

The Influence of Weight and Thickness on Permeability and Moisture Management of Knitted Fabrics

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ABSTRACT

Understanding the relationship between fabric properties and moisture management is crucial for developing functional textiles, particularly in applications such as sportswear and medical textiles. This study examined the correlation between air permeability, water permeability, and moisture management in various knitted fabric structures. Four fabric types (Mini mesh, Interlock, Scuba, and Hexagon) were tested for their permeability and moisture management characteristics. The data were analysed using statistical methods to determine the relationships between these variables. The analysis of Hexagon fabrics indicates a strong relationship between air permeability and fabric characteristics, with an R value of 0.774 and an R Square of 0.599. For Interlock fabrics, the analysis shows limited impact of weight and thickness on permeability properties and moisture management. The R Square values for air permeability, water permeability, and moisture management are 0.045, 0.150, and 0.100, respectively. The analysis of Mini mesh fabrics reveals weak relationships between weight and thickness with air permeability, water permeability, and moisture management. For Scuba fabrics, the analysis indicates a positive relationship between thickness and moisture management, with an R Square of 0.864 for moisture management. The findings reveal that air permeability significantly influences moisture management, with its effect varying based on the fabric structure. Water permeability also contributes to moisture regulation, particularly in applications like sportswear and medical textiles. These results underline



the importance of fabric construction and material choice in optimizing comfort and performance. The study suggests that future research should include larger sample sizes and more comprehensive testing methods to enhance the understanding of fabric properties and their impact on moisture control. The insights provided are relevant for textile manufacturers and designers aiming to improve fabric functionality and comfort.

Keywords: Knitted Fabric; Air Permeability; Water Permeability; Moisture Management; Fabric Structure; Textile Properties

INTRODUCTION

Knitted fabric started as a simple way of looping yarn together to make patterns and from there, a flexible and useful material were produced. It is known for being stretchy, breathable, and easy to move in. Over time, knitted fabrics have become important in many industries. In 2023, the knitted fabric market was worth US\$ 27.99 billion, showing how much, it has grown and how widely it is used in fashion, sports, and healthcare [1]. In fashion, knitted fabrics are popular because it looks good and are comfortable to wear. This makes them a favourite for people who want clothes that feel good and look stylish. In sports, the stretchiness of knitted fabrics is used to make clothes that help athletes perform better. In healthcare, these fabrics are valued for being soft and good at absorbing moisture. This makes them useful for medical needs and shows how knitted fabrics are helping in new and creative ways [2]. Because knitted fabrics are so important in different industries, this study looks on how their physical features relate to managing moisture. It focuses on how things like air and water permeability, as well as moisture management, affect how comfortable these fabrics feel. By studying these features in different types of knitted fabrics, this research aims to show how these properties influence the functionality and comfort of the fabrics.

Knitted fabrics have asserted dominance in the consumer market owing to their remarkable properties, such as lightweight, cost-effective production, and exceptional elasticity [3]. Their versatile applications, spanning medical, protective, sports, and geotechnical domains, are intricately tied to the fabric's structural features, particularly its influence on air permeability,

water permeability, and moisture management. The process of producing knitted fabrics involves several important steps, starting with the selection of yarns. These yarns can be made from different materials, such as cotton, polyester, and spandex, depending on the desired properties of the final fabric [4]. The choice of yarn material plays a key role in determining the texture, strength, and flexibility of the fabric. Once the yarns are selected, they are prepared for the knitting process by being loaded onto a knitting machine. For weft knitting, which is one of the most common methods, a circular knitting machine is typically used. This machine interloop the yarns horizontally to create a fabric with a specific structure. The fabric structure can be adjusted by changing the knitting pattern used in the machine. For example, a cross-terry knitting structure is known to create a twill-like effect, which adds texture and style to the fabric [4]. These pattern variations allow manufacturers to produce fabrics that meet different functional and aesthetic needs.

Moisture management refers to a fabric's ability to absorb and release sweat and moisture from the body, which is essential for maintaining comfort, particularly in activewear. Ensuring that moisture is efficiently removed from the body surface in both liquid and vapor forms is critical for clothing comfort. This characteristic significantly impacts the functionality and comfort of textiles, making it a vital consideration in the design and production of fabrics [5]. Basuk explored the moisture management properties of textiles and their methods of evaluation [6]. The study emphasized the role of moisture management in high-performance sportswear and leisurewear, noting its direct impact on comfort and usability. The findings also called for advancements in moisture management techniques within the textile industry to optimize the functional properties of materials. Fabric comfort plays an important role in textile selection, especially for clothing and sportswear. It is influenced by various factors, such as the fabric's ability to manage moisture, its thermal properties, and its tactile feel against the skin. Natural fibres like cotton are commonly associated with superior comfort due to their breathability and skin-friendly nature. These fibres can effectively wick away moisture and sweat, ensuring that the wearer stays dry and comfortable during various activities [7].

