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Investigating the Impact of Air Permeability and Thermal Properties on Rib Knit Structures

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ABSTRACT

Factors influencing the comfort and performance of knitted fabrics can be investigated to enhance the understanding and development of functional accessories. Issues related to the thermal regulation and moisture management of these materials are systematically explored in this research. Additionally, the effects of fibre type, yarn properties, fabric variables, and finishing methods are examined through the evaluation of physical properties relevant to the comfort of rib knit structures, particularly in sportswear design. 1x1 Rib knit 1structures were created using polyester spun, cotton spun, polyester filament, and viscose filament yarns with varying linear densities employing a KH-323N computerized flatbed knitting machine. Evaluations of physical properties, thermal characteristics, air permeability, antibacterial efficiency, and hydrophilic finish were conducted following ASTM standards and specific testing methods to thoroughly assess the quality and performance of the fabric. Significant insights into the physical and comfort properties of the fabrics were provided by the results. Varying thermal and air permeability characteristics were demonstrated by polyester-cotton and viscose-cotton fabrics. Thermal resistance and conductivity are influenced by filament denier, loop length, and knit structure, while these same factors affect air permeability. Air permeability is also impacted by finishing treatments, thereby highlighting the complex interplay between fabric properties and comfort. Advanced finishing techniques and novel fibre blends could be explored in future research to further optimize fabric comfort properties.

KEYWORDS
air permeability, thermal properties, knitted garments

INTRODUCTION

Knitted fabrics are preferred for sportswear, casual wear, intimate wear, and socks due to their excellent stretchability, good handle, and comfort. The comfort of clothing is determined by thermal comfort and the state of comfort is achieved only when the most complicated system of interacting physiological, psychological, and physical responses and actions has been processed [1]. Therefore, clothing comfort is dependent on properties such as softness, flexibility, moisture diffusion, air permeability, and thermal comfort. Moreover, extensive application of knitted fabrics in accessory sectors is being observed, especially in products intended for next-to-skin applications that align with criteria facilitating easy air movement. Accessories worn next to the skin, such as socks, gloves, and hats, must be designed using appropriately engineered fabrics to achieve both comfort and aesthetic characteristics [2-4]. The comfort characteristics of any textile material are influenced by thermal and mass transport properties. The fabric structure and overall physical and comfort properties of apparel and accessories made from engineered fabrics are affected by variables such as fibres, yarns, and fabric parameters (including finishing and printing techniques). The fabric properties like porosity and air permeability, as well as aesthetic appeal, are influenced by finishing treatments [5-8].

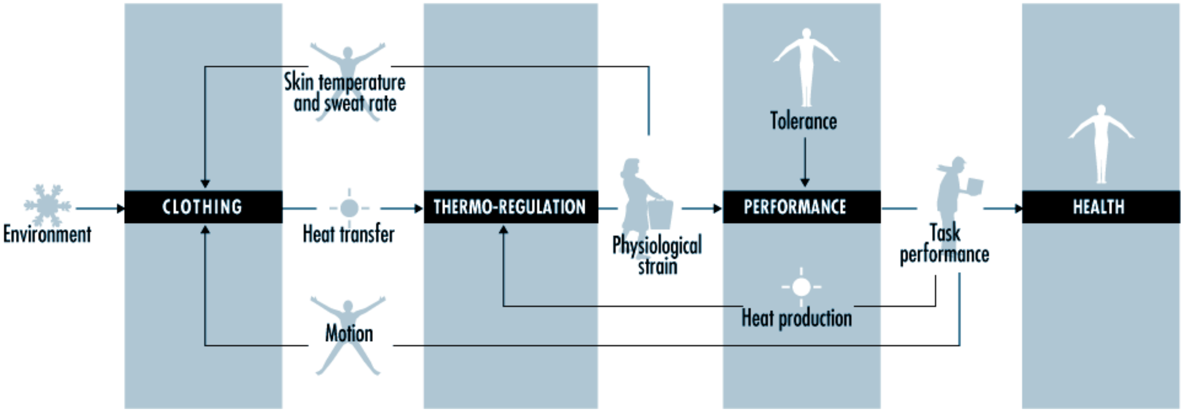

Figure 1. shows the importance of physiological responses to the environment [7]

