to offer less thermal resistance. (Karaca et al., 2012).

A combination of high linear density polyester fibre and carded yarn can lead to high thermal resistance and low thermal absorptivity. On the other hand, the coarse polyester fibre in the inner layer and combed cotton yarn improve air permeability and moisture vapour transmission. (Jhanji et al., 2015). Anti-bacterial finishing agents increase heat transmittance, air permeability and wetting time with increasing weight. (Ibrahim et al., 2010). Moisture-wicking finishes increase thermal comfort

by increasing moisture management properties and generating better-cooling properties in warm weather. (Jhanji et al., 2018).

Thermal properties of knit fabric with various proportions of blended fibres can be researched to find new fabrics and their suitable uses according to working conditions. The use of phase change materials (PCMs) can be explored further to enhancethe thermal properties of knitted fabrics. Computing models can be developed with the help of artificial intelligence (AI) to improve the design of knitted fabrics for specific requirements. Renewable and biodegradable fibres, such as bamboo, hemp, lyocell, etc., can be used in knitted fabrics to analyse their thermal performance. Silica aerogel can be a good material for imparting thermal isolation properties on knitted fabrics. Silica aerogel has a large internal surface area, low density, large pore volume, and small pore sizes, so it possesses very low thermal conductivity and high thermal insulation properties (Islam et al., 2019). Graphene oxide can also be used to improve thermal properties in knitted fabrics. Graphene knitted fabrics provide excellent thermal storage, thermal insulation properties, and anti-static properties (Shou et al., 2024)

2. Methodology

2.1. Materials

In this work, the finished fabrics used for the experiment are collected from a 100% export-oriented knit composite factory located in Dhaka, Bangladesh. Table 1 demonstrates the composition of each sample analysed for the work purpose. It was ensured that all fabrics with the same weave structure had the same weight (GSM).

Table 1: Analysed fabric sample specifications.

Fabric Type	Composition	GSM
Single Jersey	100% Cotton	180
Single Jersey	100% BCI Cotton	180
2/2 Lycra Rib	95% Cotton, 5% Elastane	230
2/2 Lycra Rib	95% BCI Cotton, 5% Elastane	230
Single Jersey Blend	93% Cotton, 2% Polyester, 5% Elastane	230
Single Jersey Blend	93% BCI Cotton, 2% Polyester, 5% Elastane	230

2.2. Methods

The thickness of the fabric samples was evaluated using an AMES Thickness Tester according to the ASTM D 1777 standard. For measuring weight (grams per square meter), samples were prepared using a GSM cutter based on the ASTM D 3776 standard. The weight of each sample in grams was then multiplied by 100 to get the final GSM value.

The fabrics' thermal properties (conductivity, resistance, transmittance, CLO value) were estimated according to ASTM D 1518-85 standard. YG606D Thermal Guarded Hotplate (Figure 3.3b) was utilised to determine the thermal properties of test samples. A test sample of 300 mm × 300 mm dimension was prepared. Each sample was heated (20-50°C) on one side by an electrically heated plate. At the same time, a guard is separately heated at a similar temperature where the heated plate is embedded. Heat flux sensors determine the heat flow from the hot surface through the fabric. Another sensor evaluates fabric thickness relative to the input value. These values are finally used to calculate the thermal resistance of the tested fabric automatically. Test results were printed out after each test, containing data on thickness, thermal resistance, CLO value, thermal conductivity, and thermal transmittance. Air permeability was determined according to the ASTM D 737 standard under the Kawabata Evaluation System (KES-F8-API) using an automatic air permeability tester.

Table 2: Details of test name, standard, and instrument.

Test Name	Standard	Instrument
Thickness Test	ASTM D 1777	AMES Thickness Tester
Weight Test	ASTM D 3776	GSM Cutter
Thermal Properties Test	ASTM D 1518-85	Thermal Guarded Hotplate
Air Permeability Test	ASTM D 737	Automatic Air Permeability Tester

3. Results and Discussions

Table 3 shows the thermal properties of tested fabric structures, single jersey and rib structures made from conventional and BCI cotton. Significant variations in their properties are observed as they are made of different knit structures and fibre types.

Table 3: Thermal properties of different fabric structures.