The significance of fabric comfort is reflected in the growth of the global textile market. In 2023, the market was valued at approximately

USD1143.91 billion, and it is projected to grow at a compound annual growth rate (CAGR) of 4.5% from 2024 to 2032 [1]. This steady growth is largely driven by the rising demand for comfortable and high-quality textiles and clothing. Understanding and improving these distinct physical attributes are essential to enhancing the sensory satisfaction provided by textiles. This knowledge supports the production of garments that prioritize comfort while meeting diverse consumer preferences and requirements. Additionally, subjective factors like size, fit, and aesthetic behaviour (softness, handle, and drape) play a significant role in shaping the overall comfort of a textile product [8]. Permeability in textiles is a fundamental property encompassing the material's ability to facilitate the passage of air or water vapour through its structure. This characteristic holds paramount importance for the overall comfort and functionality of textile materials, finding particular significance in applications ranging from everyday clothing to specialised technical uses [9].

Additionally, research conducted by Adámek delved into establishing correlations between breathability phenomena, encompassing air flow, and predicting permeability solely based on air permeability measurements [10]. The study underscored the importance of establishing a relationship between air permeability and other breathability parameters across various textile materials.

EXPERIMENTAL METHODOLOGY

The study aims to investigate the influence of different knitted fabric structures based on their basic physical properties (weight and thickness) on water and air permeability and moisture management. The research begins with the collection of four different types of knitted fabrics structures, ensuring that the samples are large enough for all the necessary tests. All samples were produced from one company using the same types of yarn with different structures. The fibre content of each fabric sample was then identified using burning tests, and the results were documented.

Following this, the basic parameters of each fabric sample, including weight and thickness were measured using appropriate tools and methods to ensure accuracy. Three sample of fabric with diameter of 10 cm were

weighed to get the average measurement of g/m^2 for each different fabric structure according to ASTM D 3776. For thickness, ten different places of measurement were taken using thickness meter according to ASTM D 1777 and all data were averaged out. Samples were examined under the microscope of Scalar model with magnification up to 1000 times to examine the structures of those selected knitted fabrics.

The next stage involves conducting tests to measure the water and air permeability and moisture management properties of each fabric sample. Standardized testing procedures are used to ensure the reliability of the results. The ASTM D737-18 standard test method is a reliable procedure used to evaluate the air permeability of textile materials. This method is specifically developed to be universally applicable to many fabrics, such as woven, non-woven, and knitted materials. It offers a standardised approach for measuring the airflow through a specific textile material. The test measures the air permeability of the fabric under controlled settings, an essential component affecting breathability and thermal comfort. ASTM D737-18 is a highly versatile instrument in textile testing, providing significant insights into the performance of different fabric structures and assisting in creating materials that meet specific comfort requirements in a wide range of applications. Water Vapour Permeability Tester M261 ASTM E96/E96M is a commonly used standard test method that evaluates materials' water vapour transmission properties, such as textile fabrics. This standard is a vital instrument to assess the moisture management properties of a material. The process for conducting moisture management in textile knitting fabric, namely Eyelet, Mini mesh, Interlock, Scuba, and Hexagon, comprises multiple sequential steps. The methodology employed in this study is derived from the AATCC Test Method 195, a recognised standard for quantifying, assessing, and categorising the liquid moisture management characteristics of textile materials.

The collected data is then analysed using appropriate statistical methods to identify patterns and relationships between the fabric structure and the measured properties. Conclusions are drawn based on the results of the data analysis, and the implications of the findings for the use of different knitted fabric structures are discussed.

Data analysis was conducted to inspect, clean, transform, and model data to analyse helpful information, draw conclusions, and support decision-making. The test results were subsequently examined to ascertain the moisture management characteristics of the knitted textiles. This analysis frequently entailed a comparative investigation of the outcomes from several tests, together with an assessment of the structural characteristics of the textiles.

In conclusion, the study included statistical analysis. It was employed to establish the correlation between the compositions of knitted textiles and their physical attributes (such as thickness and density) and their efficacy in moisture management. The SPSS software was utilised to process and analyse all the gathered data precisely, including details about air and water permeability, physical characteristics, and moisture management. This statistical method was used to identify all the connections, enhancing the understanding of relationships within the dataset more easily. By utilising SPSS, valuable insights were obtained to enhance the moisture management capabilities of knitted fabrics, hence facilitating the development of superior materials with enhanced performance characteristics. This perspective ensured that the conclusions derived from the study were reliable and based on actual data.

