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INVESTIGATION OF THE IMPACT OF PLASMA TREATMENT ON MOISTURE CONTROL CHARACTERISTICS IN KNITTED FABRICS BLENDED WITH COTTON AND POLYESTE

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Abstract:
The primary objective of the study is to examine how polyester/cotton composed knitted fabrics' (blended) moisture management properties are influenced by plasma treatment. Maintaining thermal comfort is essential for human well-being, and sweating is a key aspect of thermal regulation. However, sweating can lead to discomfort, making moisture management in clothing crucial, especially for protective and sportswear. This research investigates that how temperature regulation is affected by two-layer fabric structure made of various fibres as compared to a traditional fabric. Based on earlier research on fabric moisture management, the study shows that structure and composition of the fabric have a major impact on qualities related to moisture. Evaluations are done on the dispersing speed, drenching time, accumulative unidirectional transport index, largest drenched radius, absorption rates, and overall moisture management ability. The results exhibit that polyester fibres' nature of hydrophobic and moisture-wicking properties continue improving moisture transfer. Better moisture control is demonstrated by fabrics with longer loop lengths and a cross-miss structure. Air plasma treatment is also studied as a potential technique for surface modification. The results indicate that plasma treatment improves the fabric's properties to control moisture, which further strengthens its capacity to wick away perspiration and give comfort to the wearer.
Keywords: Cotton, Knitting, Moisture, Plasma, Polyester, Structure

Introduction

The average body temperature of a human is 37 degrees Celsius, and they are continuously interacting with their surroundings. Sweating is a vital component of this temperature regulation, even though it can be uncomfortable for certain people (Prakash et. al., 2019). A garment's comfort level is determined by its moisture management qualities, which assess the fabric's capacity to control moisture (Karthikeyan et. al., 2017). This is particularly crucial for sporting and protective apparel because physical activity increases perspiration (Karthikeyan et. al., 2017; Ramakrishnan et. al., 2015). Hydrophobic fibres enable fabrics to swiftly release moisture and start the drying process. However, they may not prevent the fabric from feeling wet. Fabrics with high hygroscopicity, on the other hand, have lower drying efficiency. As a result, it is thought that the two-layer structured fabrics —that is, layers with distinct properties—has superior temperature regulation than a single-layer fabric. Two-layer textiles composed of Knit and woven fabric were investigated by Geralde et al. (2002) and Zhu et al. (2017); these materials showed good moisture management qualities even in the absence of additional treatment. Rapid sweating happens as the body cools down and releases extra heat during physical activities like sports, work, and exercise. The wearer`s stage of bodily hobby and the cloth moisture management abilities significantly have an impact on how successfully perspiration is transferred from the skin's floor with the aid of using the garment. Thus, the wearer's consolation mainly relies upon at the cloth moisture management properties. Many researchers investigated these properties and testing methods (Onofrei et. al., 2011; Sarkar et. al., 2007; Schuster et. al., 2006). A Moisture Management Tester (MMT) was created by Hu et al. (2005) and is used commercially to measure the multifaceted liquid moisture transportation of Knit and woven fabrics. It also discovered that, in comparison to cellulose fibres, polyamide fibre has better overall moisture management qualities and efficiently transfers perspiration away from the body. Süpüren et al. (2011) examined how cotton and polypropylene fibres managed moisture in textiles. They found that using polypropylene fibers for the inner layer and cotton fibers for the outer layer improved moisture management. The water transport behaviour of Knit fabrics derived from recycled bamboo fibres was tested with different cover factors by Wardiningsih and Troynikov (2011). They noticed that when the cover factor rose, the moisture management properties reduced.

According to Namlıgöz et al. (2010), mixes of cellulose and polyester have superior liquid transport than blends of cotton and polyester. The moisture absorption characteristics of double-layered Knit fabrics, produced from combinations of polyester with wool and bamboo with wool was researched by Troynikov and Wardiningsh (2011). They found that, in comparison to blends of polyester and wool, materials blended with bamboo and wool exhibited better overall hygroscopicity qualities. To give fabric comfort, textile materials must effectively control moisture. The fibre material's moisture-related capacity depends on the fibre blending technique, the characteristics of the fibre components, and the ratios of the various fibre kinds (Prakash et. al., 2013; Karthikeyan et. al., 2017).

