Enhancing Moisture Wicking and Drying Rate in Linen/Cotton Fabric using Weft Knitted Structure

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I. Introduction

The fabrics used in activewear are specially engineered to support thermal and moisture regulation through the careful design of fiber geometry, yarn packing density, and overall fabric structure [1]. Synthetic fabrics such as polyester have gained popularity in sportswear due to their excellent moisture wicking and quick drying capabilities, which enhance sweat transport, improve wearer comfort and performance [2]. However, the extensive use of synthetic fibers causes environmental concerns, including increased landfills due to non-biodegradability and heavily depend on non-renewable resources like petroleum [3].

So, there is a growing interest in the sportswear industry to shift towards natural and regenerated fibers which are biodegradable and renewable to avoid the environmental damage caused by synthetic fabrics and to maintain the comfort properties of natural fabrics [4]. Regardless of their environmental advantages, natural fibers tend to absorb moisture rather than transport it, leading to longer drying times, cling to the skin and reduced comfort during physical activity negatively affecting athletic performance [2] [5].

This study aims to Develop a natural fabric with improved moisture wicking and quick drying properties using a weft knitted structure to achieve the comparable performance of the synthetic fabrics such as polyester and nylon for sports and active wear. The study will identify suitable weft knitted structures for enhanced moisture management properties, develop a concept to improve the wicking and drying rate, validate prototype fabric and propose methods to improve wicking and drying rate using natural fiber types.

II. Literature Review

Sports and active wear are used in high performance activities where sweat production is high [1] [7]. The human body releases around 60ml of water vapor per hour during rest, increasing to 450ml with moderate activity. High intensity sports such as tennis and cycling increase metabolic heat production by up to six times, resulting in an average perspiration rate of approximately 840ml per hour. Textile clothing absorbs bodily moisture when perspiring, which prevents cooling and increases sweating [5] [7]. So, during this high performance activities 60 – 80% sweat should be evaporated to maintain body cooling and prevent overheating [8]. The typical human body temperature is around 37°C, but it rises during physical activity due to an increase in metabolic rate. 1.5 - 2ºC increase in body temperature can be seen in high active sports like soccer and tennis [9]. Perspiration begins when skin temperature matches the core temperature of 37°C, helping to cool the body. Fabrics that dry quickly enhance thermal comfort by effectively channeling sweat away from the skin and into the surrounding environment, aiding in moisture regulation [7]. This temperature regulation is important as a fluctuation of ± 3.5°C from the normal resting body temperature of 37°C can lead to physical dysfunctions and potentially death [10]. Therefore, efficient moisture management and drying in sportswear fabrics are critical to maintaining thermo-physiological balance, wearer comfort and performance [1] [7] [8].

The comfort properties of high-performance sportswear can be categorized into four categories. Thermo physiological comfort-manage heat and moisture. Skin sensorial comfort-tactile sensations such as smoothness, softness, and the overall feel of the fabric against the skin. Ergonomic wear comfort-fit and freedom of movement. Psychological comfort-wearer's mental and emotional comfort depend on style, color, and overall aesthetic appeal [9]. Moisture management is defined as the controlled transport of sweat and water vapor away from the skin through the fabric to the environment, keeping the wearer cool and dry [5]. Synthetic fibers such as polyester and nylon are widely used in sportswear because of their low moisture absorption and superior wicking ability [2] [6]. However, their environmental drawbacks including non-biodegradability and heavy reliance on petroleum resources have increased interest in natural and regenerated fibers [3][4]. While these fibers are biodegradable and renewable, they inherently absorb and retain moisture, resulting in longer drying times, skin cling, and reduced comfort during activity. [2] [5].

Fabric structure plays a critical role in overcoming these limitations. The hydrophilicity or hydrophobicity of fibers, yarn density, twist, and cross-sectional shape directly influence liquid transport properties [6] [11]. Knitting parameters including GSM, loop length, and porosity further determine wicking and drying efficiency [12]. For example,

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Longer stitch lengths tend to create a looser fabric structure, which can lead to increased porosity but may result in poorer moisture management due to larger air gaps [12].