RESULTS AND DISCUSSION

Figure 1 shows four types of fabrics structures used for the study. The examination under microscope shows different structures known as Mini Mesh, Interlock, Scuba and Hexagon.

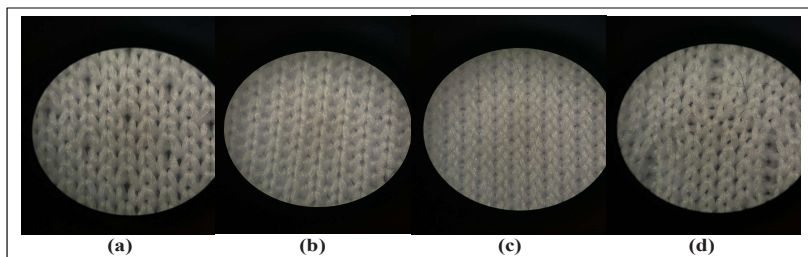


Figure 1: Fabric under microscope (a) Mini Mesh, (b) Interlock, (c) Scuba and (d) Hexagon.

Table 1 listed the basic physical properties of those four different fabric structures which include weight and thickness. Meanwhile, Table 2 listed three properties that tested on fabrics which include air permeability, water permeability and also moisture management test.

Table 1: Basic Physical Properties.

Type	Structure	Weight (g/m ²)	Thickness (mm)
A	Mini Mesh	175.67	0.55
B	Interlock	173.14	0.47
C	Scuba	238.58	0.75
D	Hexagon	174.67	0.56

Table 2: Permeability and Moisture Management Properties.

Type	Air Permeability (mm/s)	Water Permeability (g/m ² /day)	Moisture Management (OMMC)
A	1583.03	1095.6977	0.8871
B	696.58	1303.2051	0.8075
C	679.15	788.0519	0.8512
D	1600.04	788.6807	0.8606

The analysis reveals a correlation between fabric characteristics and structural designs. Scuba fabric, known for its dense structure, is identified as less effective in moisture management due to its limited air and water permeability [11]. This demonstrates that its structural properties restrict breathability and moisture control [12]. Interlock fabric, while effective in water permeability, exhibits lower air permeability and moisture management capabilities. These characteristics suggest that it absorbs moisture effectively but provides less breathability [13]. Mini mesh and hexagon fabrics are observed to maintain a balanced relationship between air and water permeability, along with management. Mini mesh is highlighted as suitable for applications requiring both breathability and moisture control. Similarly, hexagon fabric is identified as effective in providing breathability with moderate moisture management capabilities [6].

The correlation analysis in Table 3 examined the relationships between fabric characteristics (weight and thickness) and their permeability properties across different fabric types. The results revealed fabric-specific trends that provide insights into how structural properties influence performance. For Mini mesh, the analysis showed weak relationships between weight and thickness with air permeability, water permeability, and moisture management. This suggests that these characteristics have minimal influence on permeability for this fabric type, indicating its relatively stable performance regardless of structural variation. In the case of Interlock, weight and thickness were found to have limited impact on permeability properties and moisture management. The results align with its structural design, which favours moisture absorption but does not significantly enhance breathability or overall moisture management performance [14]. For Scuba, the analysis indicated a potential negative relationship between thickness and moisture management, suggesting that increased thickness may reduce its efficiency in managing moisture. This aligns with the dense and less porous structure of Scuba fabrics, which limits their permeability and moisture control capabilities [15]. Hexagon fabrics exhibited a trend where heavier fabrics appeared to have lower air permeability. This indicates that the structural density of the material influences its breathability, which is a critical factor for applications requiring high air permeability while maintaining moderate moisture management.

The analysis in Table 4 showed that Hexagon fabrics indicates a strong relationship between air permeability and fabric characteristics, with an R value of 0.774 and an R Square of 0.599. This suggests that approximately 60% of the variability in air permeability can be explained by the fabric's characteristics. However, the relationships between water permeability and moisture management are weaker, with R Squares of 0.157 and 0.072, respectively. This indicates that these characteristics have minimal influence on water permeability and moisture management for Hexagon fabrics. This finding aligns with the research by Mukhopadhyay & Midha [15], which highlights the importance of fabric structure in determining air permeability. For Interlock fabrics, the analysis shows limited impact of weight and thickness on permeability properties and moisture management [15]. The R Square values for air permeability, water permeability, and moisture management are 0.045, 0.150, and 0.100, respectively. These results are consistent with the structural design of Interlock fabrics, which favour