Plasma treatment was examined by Kan and Yuen (2006) as a mechanical and chemical technique for altering fabric surfaces without affecting the material's overall characteristics. According to Leroux et al. (2009), the formation of carboxyl and hydroxyl groups during air and atmospheric plasma treatment greatly increased the surface energy, water wettability, and water capillarity of polyester fabrics. Building upon the findings of Seki et al. (2010), this study investigates the enhancement of jute/ploymet's tensile strength and flexural strength using oxygen plasma treatment. The primary objective of the study is to examine how the moisture management properties of Knit fabrics (blended) composed of polyester/cotton is influenced by plasma treatment.

Patients and the Method

Patients

In this study, we utilized polyester fibers and cotton fibers, blending them in three different ratios: 100% polyester, a 50:50 mix of polyester and cotton, and 100% cotton. We then transformed these blends into yarns with a linear density of 19.7 Tex using the ring spinning method. To conduct our experiments, we prepared various single jersey fabric specimens, including those exclusively made from polyester fibers, those entirely composed of cotton fibers, and those containing cotton and polyester blended at the ratio of 50:50 blend of polyester and cotton.

Development of Knit fabric

A standard single jersey knitting machine to create Knit materials. These materials were then used to create specimens that underwent three relaxation states: DR, WR, and FR. From these relaxed specimens, we cut fabric specimens of standard dimensions and processed them for testing their thermal comfort, moisture management, and stretchability properties. The machine parameters remained constant throughout the process. We employed a Mayer & Cie knitting machine, which offered various structures including cross tuck, twill, cross miss and single jersey.

We combined polyester (150 denier) and cotton (36s) fibres in three different ratios—100:0, 50:50, and 0:100—for our study. These mixes were tested at 0.32 cm and 0.39 cm, separate loop lengths, in 4 structures namely single jersey, twill, cross miss, and cross tuck,.

Plasma Treatment

A vacuum plasma apparatus manufactured by Diener Electronic GmbH was utilized for treating the Knit materials. The process involved placing the fabric samples between two electrodes within the device. To control the working pressure, a vacuum pump was employed. After 10 minutes of evacuation, the electricity was reactivated. The glow discharge process commenced with a gradual increase in plate current. The power control knob played a pivotal role in adjusting the electrical current flowing between the electrodes. All plasma treatments were conducted using a consistent glow discharge plasma device that operated in an air-gas atmosphere. Each plasma therapy session lasted for precisely 10 minutes by operating the machine at 70KHz frequency. 7 cm distance is used between the electrodes for positioning the samples.

Moisture management properties determination

An experimental study following the guidelines outlined in American Association of Textile Chemists and Colorists Test Method 195-2009. Our objective is to assess the characteristics of moisture management of the fabric used in manufacturing socks. To achieve this, we employed a MMT (manufactured by SDL Atlas, USA). This specialised tester provides information about the dynamic liquid transport capacities of a fabric by working based on electrical resistance.

Essentially, it measures electrical resistance by considering conductivity and volume of liquid present on the fabric's surface. Even though a liquid's electrical characteristics are often quite stable, the electrical resistance that may be detected on the surface of a fabric can reveal how much moisture is present in the material. With an accuracy of 0.1 cm², we meticulously chosen sections of fabric measuring 8.0 cm × 8.0 cm to make our sample. 24 hours is the conditioning period of the samples where it is cleaned and kept wrinkle free and smooth. We tested the moisture management properties of each fabric samples using the MMT). We next carefully examined the outcomes and assessed these fabric samples' moisture contro capabilities. These fabric specimens were categorised according to their appropriate grades and moisture management indices.

Results and Interpretations

Drenching time

The time taken for the entire fabric to become wet is called "drenching time," and it is often expressed in seconds. In this situation, we refer to the drenching times of the crown layer as WTt and the lower layer as WTb. Droplets of simulated sweat solutions are first applied to the fabric's outside to evaluate this (Yao et al., 2006). The drenching timings of a cotton fabric sample are shown in Figure 1 for both the surfaces. Obvious result is that the fabric's bottom layer dries down more slowly than its crown layer. This is because the fabric's crown surface is first moistened by the sweat simulation before progressively moving down to the bottom surface. The fabric composed of 100% polyester yarn fiber exhibits a shorter drenching time. This is because fabrics made from 100% polyester yarn can rapidly absorb and transport water to the other layers. Polyester fiber's hydrophobic nature and moisture-wicking capability contribute to this quick water movement. Consequently, fabrics composed entirely of polyester yarn fiber move water more efficiently than other fabric samples.