Thermo-physiological comfort

Thermo-physiological comfort is comprised of thermal comfort, air permeability, and moisture management properties. It is defined as "the absence of any unpleasant sensations of being too cool or too warm, or of having excessive perspiration on the skin." These factors are interconnected and are influenced by clothing and environmental conditions, contributing to overall comfort performance and affecting our body's thermal balance and movement [9-11]. Thermal comfort is influenced by multiple parameters, including moisture and thermal interactions that impact human perception. This includes the generation of metabolic body heat, the transfer of heat and moisture from the body to the clothing microclimate (the region between the skin and clothing), and the transfer of heat and moisture from clothing to the environment. The thermophysiological characteristics of textiles are deemed critical for overall user comfort and are interconnected with various parameters [12].

Role of clothing in providing comfort

Clothing is considered a second skin, playing an important function in maintaining thermal equilibrium with the environment and keeping an individual comfortable. Textiles should be able to retain heat that the body dissipates while also dissipating heat from the body's surroundings when the body creates it. Because of the two distinct behaviours described above, it is difficult to create a single garment system that provides comfort in different seasons and levels of activity [13].

Mechanism of thermal comfort

Heat Balance

The heat balance is mathematically expressed in equation 1:

$$\mathrm{S} = \mathrm{M} - \mathrm{W} - \mathrm{E} - (\mathrm{R} + \mathrm{C})\mathrm{W/m^2} \tag{1}$$

Where S is the body's rate of heat storage, M is the metabolic rate, W is the body's mechanical work rate, E is the rate of total evaporation loss, and R+C is the number of dry heat exchanges [14-15]. Following the efficiency of the human body, only 15–30% of the energy consumed as food is transformed into beneficial labour, with the remaining 70–85% of energy being lost as heat. Any amount of physical activity beyond what is required to keep the body temperature stable will produce extra heat energy that needs to be expelled to prevent the body temperature from rising [16]. Air permeability, defined as the rate at which air flows perpendicularly across a known area under a specified air pressure difference between two material surfaces, indicates a fabric's ability to allow air passage [17-18]. High air permeability is desirable for coolness in hot weather clothing, while low permeability is preferable for warmth in winter wear. Fabrics with higher water absorption tend to be less permeable to air due to fibre and yarn swelling. The air permeability of garment fabrics is influenced by factors such as fibre type, yarn type and twist, yarn count, yarn structure, ends per inch, picks per inch, fabric thickness, density, porosity, and coverage factor. These factors can increase or decrease air permeability by altering the length and area of airflow through the materials [19]. The invention of synthetic fibres revolutionized the textile industry, though cotton-knitted fabrics remain highly popular among various knitted fabrics [20-21]. This research aims to thoroughly investigate the impact of numerous factors, including fibre type, yarn characteristics, fabric variables, and finishing applications, on the physical properties and comfort attributes of 1x1 rib knit structures. Additionally, the development and design of functional accessories are sought to be contributed to through a systematic exploration of these factors.

EXPERIMENTAL

Materials and Methods

Rib-knit structures were prepared using polyester spun, cotton spun, polyester filament, and viscose filament yarns of different linear densities. 1x1 Rib knitted fabric was made using different yarns, with yarn details provided in Table 1. Seventeen rib knit structures were produced using a total of four yarns. All fabric samples were manufactured using a KH-323N automated flatbed knitting machine (5G) at SANGAM PVT. LTD., Bhilwara, India.