moisture absorption but do not significantly enhance breathability or overall moisture management performance. This observation is supported by the study conducted by Nazir, which found that knitting parameters significantly influence the moisture management and air permeability of Interlock fabrics [14]. The analysis of Mini mesh fabrics reveals weak relationships between weight and thickness with air permeability, water permeability, and moisture management. The R Square values for these properties are 0.059, 0.069, and 0.071, respectively. This suggests that these characteristics have minimal influence on permeability for this fabric type, indicating its relatively stable performance regardless of structural variation. For Scuba fabrics, the analysis indicates a positive relationship between thickness and moisture management, with an R Square of 0.864 for moisture management. This suggests that increased thickness may increase the efficiency of Scuba fabrics in managing moisture. The dense and less porous structure of Scuba fabrics limits their permeability and moisture control capabilities. This observation is consistent with the findings of Mukhopadhyay and Midha, who noted that fabric density significantly impacts moisture management properties [15].

Table 3: Correlation between weight and thickness with permeability and moisture management

	Minimesh	Air Permeability	Water Permeability	Moisture Management
Weight	Pearson Correlation	-0.143	-0.226	-0.179
	Sig. (2-tailed)	0.735	0.590	0.671
	N	8	8	8
Thickness	Pearson Correlation	0.179	-0.159	-0.218
	Sig. (2-tailed)	0.672	0.706	0.604
	N	8	8	8
	Interlock	Air Permeability	Water Permeability	Moisture Management
Weight	Pearson Correlation	-0.212	0.343	0.114
	Sig. (2-tailed)	0.614	0.405	0.789
	N	8	8	8
Thickness	Pearson Correlation	-0.067	-0.043	-0.234
	Sig. (2-tailed)	0.874	0.920	0.577
	N	8	8	8
	Scuba	Air Permeability	Water Permeability	Moisture Management
Weight	Pearson Correlation	0.268	-0.257	-0.585
	Sig. (2-tailed)	0.520	0.538	0.128
	N	8	8	8
Thickness	Pearson Correlation	0.329	0.263	-0.615
	Sig. (2-tailed)	0.426	0.529	0.105
	N	8	8	8
	Hexagon	Air Permeability	Water Permeability	Moisture Management

Weight	Pearson Correlation	-0.627	0.254	-0.147
	Sig. (2-tailed)	0.096	0.544	0.728
	N	8	8	8
Thickness	Pearson Correlation	0.120	0.387	-0.267
	Sig. (2-tailed)	0.778	0.344	0.523
	N	8	8	8

Table 4: Relationship between permeability with moisture management for different structures.

		R	R Square	Adjusted R Square	Std. Error of the Estimate
Hexagon	Air Permeability	.774 ^b	0.599	0.439	27.39102
	Water Permeability	.396 ^b	0.157	-0.180	32.87081
	Moisture Management	.269 ^b	0.072	-0.299	0.01578
Interlock	Air Permeability	.212 ^b	0.045	-0.337	33.14910
	Water Permeability	.387 ^b	0.150	-0.190	212.92064
	Moisture Management	.317 ^b	0.100	-0.260	0.18492
Minimesh	Air Permeability	.244 ^b	0.059	-0.317	32.02165
	Water Permeability	.262 ^b	0.069	-0.304	116.69213
	Moisture Management	.267 ^b	0.071	-0.300	0.00686
Scuba	Air Permeability	.465 ^b	0.216	-0.098	28.60523
	Water Permeability	.341 ^b	0.116	-0.237	27.46469
	Moisture Management	.930 ^b	0.864	0.810	0.00883

b. Predictors: (Constant), Thickness, Weight

The analysis highlights the varying influence of fabric characteristics on permeability and moisture management across different fabric structures. Hexagon fabrics show a strong relationship between air permeability and fabric characteristics, while Interlock and Mini mesh fabrics exhibit limited impact of weight and thickness on permeability properties. Scuba fabrics demonstrate a positive relationship between thickness and moisture management.

CONCLUSION

The study has identified the relationships between air permeability, water permeability, and moisture management in knitted fabric structures. These properties were analysed to understand their impact on fabric performance and comfort. The findings showed that structural factors such as weight and thickness influenced the permeability and moisture management characteristics of the fabrics. Fabrics like Mini mesh and Hexagon exhibited different permeability behaviours due to their structural differences, demonstrating the importance of fabric design and material selection in achieving specific performance requirements. Air permeability was found to facilitate moisture transport, enabling air circulation and improving moisture evaporation. Water permeability was identified as essential for the absorption and removal of liquid moisture, particularly in applications requiring efficient moisture transfer, such as sportswear and functional textiles. These results emphasize the significance of balancing fabric properties to suit the intended use. In conclusion, this study has contributed to an understanding of how knitted fabric properties affect permeability and moisture management. The relationships identified in this research can inform further studies and facilitate advancements in fabric design and performance evaluation.

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