Furthermore, due to its smaller fabric cover area, which offers more room for water to travel through, the fabric with a loop length of 0.32 cm exhibits the quickest drenching time. This data unequivocally shows that a smaller fabric cover area leads to a shorter drenching time. Additionally, drenching periods are considerably shortened after air plasma treatment since the fabric surface has been superficially etched.

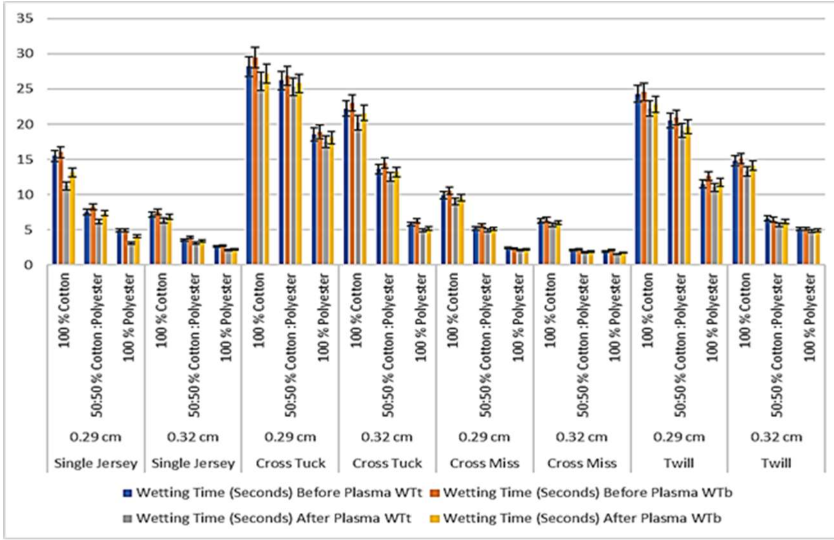

Figure 1 – Graphical representation of Double Knit fabrics' drenching time

Rates of Absorption

The rate at which a fabric absorbs moisture primarily raises on the porous arrangement within the yarn and fiber structures. Figure to depicts the rate of absorption of both the surfaces of the fabric. Especially, the rate rises with % of polyester fibre. It is interesting to state that the crown surface absorbs excess than the other surface.

It is a cross-miss structured fabric with the 0.32 cm as loop length, which results in the maximum absorption rate. The rapid absorption and transmission of water is made possible by the cross-miss fabric structure and the polyester fibres included in these phenomena. It's important to note that air plasma treatment increases the fabric's absorption rate even more.