Table 1. Experimental plan

S.NO	Sample Code	Fiber Content	Yarn Type	Filament Denier	Finishing	Knit Structure	loop length
1	C	Cotton	Spun	40^S	Untreated	S.F	9.5
2	C_{AT}	Cotton	Spun	40^S	Antimicrobial	S.F	9.5
3	PET/C_T	Polyester Cotton	Filament Spun	100D40^S	Antimicrobial	S.F	7.5
4	PET/C_M	Polyester Cotton	Filament Spun	100D40^S	Antimicrobial	S.F	9.5
5	PET/C_S	Polyester Cotton	Filament Spun	100D40^S	Antimicrobial	S.F	10.3
6	PET_{100}/C	Polyester Cotton	Filament Spun	100D40^S	Untreated	S.F	9.5
7	PET_{200}/$C_{S.F}$	Polyester Cotton	Filament Spun	200D40^S	Untreated	S.F	9.5
8	PET_{200}/$C_{AT,S.F}$	Polyester Cotton	Filament Spun	200D40^S	Antimicrobial	S.F	9.5
9	PET_{200}/$C_{AT,D.F}$	Polyester Cotton	Filament Spun	200D40^S	Antimicrobial	D.F	9.5
10	PET_{200}/$C_{D.F}$	Polyester Cotton	Filament Spun	200D40^S	Untreated	D.F	9.5
11	PET_{HT}/C	Polyester Cotton	Spun	40^S 40^S	Hydrophilic	S.F	9.5
12	PET/C_{HT}	Polyester Cotton	Spun	40^S 40^S	Hydrophilic	S.F	9.5
13	V_{120}/C_{HT}	Viscose Cotton	Filament Spun	120D40^S	Hydrophilic	S.F	9.5
14	V_{225}/C_{HT}	Viscose Cotton	Filament Spun	225D40^S	Hydrophilic	S.F	9.5
15	V_{225}/C	Viscose Cotton	Filament Spun	225D40^S	Untreated	S.F	9.5
16	V_{225}/C_{AT}	Viscose Cotton	FilamentSpun	225D40^S	Antimicrobial	S.F	9.5
17	V_{600}/C_{HT}	Viscose Cotton	FilamentSpun	600D40^S	Hydrophilic	S.F	9.5

Note: PET-Polyester,100,200-polyester denier; V-viscose,120,225,600-viscose denier; C-cotton; 7.5-tight;9.5-Medium;10.3-Slack; S.F-single feeder; D.F-Double feeder; AT-antimicrobial treated; HT-hydrophilic treated

The physical properties of tested samples were comprehensively evaluated to assess various characteristics essential for understanding their quality and performance. Wale and course density were determined by methodically measuring the number of wales and courses per cm (centimetre) using a pick glass, complying with the ASTM D 3775-03 criteria. Stitch density, a critical parameter, was calculated as the product of courses/cm and wales/cm, providing insights into the fabric's structural integrity. Fabric thickness was measured using an R&B cloth thickness tester under a standardized pressure, facilitating an accurate assessment of the material's volume. Another important parameter, aerial density, was calculated by weighing standardized samples and dividing the weight by the area to ensure uniformity in measurement. Bulk density, an indicator of fabric bulkiness, was computed as a ratio of the fabric weight per unit area to its thickness, shedding light on the density distribution. Fabric porosity, a key factor influencing comfort, was quantified as a percentage, considering the entrapped air volume within the fabric. Lastly, the tightness factor, assessed through loop length, provided valuable insights into the openness or compactness of the fabric structure, influencing its insulation and comfort properties. Together, these physical properties evaluations offer a comprehensive understanding of the test samples' characteristics, aiding in their assessment and optimization for various applications.

Comfort Characteristics

Thermal Properties

The thermal properties of the samples were analyzed using the KES-F7-2 Thermolabo Tester, specifically focusing on thermal conductivity (TC), thermal resistance (TR), and qmax value. The instrument includes a BT-Plate, guard, flange, heater connector, and relay box. The temperature of the BT plate and guard is 10 °C higher than the ambient temperature to meet the test requirements. To test thermal resistance, a BT plate was heated to 32 °C (similar to human skin temperature) and a 10 × 10 cm sample was placed on it. The wind column has a constant air flow rate of 1 ms and a temperature of 20 °C ± 2 °C. Switching on the fan ensures constant airflow. After 60 s, the W value is displayed on the digital panel meter. There are four ways to determine heat flow loss: dry contact, dry contactless, wet contact, and wet contactless. The presented experiments employ a dry contactless technique. The thermal resistance, thermal conductivity, and qmax are calculated using the values obtained for heat flow loss.

Parameters obtained from KES-F7-2 Thermolobo Tester:

Thermal Resistance

Thermal resistance measures a material's ability to withstand heat transmission through it. The thermal resistance of the test samples was calculated in m^2 °CW^{-1} as per the following equation 2.

$$\text{Thermal resistance} = \frac{\text{Area}\times\Delta\text{T}}{\text{W}}\ \text{m}^2\ {}^\circ\text{CW}^{-1} \tag{2}$$

Where ΔT is the temperature gradient, and W is the loss of heat flow.