	Fabric Structure					
	100% Conventional Cotton			*BCI Cotton*		
Fabric Properties	*Single Jersey*	*Rib*	*Single Jersey Blend*	*Single Jersey*	*Rib*	*Single Jersey Blend*
Thickness, mm	0.41	0.75	0.50	0.42	0.78	0.53
Thermal Resistance, $m^2 \cdot K/W$	0.02952	0.01347	0.02476	0.01589	0.00987	0.01708
CLO Value, clo	0.19047	0.08689	0.15972	0.10254	0.06369	0.11021
Thermal Conductivity, $W / (m \cdot K)$	0.01389	0.05569	0.0202	0.02643	0.07901	0.03103
Thermal Transmittance, $W / (m^2 \cdot K)$	33.873	74.250	40.394	62.92	101.297	58.539
Air Permeability, $cm^3 / cm^2 / s$	40.07	33.37	19.6	39.2	37.33	28.6

The thickness of a fabric may have a significant impact on thermal properties. Whether the sample fabric is a single jersey (S/J), rib, or S/J blend, the thickness of BCI cotton and conventional cotton are almost similar. For example, the thickness of S/J conventional cotton is 0.41 mm, and S/J BCI cotton is 0.42 mm. Similarly, the thickness of conventional rib cotton is 0.75 mm, and that of rib BCI cotton is 0.78 mm. Generally, thicker fabrics exhibit better insulating properties because of the entrapped air between the fibres (Erdumlu & Saricam, 2017). Air is a poor heat conductor, creating a barrier that slows heat transmission away from the body. (Čubrić et al., 2012). The fabrics chosen for this work are almost of similar thickness, so the thickness of the fabric does not significantly affect other fabric properties while determining the thermal properties. The thickness of rib knitted fabric is slightly higher than that of single jersey fabric because its structure has two series of knitted loops arranged into two parallel lines in a course. (Ziaei et al., 2018).

3.1. Thermal Resistance

Thermal resistance measures a fabric's ability to restrict heat flow through it. (Mishra et al., 2019). It indicates how difficult it is for heat to pass through a fabric. The higher the value, the higher the insulation property of the fabric, and it is better for winter use. (Afzal et al., 2017)For S/J, the thermal resistance of BCI cotton is 0.01589 m^2·K/W, while in conventional cotton, it turns into double 0.02952 m^2·K/W. For rib fabric, the thermal resistance of BCI cotton is 0.00987 m^2·K/W, while for conventional cotton, it is 0.01347 m^2·K/W.

The result (Figure 1) shows that conventional cotton has significantly higher thermal resistance properties than BCI cotton, whether single jersey, rib, or blended structure. Again, the tested samples reveal that single jersey fabrics show better thermal resistance than rib fabric structures. Single jersey fabrics have better moisture management properties and higher water vapour permeability values. (Mazedul Islam et al., 2014).

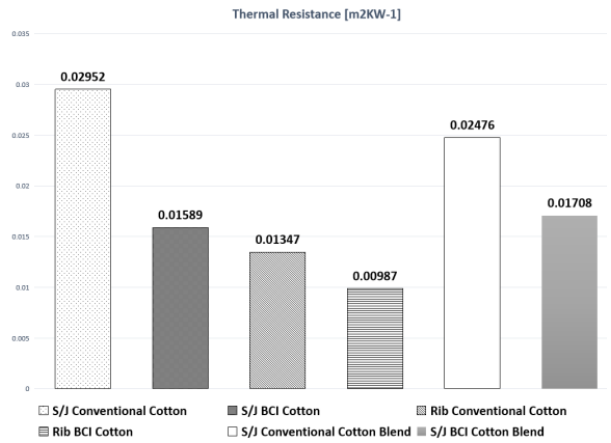


Figure 1: Thermal resistance result of 100% conventional cotton and BCI cotton.

3.2. CLO Value

CLO value is another measurement of a fabric's thermal insulation property. It denotes the required insulation for keeping a resting person comfortable at 21°C (70°F) temperature in a customarily ventilated room (Collins & Hoinville, 1980). Many factors, such as thickness, the structure of the fabric, the type of fibre, and the number of layers, affect the CLO value (Goldman, 1974). For rib fabric, the CLO value of BCI cotton is 0.06369 clo, but in conventional cotton, it changes to 0.08689 clo. For S/J blended fabric, the CLO value of BCI cotton is 0.11021 clo, and for conventional cotton, it is 0.15972 clo.

The higher the CLO value, the greater the amount of fabric insulation and the warmer it will keep the wearer. Figure 2 shows that conventional cotton exhibits a higher CLO value, which means higher insulation than BCI cotton for single jersey and blended structures. It also shows that single jersey fabrics exhibit better thermal insulation properties (CLO value) than single-layer rib structures of similar thickness.