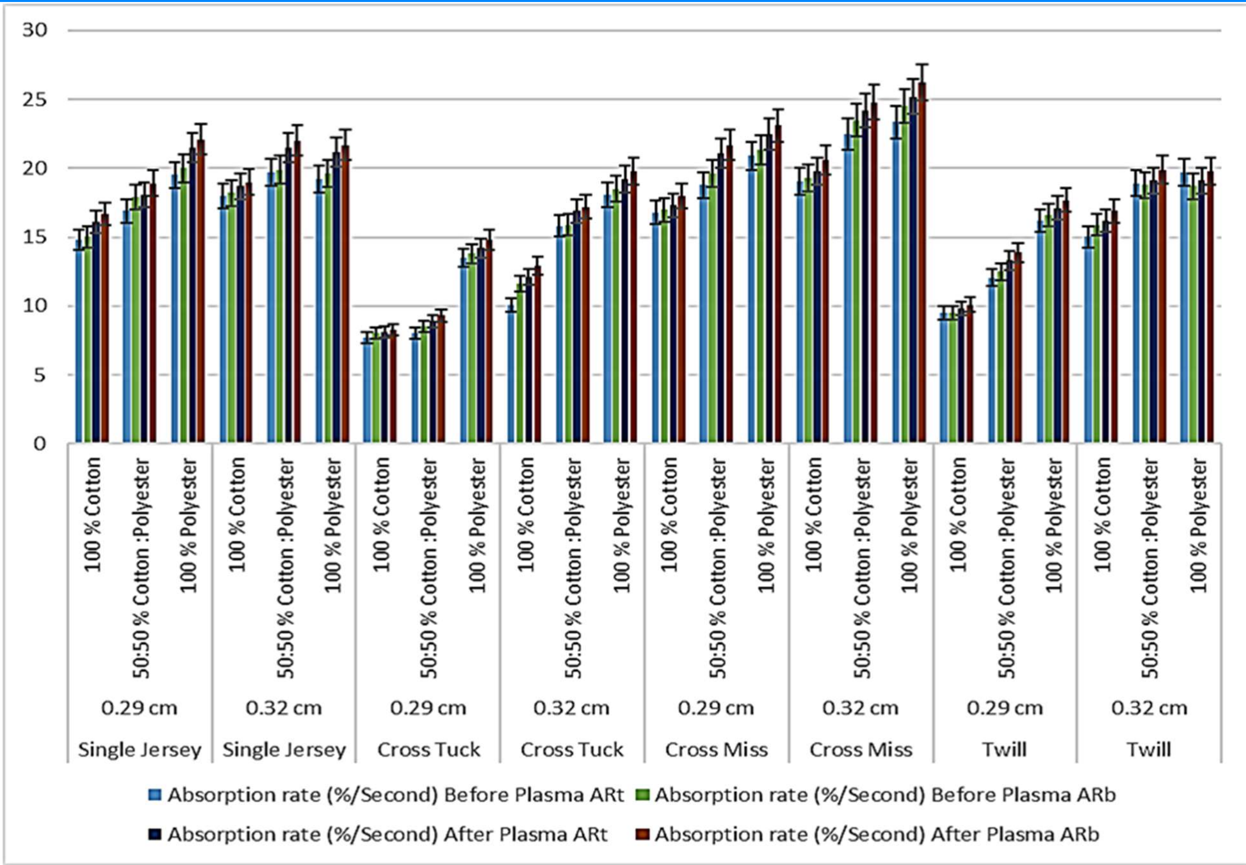

Figure 2 Graphical representation of rate of absorption

Largest drenched radius

Figure 3 depicts the largest drenched radius on both the surfaces of the fabric. It reveals the rise in drenched radius when the polyester fibres % in the fabric increases. The reason behind these phenomena is the distinct capillary force characteristics of polyester fibres, which enable the quick dispersion of liquid perspiration over a greater surface area of the material. To further contribute to this increase in drenched radius, polyester fabric also has low hygroscopicity and breathability, which leads to greater ability to transmit water vapour through it. On the other hand, the largest drenched radius reduces as the fabric's cotton fibre percentage rises. The main cause of this is that cotton cloth has sticking strands that prevent moisture from wicking away. Notable point is that for moisture transmission determination, the key factor is the structure of the cloth. Fabrics with rapid drying properties and less wetness tend to provide the wearer with increased comfort (Barnes et. al., 1996; Su et. al., 2007). Materials possessing a cross-miss structure exhibit a significantly greater largest drenched radius. The fabric loop length of about 0.32 cm has a more visible effect. Longer loop lengths are generally related with looser-structured materials, which allows for a larger drenched radius. This largest drenched radius is further enhanced by applying air plasma treatment.