Thermal Conductivity

Thermal conductivity is a fundamental property of materials that reveals their capacity for transferring heat. The thermal conductivity of the specimens was calculated as m^{-1} $°C^{-1}W$ utilizing equation 3:

$$\text{Thermal conductivity} = \frac{\text{Thickness}}{\text{Thermal resistance}} \qquad m^{-1}\,°C^{-1}W \tag{3}$$

Air Permeability

Air permeability is a type of fabric property that is often used as a variable for comparing and assessing "breathability," which is a fabric's capacity to let moisture vapour penetrate through its component materials, including the coating and uncoating. The air permeability of fabric samples was determined using an FX 3300 Mackintosh air permeability tester 98 Pa, as outlined in ASTM D737. To prevent the curling of the knitted textiles, the test specimens were cut to dimensions greater than the apparatus's test area (5 cm^2). Specimens were placed on the test area to represent a broad distribution over its length and width. Test samples were handled carefully to avoid altering the material's natural state, and they were free of folds, creases, and wrinkles.

Antibacterial Efficiency

The AATCC Test Method 147-2004 standard was used for antibacterial testing. The parallel streak method is a qualitative method for determining the antibacterial activity of diffusible antimicrobial agent-treated textile fabrics. The following equation 4 was used to calculate the average width area of resistance throughout the strip on both sides of the test specimen:

$$W = \frac{(T-D)}{2} \tag{4}$$

W is the width of the clear zone of inhibition in mm, T is the total diameter of the test specimen and clear zone in mm, and D is the diameter of the test specimen in mm.

Hydrophilic Finish

By encouraging moisture absorption, a hydrophilic treatment improves fabric and makes it more water-friendly. Chemical treatments enhance textiles' wetting capacities, facilitating the dispersal of perspiration or sweat and enhancing comfort. In sportswear, this finish is essential because it guarantees permeability and quick-drying qualities, which improve performance.

RESULTS AND DISCUSSION

Physical Properties

Table 2 presents the physical characteristics of the tested fabrics. The thickness ranged from 1.30 to 1.82 mm, while the aerial density was observed in the range of 168 – 343 g/m^2. It was observed that viscose-cotton fabrics exhibited higher aerial density compared to polyester-cotton fabrics. Aerial density decreased from 301 g/m^2 to 168 g/m^2 as the loop length increased from 7.4 to 10.3 mm. The permeability of the tested samples varied from 75% to 92%. An increase in the loop length resulted in higher porosity due to a more open structure. Rib knitted fabrics exhibited a variation in tightness factor from 5.1 to 11.3 ($\sqrt{\text{Tex}}$ cm^{-1}). The tightness factor showed an increasing trend with an increase in filament denier and a decrease in loop length.

Table 2. Physical properties of tested samples

Sample Code	Areal density (g/m^2)	Thickness (mm)	Fabric porosity (%)	Courses /(cm)	Wales /(cm)	Loop length (mm)	Bulk density (kg/m^3)	Tightness factor ($\sqrt{\text{tex}}$ cm^{-1})
C	307	1.68	90.0	6.29	7.08	7.40	204.66	7.28
C$_{AT}$	247	1.50	91.0	7.87	7.48	7.42	224.50	7.50
PET/C$_{T}$	301	1.58	87.0	7.48	8.97	7.20	216.54	7.25
PET/C$_{M}$	311	1.30	91.0	7.48	8.85	9.50	222.14	5.64
PET/C$_{S}$	168	1.19	91.0	6.61	8.66	10.25	178.72	5.08
PET$_{100}$/C	223	1.32	90.0	6.61	6.61	7.47	172.86	7.40
PET$_{200}$/C$_{S.F}$	167	1.52	87.9	6.69	7.87	8.10	175.78	7.90
PET$_{200}$/C$_{AT,S.F}$	170	1.53	88.2	7.20	7.08	10.77	245.00	7.60
PET$_{200}$/C$_{AT,D.F}$	304	1.52	90.4	7.08	7.08	10.71	208.21	7.40
PET$_{200}$/C$_{D.F}$	331	1.53	90.3	7.20	7.08	10.71	209.90	7.40
PET$_{HT}$/C	346	1.64	92.0	7.63	7.08	9.28	226.14	5.60
PET/C$_{HT}$	263	1.37	92.0	6.90	7.87	8.71	231.82	5.90
V$_{120}$/C$_{HT}$	332	1.40	86.8	7.08	7.08	10.73	219.86	4.80
V$_{225}$/C$_{HT}$	616	1.61	83.0	7.08	8.66	8.62	382.66	6.30
V$_{225}$/C	217	1.60	83.9	6.29	7.08	9.88	155.00	6.30
V$_{225}$/C$_{AT}$	217	1.67	84.2	5.51	7.08	10.25	155.00	6.30
V600/CHT	343	1.82	75.0	7.08	7.08	10.42	245.00	11.26