Bi-layer knitted fabrics have been identified as an effective approach for enhancing directional moisture transport. By combining layers of different structures or porosities, these fabrics create a moisture gradient that channels sweat from the inner (skin-facing) side to the outer surface, where evaporation occurs [6]. Incorporating mesh structures within one or both layers provides continuous capillary channels and increases air permeability, thereby improving both wicking and drying [13]. Previous studies confirm that bi-layer fabrics with asymmetric mesh designs perform significantly better than single-layer plain knits in terms of moisture management [13]

III. Materials and methods

The yarn Linen yarn (20/2Ne) and Cotton yarn (30/3 Ne) were selected for the inner and outer layers of the bi layer structures respectively. Six Bi layer structures were developed by incorporating porous designs, such as mesh, and varying knit-tuck-miss combinations. All the structures were programmed using One Knit Paint software and produced on the Shima Seiki 14 Gauge flatbed knitting machine, with consistent knitting parameters across all structures at the Knitting laboratory of the University of Moratuwa. Then the loop length settings were systematically varied from tight to loose, using stitch length values of 29, 33, 37, 41 and 45. This allowed for a controlled evaluation of how fabric tightness influences vertical wicking, drying rate. Yarn path notation and details of Bi layer structures presented in Table 1. Moisture management properties of commercially available single jersey sportswear fabrics (180-220) in greige form were evaluated. Polyester, chosen for their relevance in activewear to ensure real-world applicability and cotton in the same GSM and Gauge as polyester was selected for comparison.

All the samples including commercial sportswear fabrics and Bi layer structures were tested on Vertical Wicking Test adapted from AATCC 197 and Drying Test adapted from ISO 17617. All samples were conditioned in a controlled environment (relative humidity: 65 ± 3%, temperature: 20 ± 1°C) for 24 hours.

For Vertical Wicking Test, Three specimens (165±3×25±3mm), were cut with the long dimension parallel to the warp direction. A 5 mm reference line was marked. A beaker was filled with distilled water to a depth of 5 mm, and a ruler was fixed with its zero-level aligned to the water surface. The fabric specimen was suspended so that the 5 mm line touched the water. The timer was started immediately, and wicking height was recorded at 2, 10, and 30 minutes.

For Drying Test, Three 100 cm² Specimens were cut using a GSM cutter. The dry weight of each specimen was measured using an electronic scale. Then the specimen was removed and a distilled water drop (0.02g–0.03g) was placed on the specimen, and the weight was recorded. The backside of the sample was then positioned over the water drop, ensuring the center aligned with it. The combined weight of the specimen and water drop was measured, and the timer was started immediately. Weight measurements were taken at 2 minute intervals until the specimen returned to its original weight.

IV. Results and Discussion

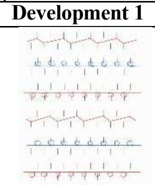
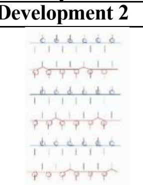
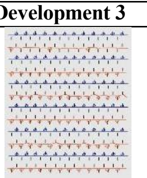
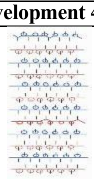
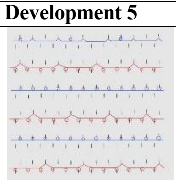
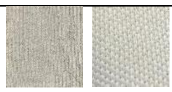
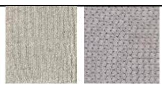
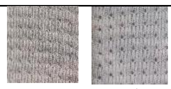
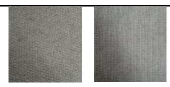
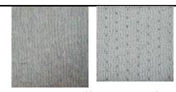
The test results of vertical wicking and drying properties of Greige Polyester and Cotton fabrics highlight the need for moisture management enhancement in natural fabrics to reach the performance levels of synthetic fabric like polyester. Based on the results, a benchmark can be established for the improvement of natural fabrics. The analysis identified polyester greige fabric, with a wicking height of 116 mm at 10 minutes and a drying rate of 0.287 g/m2.min as a reference point.

According to the ANOVA analysis of the Vertical wicking test data at 10 minutes there is a significant difference between each development with $p = 1.29 \times 10^{-8}$, $F = 74.526$ at a 95% confidence level. The mean value of each development were compared in Figure 1 and it indicated the highest wicking height in development 6 that even close to the benchmark of 116mm. This indicates that through appropriate bi-layer structure optimization, natural yarn-based fabrics can closely match the wicking performance of synthetic fabrics. Structures with mesh elements on both sides (Development 4 and Development 6) provided continuous capillary channels that facilitated upward moisture movement more efficiently than compact plain knits.