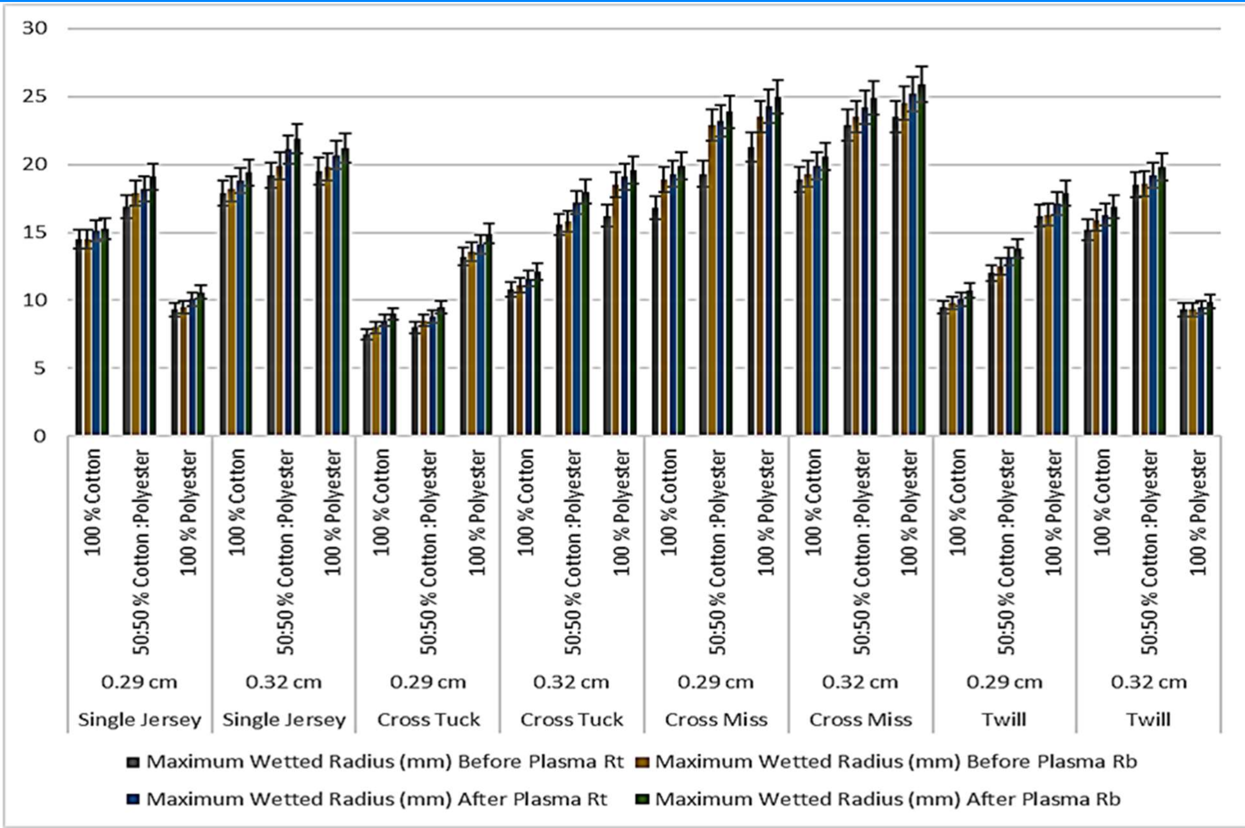

Figure 3 Graphical representation of Largest drenched radius

Dispersing speed

A fabric ability to dry quickly and enhance wearer comfort depends critically on how quickly moisture penetrates through it. The rates at which the textiles crown and bottom surfaces spread is shown in Figure 4. The pace at which the cloth spreads increase with the percentage of polyester fibre. The larger surface area of polyester fibres, which promotes quicker liquid evaporation, is mostly to affect. In addition, cross-miss structure with loop length as 0.32 cm accelerate the dispersing speed. Moreover, the dispersing speed is increased by atmospheric pressure plasma treatment.