Comfort Properties

Thermal properties

The thermal resistance of rib knit structures with two varying fibres, polyester and viscose, was investigated. It was found that polyester cotton fabrics exhibited superior heat resistance compared to viscose cotton fabrics. Similar trends were noted when untreated cotton in both scenarios was substituted with cotton yarn treated with a hydrophobic finish. The observed trend is likely attributable to the alteration in fibre type employed in fabric manufacturing.

Table 3. Thermal properties of rib knitted fabrics

Sample code	Thermal Resistance (m^2 °C W^{-1})	Thermal Conductivity (m^{-1} °C^{-1} W × 10^{-3})	Warm/CoolFeeling ($\underline{q_{max}}$) (W s m^{-2} °C^{-1})
PET/C_T	0.18	8.70	80
PET/C_M	0.20	6.50	76
PET/C_S	0.22	5.00	58
PET_{100}/C	0.18	6.70	76
$PET_{200}/C_{S.F}$	0.20	7.60	84
$PET_{200}/C_{AT,S.F}$	0.20	7.50	79
$PET_{200}/C_{AT,D.F}$	0.20	5.70	72
$PET_{200}/C_{D.F}$	0.20	5.50	69
PET_{HT}/C	0.18	5.20	92
PET/C_{HT}	0.18	5.20	92
V_{120}/C	0.18	7.60	90
V_{225}/C_{HT}	0.18	8.80	96
V_{225}/C_U	0.18	8.80	104
V_{225}/C_{AT}	0.18	8.80	96
V_{600}/C	0.20	9.00	167

Tyagi et al. observed that higher fibre conductivity results in increased thermal conductivity and consequently reduced thermal resistance of samples manufactured from such fibres, owing to the inverse relationship between thermal conductivity and thermal resistance. Viscose fibres with high conductivity (0.06) utilized in knitting viscose cotton fabrics demonstrate elevated thermal conductivity (Table 3), thereby yielding lower thermal resistance compared to polyester cotton fabrics. Tyagi et al. also noted that polyester cotton fabrics exhibited greater heat resistance than polyester viscose fabrics, attributed to a higher volume of trapped air.

Thermal resistance (TR)

Effect of Different fibre on Thermal Resistance

The thermal resistance of rib knit structures fabricated using two different fibres, polyester and viscose, was investigated. Polyester cotton fabrics exhibited higher heat resistance compared to viscose cotton fabrics. Similar trends were noted when untreated cotton in both scenarios was substituted with cotton yarn treated with a hydrophobic finish. These observations may be attributed to the distinct fibre types utilized in fabric production. The higher thermal conductivity of superior fibres contributes to lower thermal resistance in the resulting samples, reflecting an inverse relationship between thermal resistance and thermal conductivity. Viscose fibre with high conductivity (0.06), when used to knit viscose cotton fabrics, exhibit higher thermal conductivity (Table 3), and thus lower thermal resistance compared to polyester cotton fabrics.

Tyagi et al. found that polyester cotton fabrics were more effective in heat resistance than polyester viscose fabrics because of the larger volume of trapped air.

Effect of filament denier on thermal resistance

The thermal resistance of fabrics with varying filament denier was compared, revealing an upward trend in both viscose cotton and polyester cotton rib knit structures as the filament denier of viscose (V600/C) and polyester (P200/C) increased, as indicated in Table 3. The observed trend is thought to be influenced by increased fabric thickness, which is widely recognized as the predominant factor affecting thermal resistance in textile systems, thereby explaining the observed trend. The findings are consistent with the work of Cubric et al., who revealed that air trapped in knitted fabric structures plays a significant role in the thermal resistance of knitted samples. The statistical analysis of results revealed that there are no significant differences between the V120/C and V225/C, but there is a substantial difference between the V225/C and V600/C, as well as between polyester cotton fabrics knitted with different polyester filament denier.