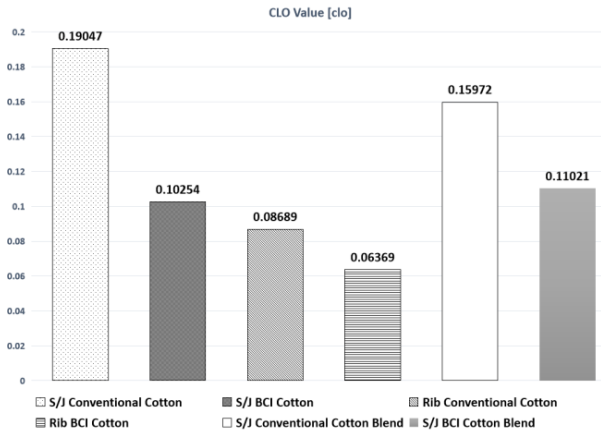


Figure 2: CLO value of 100% conventional cotton and BCI cotton.

3.3. Air Permeability

Air permeability expresses how easily air can pass through a fabric (Dhingra & Postle, 1977). It indicates the breathability of clothing. For the S/J BCI blend structure, air permeability is 28.6, and for the conventional cotton blend, it is 19.6. It also differs the same way in the case of the rib structure. But in the case of the S/J structure, both values are almost similar, which is caused by the finishing treatment applied on the fabric, and we didn't take it into consideration for our experiment. The higher the air permeability value, the easier it is for air to flow through the fabric. The level of air permeability depends on fabric structure, yarn type, fibre parameters, etc. (Zupin et al., 2012). The tested samples (Figure 3) show that BCI cotton has better air permeability properties than conventional cotton in most cases. Whether it is a single jersey, rib, or blended structure, BCI cotton performs better.

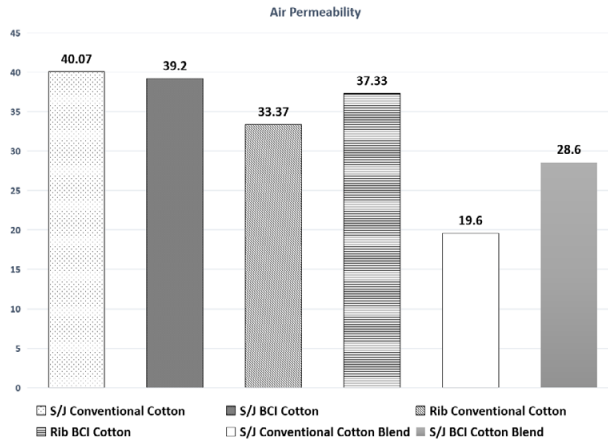


Figure 3: Air permeability result of 100% conventional cotton and BCI cotton.

3.4. Thermal Conductivity

Thermal conductivity denotes the ability of a fabric to conduct heat through it. It measures how effectively a fabric can transfer heat from hot to cool areas (Chen et al., 2018). Thermal conductivity for rib conventional cotton is 0.05569 W/m·K, and for rib BCI cotton, it gives 0.07901 W/m·K. For S/J and blend structure, thermal conductivity acts similarly, with BCI cotton performing better than conventional cotton. According to Figure 4, BCI cotton has a little higher thermal conductivity than conventional cotton, whether it is single jersey, blended, or rib structure. But in terms of fabric structure, rib fabric has better air permeability property than single jersey fabric. This characteristic depends on the amount of trapped air within fabric structure. As heavier fabric, like rib fabric, contains less trapped air, exhibit higher value of thermal conductivity (Oglakcioglu & Marmaralı, 2007).

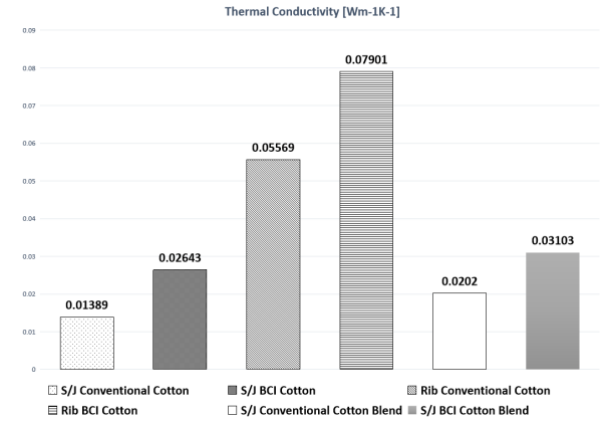


Figure 4: Thermal conductivity results of 100% conventional cotton and BCI cotton.