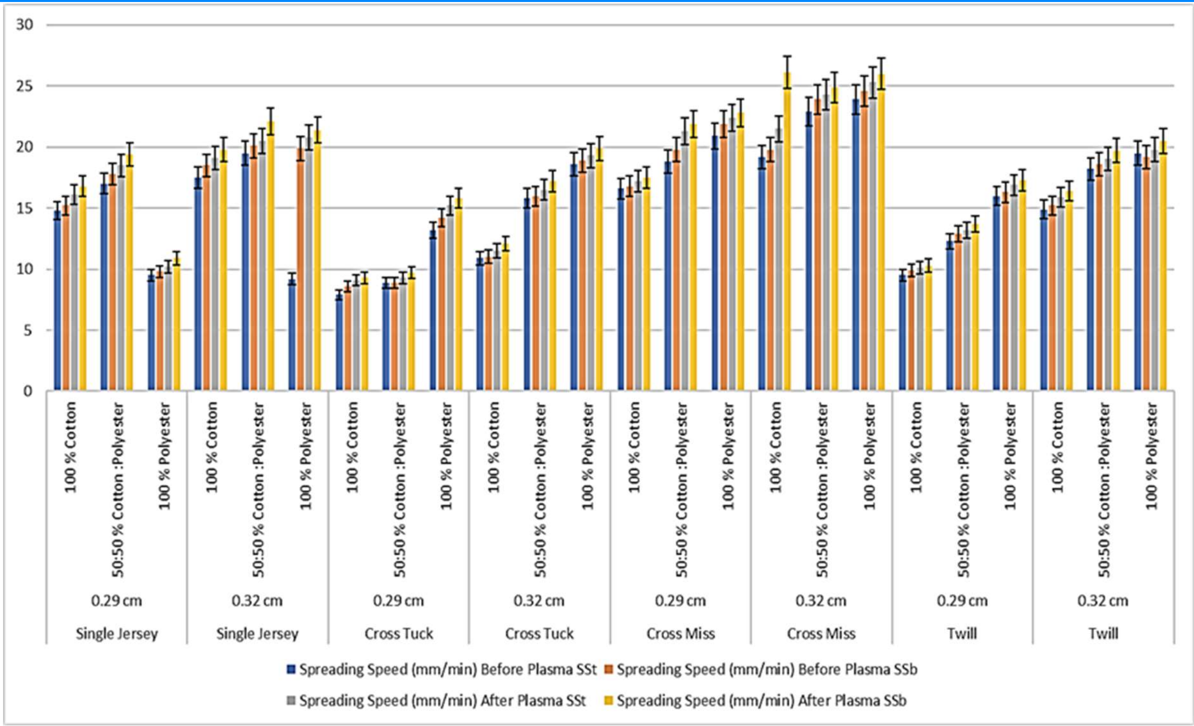

Figure 4 – Graphical representation of Knit fabrics' Dispersing speed

Accumulative unidirectional Transport Index

The Cumulative Unidirectional Transport Index for blended cotton and polyester fabrics is shown in Figure 5. Especially, the Cumulative Unidirectional Transport Index similarly rises as the polyester fibre content performs. Fabrics made predominantly of cotton, on the other hand, have a lower cumulative Unidirectional Transport Index. This is because they have a propensity to take in and hold onto perspiration inside the fabric structure, giving the wearer a feeling of moisture. Additionally, the Cumulative Unidirectional Transport Index experiences an increase with a cross-miss structure with loop length as 0.32 cm1. Furthermore, the application of atmospheric pressure plasma treatment enhances the rate at which moisture spreads through the fabric.

Overall Moisture Management (MM) Capacity

Figure 6 illustrates the comprehensive MM capabilities of cotton/polyester blended fabrics. Notably, fabrics crafted from polyester fibers stand out with the highest whole moisture management capacity. This distinction arises from polyester's remarkable capillary properties, which swiftly transport liquids (Babu et al., 2015). Consequently, garments fashioned from polyester fibers excel in efficiently whisking away sweat, thereby enhancing wearer comfort. On the other hand, the total moisture management capacity decreases as the cotton fibre content rises. Due to its high hygroscopicity and hydrophilicity, cotton has poor moisture regulation, which is the cause of this tendency. Additionally, when a cross-miss structure with loop length as 0.32 cm are used, the overall moisture management capacity shows an increased trajectory. Moreover, the liquid distribution is accelerated by applying atmospheric pressure plasma treatment