The effect of knitted fabric loop length on thermal resistance

Table 3 indicates that heat resistance rose from 0.18 to 0.22 m^2 °C W^{-1} as loop length grew from 7.5 to 10.3 mm. Thermal resistance rises as the loop's length enlarges, which can be ascribed to a reduction in the tightness factor for loose construction. Slack textiles with longer loop lengths feature larger air gaps within the knitted fabric interstices, leading to increased thermal resistance due to the high thermal resistance of air. These findings align with those of Gupta et al., who demonstrated that as the loop length increases, the knit fabric structure becomes more porous, resulting in a higher air volume percentage and, consequently, greater heat resistance.

A linear equation with a positive slope of 0.02, an intercept of 0.16, and an R2 value of 1 also confirms the association between loop length and heat resistance of materials.

Effect of knitted structure on the thermal resistance

A comparison of polyester-cotton fabrics with varying knit structures showed that there is no significant difference between single-feeder and double-feeder fabrics.

Effect of Finish Application on the Thermal Resistance

The Thermal resistance ratings for several samples are reported in Table 3. A statistical assessment of experiment data reveals that there is no significant difference in the heat resistance of finished and raw materials.

Thermal conductivity

Thermal conductivity can be described as the rate of heat transfer (energy per unit area per unit time) divided by the temperature difference. In textiles, the air trapped within the fabric structure plays a crucial role in determining the conductivity value.

Effects of fiber types on thermal conductivity

Polyester/cotton and viscose/cotton fabrics were compared for their thermal conductivity. Thermal conductivity for viscose/cotton fabrics irrespective of finishing treatment was discovered to be greater (8.5 $m^{-1}\,°C^{-1}\,W \times 10^{-3}$) as compared to polyester/cotton fabrics (7.5 $m^{-1}\,°C^{-1}\,W \times 10^{-3}$). The observed trend can be attributed to the higher heat conductivity of viscose fibre (0.06) than polyester fibre (0.05).

Effect of filament denier on thermal conductivity

Table 3 presents the thermal conductivity of rib knit fabrics. An increase in thermal conductivity was observed in viscose cotton (V120/C, V225/C, V600/C) and polyester cotton (P100/C, P200/C) fabrics as the denier of viscose and polyester filaments were respectively increased. The aerial density of the sample textiles was used to measure their thermal conductivity. It was found that as thermal resistance decreased, thermal conductivity also decreased. This discrepancy can be attributed to fabric thickness, which decreases as the filament becomes finer. If the reduction in thickness exceeds the decline in thermal conductivity, thermal resistance decreases, resulting in a reduction in the thermal conductivity of textiles knitted with finer filament yarns. The results were determined to be statistically significant. Results are reliable with the findings of Hurd JCH et al.

Effect of loop's length on thermal conductivity

The porosity or degree of openness in knitted materials is influenced by the loop length of the knit structure, which, in turn, determines their thermal qualities. Fabric samples PET/CT, PET/CM, and PET/CS were prepared with varying loop lengths while keeping all other parameters constant; loop length ranged from 7.5 mm to 10.3 mm for PET/CT (tight), PET/CM (medium), and PET/CS (slack) fabrics. A decrease in thermal conductivity from 8.70 m^{-1} $°C^{-1}$ W × 10^{-3} to 5.0 (m^{-1} $°C^{-1}$ W × 10^{-3} was observed as the knit structure became slack with increased loop length. Materials knitted with longer loop lengths exhibit reduced thermal conductivity due to their slacker constructions, which contain less fibre per unit area and trap more air. This drop in thermal conductivity occurs because the thermal conductivity of fibres is higher than that of entrapped air. A linear equation with a slope of 1.85, an intercept of 10.43, and an R2 value of 0.988 reveals a negative and linear connection between loop length and heat conductivity.

Findings are in according with the results of Hurd JCH et al. who indicated that thermal conductivity of fabrics decreases significantly as the loop length increases.