According to the ANOVA analysis of Dying test results of the Development 1 – 6 the drying rates of the fabric samples were significantly influenced by the porous structure at a 95% confidence interval, with $p = 1.29 \times 10^{-20}$, $F = 7750$. The mean drying rate values illustrated in Figure 2 indicating the difference in drying rate related to the porosity values indicated in Table 1. The highest drying rate was recorded by Development 4 which has the highest porosity value while Development 1 and 5 showed relatively low drying performance,

The ANOVA analysis of vertical wicking test results of five Bi layer structures with varying loop length setting at 10

Table 1. Yarn path, Appearance and Porosity of Bilayer structures

Development	Development 1	Development 2	Development 3	Development 4	Development 5	Development 6
Yarn path						
Appearance (Inner and Outer)	 Plain knit on both side	 Inner – Plain knit Outer – Small mesh	 Inner –Plain knit Outer–Large mesh	 Inner-Large mesh Outer–Large mesh	 Inner -Small mesh Outer-Medium mesh	 Inner–Medium mesh Outer-Large mesh
Porosity (Relative to Development 1)	-	23%	28%	36%	14%	34%

minutes, indicate that there is a significant effect of loop length on vertical wicking height with $p = 0.00017$, $F = 17.3$ at a 95% confidence level. The mean wicking height values at 10 min of these loop length variations were illustrated in Figure 3. This indicates that an intermediate loop length creates an optimal fabric density for moisture transportation. In tighter structures, high yarn packing density restricts the formation of capillary channels, which limits moisture movement. also, too loose structures have more yarn spacing and fewer small capillaries, which reduces capillary pressure, reducing the efficiency of wicking performance.

The ANOVA analysis of drying test results of three Bi layer structures with varying loop length setting, indicate that loop length has a statistically significant effect on drying rate with $p = 2.44 \times 10^{-11}$, $F = 471.44$ at a 95% confidence level. Mean value comparison of drying rate illustrated in Figure 4, and it shows that drying rate has increased consistently from loop length setting 29 to 45. This indicates the structural impact of increasing loop length, where looser fabrics facilitate higher porosity, air permeability, and surface exposure, all of which promote faster moisture evaporation.

So, balanced loop length has to be selected for improved moisture management because loose structures may not wick moisture well but facilitate drying efficiently due to increased airflow and reduced fabric thickness.

Final bi-layer prototype was developed integrating all optimized parameters. Bi-layer knit with medium mesh in the inner layer and large mesh in the outer layer (Development 6) and Loop Length (Machine value) 33. In the prototype fabric Vertical wicking height at 10 min was 126mm which is achieved the polyester greige benchmark 116mm and drying rate was 0.2526 g/m^2.min close to the polyester greige benchmark 0.287 g/m^2.min.

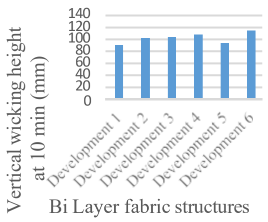


Fig 1. Mean value comparison of wicking height at 10 min of Development 1 – Development 6

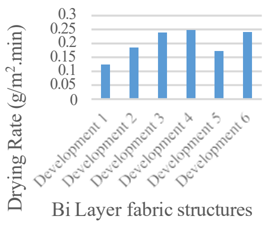


Fig 2. Mean value comparison of Drying rate of Development 1 - Development 6

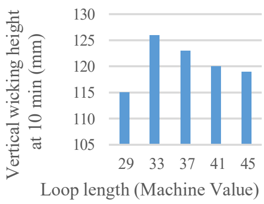


Fig 3. Mean value comparison of vertical wicking height at 10 min of development 6 with varying loop length

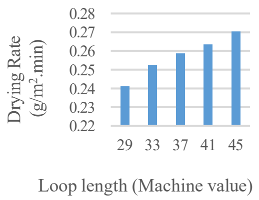


Fig 4. Mean value comparison of drying rate of development 6 with varying loop length

V. CONCLUSION

The results confirmed that the selected combination provided the best overall performance, achieving moisture management properties that were comparable to greige polyester fabric, thus validating the feasibility of using 100% natural yarns alternative to the synthetic. The study highlighted several effective strategies for improving moisture-wicking and drying performance in natural fiber fabrics without the use of synthetic fabrics.

Creating a functionally layered structure using natural yarns where the inner layer is less absorbent and the outer layer is more absorbent enables directional moisture transport from the skin to the fabric's outer surface, mimicking the behavior of synthetic sportswear. Incorporating mesh structures into both layers, especially a controlled porosity (medium mesh inside, large mesh outside), creates continuous capillary channels and improves air permeability, facilitating both moisture transport and drying. A moderate loop length was identified as best choice for balancing wicking and drying behavior. Tighter fabrics restrict moisture transport, while too loose fabrics lose capillary effectiveness. A balanced structure supports both wicking and drying performance.

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