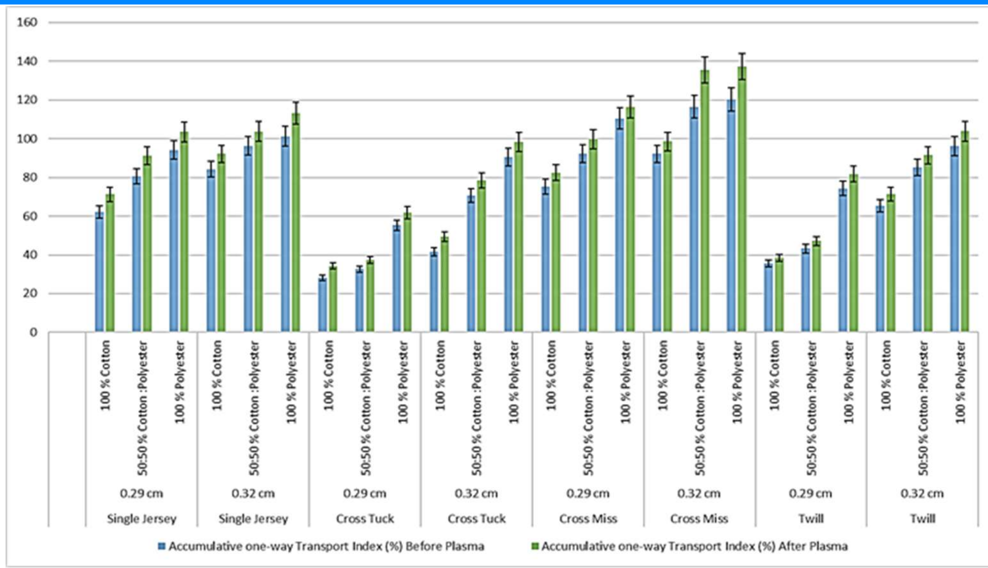

Figure 5 Accumulative unidirectional transport index graphical representation

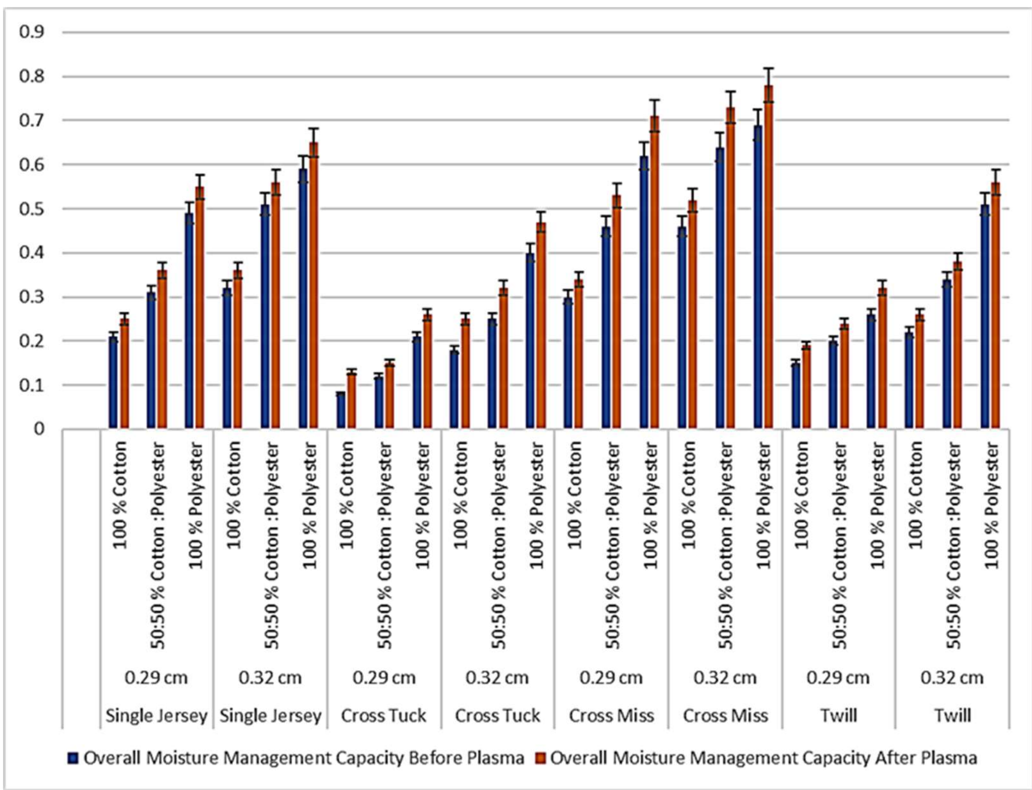

Figure 6 Graphical representation of Knit fabrics Over all Moisture management capacity

Conclusion

According to our research, the drenching time decreased as the blend's percentage of polyester fibres rose. In addition, the drenching time dropped when a 0.32 cm loop length and a cross-miss structure were present. Additionally, higher polyester fibre content, the existence of a cross-miss structure, and a loop length of 0.32 cm were associated with improved drenched radius, dispersing speed. absorption rate, accumulative unidirectional transport index, and overall moisture management capacity. It is noteworthy to mention that the cotton/polyester blended fabric's overall moisture management capabilities were greatly enhanced by the use of atmospheric pressure plasma treatment.

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