Effect of knit structure on thermal conductivity

The thermal conductivity of the rib knit structure prepared using a double feeder was found to be reduced compared to its single feeder counterpart, irrespective of the finishing treatment, as demonstrated in Table 4.2. The observed trend may be attributed to the open structure and high porosity of textiles manufactured using a double feeder. The openness of the structure allows for increased air entrapment. Due to air's poor thermal conductivity, fabrics exhibit lower thermal conductivity, thus explaining the observed trend. These results were considered significant at the 95% confidence level. The findings were consistent with the findings of Licheng, who proposed that knitted textiles can capture more still air and minimize the amount of heat transmission from the human body to the fabric, resulting in poorer thermal conductivity.

Effect of finish application on thermal conductivity

Thermal conductivity estimates of different samples are shown in Table 3. It was observed that finishing treatment did not significantly affect the thermal conductivity of rib knit fabrics.

Air Permeability

Air permeability is defined as the rate at which air is allowed to flow perpendicularly through a unit area of a material when a specified air pressure difference exists between its two surfaces. In textile materials, air permeability is affected by factors associated with yarn and fabric construction, as well as bulk properties such as thickness, aerial density, and porosity. The spacing of yarn is considered a crucial parameter for determining the openness of fabric, and the air permeability of knit structures is influenced by characteristics of fabric construction because air movement takes place through interyarn holes or interstices.

Table 4. Air permeability

Sample code	Air permeability ($cm^3/cm^2/s$)
PET/C_T	161.8
PET/C_M	202.6
PET/C_S	246.8
PET_{100}/C	202.0
$PET_{200}/C_{S.F}$	141.0
$PET_{200}/C_{AT,S.F}$	149.0
$PET_{200}/C_{AT,D.F}$	476.8
$PET_{200}/C_{D.F}$	480.6
PET_{HT}/C	109.4
PET/C_{HT}	109.0
V_{120}/C	209.6
V_{225}/C_{HT}	144.4
V_{225}/C_U	167.0
V_{225}/C_{AT}	144.4
V_{600}/C	73.50

Effect of fibre type on air permeability

The impact of fibre type on air permeability was studied by varying polyester and viscose fibres. However, no significant difference in air permeability was observed with varying fibre types.

Effect of filament denier on air permeability

The flow of air passed inters yarn spaces in a knitted fabric is an important means of keeping the body ventilated and comfortable. Fabric structural and yarn linear density factors like fabric thickness and porosity reportedly affect the air permeability and hence, the breathability of the fabric. The influence of filament deniers on air permeability was analysed for PET/C and V/C rib knit structures by varying polyester (100D, 200D) and viscose (120,225,600 deniers).

Air permeability was found to decrease with increases in viscose filament denier. A similar trend was observed with increases in polyester filament denier for polyester cotton fabrics. More fabric thickness and mass per square meter are also consequences of filament-denier growth. With higher mass per square meter and fabric thickness (Table 4), which also serves as a barrier to the airflow through a fabric, air permeability turns less. An analysis of test results showed that the impact of filament denier on air permeability is statistically significant at a 95 per cent confidence level.

Effect of loop's length on the air permeability

The impact of loop length on air permeability was studied across three fabrics with slack, medium, and tight structures achieved by varying loop length. As the rib knit structure loosened with longer loops, air permeability rose significantly from 161.8 $cm^3/cm^2/s$ to 246.8 $cm^3/cm^2/s$. These findings corroborate earlier studies by Chidambaram et al. and Bivainyte and Mikucioniene. The increased air permeability with longer loops is attributed to reduced fabric tightness, allowing air to flow more freely through the fabric's voids. Furthermore, the porosity of textiles rises as the fabric loop length grows. All of these variables lead to higher levels of air permeability for textiles knit with longer loop lengths. The results have been determined to be statistically significant. A linear equation with a positive slope of 75.87, an intercept of -35, and an R2 value of 0.88 further confirms the association between loop length and air permeability of materials.

Effect of knit structure on air permeability

Two types of rib knit structures were developed by altering the feeding of input yarns such that in one case (a) the two constituent yarns were fed through the same feeder and secondly (b) feeding two yarns through two separate feeders. It was observed that feeding the yarns through separate feeders resulted in fabrics of loose constructions irrespective of the finish application on cotton yarns. Consequently, such fabrics would exhibit higher porosity and air permeability compared to their single-feeder counterparts. The statistical analysis of results showed that there is a significant difference in air permeability of single-feeder and double-feeder structures.

Findings are in accordance with Abd el who was of the view that porous and loose-knit structures exhibit maximum air permeability.