3.5. Thermal Transmittance

Thermal transmittance denotes the volume of heat that passes through one square meter area in one second in a stable heat transfer condition (Buzatu et al., 2017). It combines thermal conductivity and fabric thickness to determine the heat transfer rate through the fabric (Ziegler & Kucharska-Kot, 2006). It is pretty similar to thermal conductivity and the inverse of thermal resistance. As it is the inverse of thermal resistance, it shows a similar characteristics pattern as before. According to the test result (Figure 5), BCI cotton has better thermal transmittance than conventional cotton, which is observed for single jersey, rib, and blended structures. Lower thermal transmittance indicates better thermal insulation properties, effective at preventing heat flow, suitable for winter. Higher thermal transmittance means more heat transfer, ideal for summer.

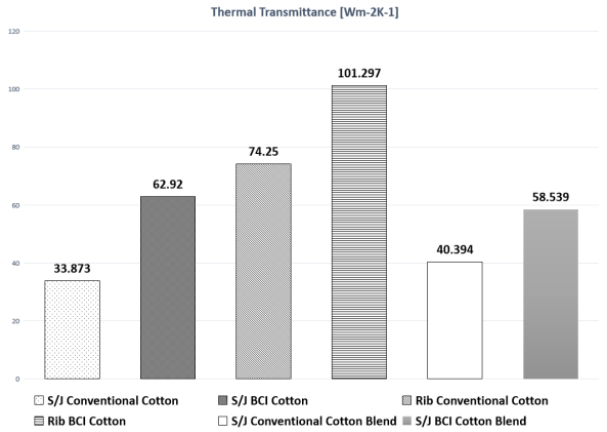


Figure 5: Thermal transmittance results of 100% conventional-cotton and BCI cotton.

4. Conclusions

The study explores the thermal properties of knitted fabrics and their application in different thermal conditions. It suggests that single jersey and rib structure fabrics are more suitable for activewear and summer apparel due to their better thermal conductivity. This knowledge is particularly valuable for product design and development, as it can inform the selection of knitted fabrics for specific usage purposes, such as designing breathable sportswear for hot climates or warm winterwear for cold climates. The analysis focused on six types of knitted fabric chosen as raw materials for knitted apparel. All three structured fabrics of BCI cotton have demonstrated higher air permeability and thermal transmittance values due to the variation of fiber compositions. The cotton cultivation process of BCI cotton significantly impacts these attributes, leading to better fineness, uniformity, and openness of the fiber and good quality yarn. Conventional cotton has higher thermal resistance and CLO values, which indicate the required amount of insulation to maintain a comfortable temperature in a given environment. Rib-structured apparel with conventional cotton suits cold weather in contrast to single-jersey structured apparels. Further investigation may be conducted to ascertain improved thermal resistance for BCI cotton clothing.

The findings suggest that distinct compositions with diverse structures have various comfort properties for different climate settings. It is essential to consider the end use of the products when selecting fabrics to achieve the ideal clothing comfort, although clothing comfort also depends

heavily on the wearer's mindset. BCI cotton is better for sportswear and summer attires, providing better thermal comfort properties than conventional cotton in most areas. These findings directly inform the selection of fabrics for specific usage purposes, making them highly relevant to product designers and developers in the textile industry.

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Author contributions

Study design: Sumaiya Tabassum, Irfan Najib. Data collection: Irfan Najib, S M Saiful Islam. Analysis: Sumaiya Tabassum, Shah Md. Maruf Hasan, Md. Nahid-Ull-Islam. Writing: Sumaiya Tabassum, Rehnuma Razzak Fera, Irfan Najib, S M Saiful Islam. Critical review: Shah Md. Maruf Hasan, Md. Nahid-Ull-Islam. Supervision: Shah Md. Maruf Hasan.

Conflicts of Interest

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of our manuscript, we used QuillBot and Grammarly to correct grammatical errors and refine language quality. These tools were applied solely to enhance readability and language clarity. All core content, data interpretation, and conclusions are the original work of the authors. We have thoroughly reviewed the final manuscript and take full responsibility for its accuracy and integrity.

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