Effect of finish application on air permeability

Table 4 illustrates the influence of finishing treatment on air permeability. Viscose/cotton textiles made with finished cotton yarn have lower air permeability than their unprocessed counterparts. The impact might be attributed to the decrease in inter-yarn space and pore size in the cloth as a result of finishing. However, the impact of finishing treatment on, the air permeability of PET/C textiles was shown to be statistically negligible.

The results are consistent with the discoveries of Tyagi et al., who reported that there is a considerable drop in air permeability after completion.

Significant insights were revealed in the investigation into factors affecting air permeability. It was found that variations in fibre type had no notable impact, whereas filament denier was correlated with decreased air permeability as fabric mass per square meter and thickness were increased. Increased air permeability was observed with longer loop lengths due to a decreased tightness factor and enhanced porosity. Fabrics with double feeder structures were found to exhibit higher permeability, suggesting their looser construction. Additionally, air permeability in viscose/cotton fabrics was reduced by finishing treatments, which decreased inter-yarn space, whereas their effect on PET/C fabrics was deemed insignificant. These findings highlight the complex interplay between fabric properties and air permeability, a critical consideration for optimizing breathability and wearer comfort.

CONCLUSION

The pivotal role of knitted fabrics in ensuring comfort and performance across various applications, notably sportswear and accessories, is underscored by this research. Valuable insights into the impact of factors such as fibre type, yarn characteristics, fabric variables, and finishing techniques on the physical properties and comfort attributes of rib-knitted fabrics have been gained through examination. The design and development of functional accessories, emphasizing thermal regulation and moisture management for optimal wearer comfort and performance, are facilitated by this systematic investigation. A thorough and systematic approach to evaluating the diverse properties of fabric samples was employed in this study. A comprehensive understanding of the physical attributes, thermal behaviour, air permeability, antibacterial efficacy, and hydrophilic finish of the fabrics was provided by rigorous testing procedures and adherence to recognized standards. The findings are crucial for assessing the suitability of these fabrics for various applications within the textile industry and for guiding potential optimizations in fabric design and production. This detailed assessment enhances understanding of materials and highlights the importance of considering multiple factors when developing textiles for specific purposes. Significant insights into the intricate relationship between fabric properties and wearer comfort are offered by the study. A deep understanding of how factors such as filament denier, loop length, and knit structure influence thermal resistance, conductivity, and air permeability has been gained through examination. The need to optimize these parameters to enhance overall comfort is emphasized by the findings. Polyester/cotton and viscose/cotton fabrics were compared for their thermal conductivity. Thermal conductivity for viscose/cotton fabrics irrespective of finishing treatment was discovered to be greater (8.5 $m^{-1}\,°C^{-1}\,W \times 10^{-3}$) as compared to polyester/cotton fabrics (7.5 $m^{-1}\,°C^{-1}\,W \times 10^{-3}$). The observed trend can be attributed to the higher heat conductivity of viscose fibre (0.06) than polyester fibre (0.05).

The thermal conductivity of rib knit fabrics. An increase in thermal conductivity was observed in viscose cotton (V120/C, V225/C, V600/C) and polyester cotton (P100/C, P200/C) fabrics as the denier of viscose and polyester filaments were respectively increased. The aerial density of the sample textiles was used to measure their thermal conductivity.

Future research could explore advanced finishing techniques to further improve fabric properties, manipulate inter-yarn spaces and pore size, and investigate novel fibre blends for superior comfort. Additionally, promising directions for advancing fabric comfort and functionality include integrating smart technologies into textiles and exploring sustainable solutions, such as eco-friendly fibres and biodegradable finishes.

Author Contributions

Conceptualization – Guru R, Grewal D, Rani J and Santhanam S; methodology – Guru R, Rani J, Grewal D, Santhanam S and Fangueiro R; formal analysis – –Guru R, Grewal D, Rani J, Fangueiro R and Santhanam S; investigation – Guru R, Rani J, Grewal D and Santhanam S; resources – Guru R, Rani J, Grewal D, Santhanam S and Fangueiro R; writing-original draft preparation – Guru R, Rani J, Grewal D, Santhanam S and Fangueiro R; writing-review and editing – Guru R, Rani J, Grewal D, Santhanam S and Fangueiro R; supervision – Guru R, Rani J, Grewal D, Santhanam S and Fangueiro R. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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