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The Effect of Softeners Applications on Moisture Management Properties of Polyester/Cotton Blended Sandwich Weft-Knitted Fabric Structure

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Abstract: Prolonged drying times of terry fabrics is a problem as they can not be re-used until completely dry. To resolve this issue, we have designed a sandwich polyester in the mid-layer with low moisture content that could reduce the drying time with excellent wicking properties. These fabrics are widely used as activewear and sportswear. The effect of different softeners on the moisture management properties of weft-knitted terry fabrics' for various applications has also been studied. Terry knitted fabrics were prepared using a circular knitting machine. Six different softeners were applied with three different concentrations, i.e., 10 g/L, 15 g/L, and 20 g/L, on the fabric using the pad-dry-cure method. Moisture management tests and rubbing fastness tests were performed to analyze the applied softener's effect on the fabric comfort and moisture management performance. Results revealed that softener type (i.e., cationic, anionic, and non-ionic) and concentration levels considerably affect the moisture management capability of terry knitted fabrics.

Keywords: softeners; moisture management; polyester/cotton; knitted; terry fabrics

1. Introduction

The strenuous activity of sportsman cause sweat and the cloth next to the skin will get wet which cause a sense of discomfort to the wearer. Especially during sports activity, continuous sweat excretion from the body takes place. Hence, a quick-drying mechanism is required to enhance the performance of the wearer during the game. Generally, the faster the fabric can wick moisture, the moisture covers more surface area, allowing the moisture to evaporate faster, leaving the wearer dry and comfortable. Transfer of liquid moisture, especially in clothing, significantly affects the wearer's sensation regarding moisture comfort. Sweating and evaporation play a key role in the human body cooling mechanism [1,2]. Moisture management is the regulated movement of perspiration from the skin surface to the atmosphere via the fabric. The human body is a complex system that needs to be in equilibrium to perform essential functions correctly. During activities such as rest, exercise, and work, the body generates heat, and sweat is released to remove excess heat produced inside. To protect the human body's comfort, water vapor must carry excessive heat away from the skin [3]. If the produced sweat remains on the skin, then the surface temperature will drop, which will lead to the feeling of coldness and wetness. Transmission of sweat from the skin by the clothing mainly depends on the two factors, i.e., the transmission of the sweat from the skin surface by clothing and quick removal of moisture at the end of the activity. The clothes' sweat absorption and transmission capability depend on the fabric structure, fiber type, yarn type, and finishing treatments [4]. Moisture management is one of the key indicators determining the fabric comfort level, which is considered the main criteria of the present apparel industries. The wearing of the garment with excellent moisture transport properties encourages the capability of body self-cooling. Self-cooling of the skin causes less sweat, and the body maintains maximum performance for a long time. Athletes and military persons realize that appropriate moisture management improves endurance and physical performance [5].

Except for softeners, many other factors affect the moisture management of the fabric. Hydrophilicity or hydrophobicity of any fabric depends on the availability of polar and non-polar groups in the fabric. Cotton fibers have good moisture absorption but low moisture transport. Polyester fibers have low moisture absorption, but their moisture transport properties are excellent because of the few bonding sites available for water [6]. Oner et al. compare the effect of fiber type, fabric type, and tightness factor on the plain jersey's moisture management properties, pique jersey, rib knitted fabrics made of polyester, cotton, and viscose fibers. It has been found that rib polyester fabric with loose structure performs better in terms of moisture-wicking [7]. Better moisture management has been observed in multichannel fibers than round channel polyesters. Fabrics manufactured from fine diameter fibers show enhanced moisture management [8,9]. Fangueiro et al. found that the fabrics' wicking behavior mainly depends on the fabric structure, while the drying depends on the type of material used [10].

Supuren et al. reported that increasing the twist coefficient, the absorption time and spreading speed decreases, and wetting time increases [11]. By increasing the stitch length of interlock knitted fabrics, a significant decrease has been observed in the spreading speed and absorption rate while wetting time shows an increase [12]. Considering fabric structures, Sampath et al. found increasing tuck stitches in the fabric; the absorption time significantly increases due to the surface thickness [13]. Applying polysiloxane and hydrophilic polyurethane-based moisture management finish on the knitted fabric was reported with enhanced moisture management properties [14]. Balci et al. studied various silicon softeners' effects on the fabric's mechanical, thermal, and moisture management properties. Results revealed that hydrophilicity, air permeability, and transmission of moisture properties get worse [15]. Duru et al. explored the effect of different softeners and their concentrations on the fabric's drying and wicking performance. An increase in softeners concentrations hurts the fabric's wicking performance [16]. Hassan et al. applied different softeners and finishes on the 100% polyester weft-knitted jersey fabrics and studied their strength, pilling, and wicking behavior. They discovered that softener and finished marginally enhanced the knitted fabric's vertical wicking properties [17].

Much work has been done on the effect of fiber type, yarn parameters, fabric parameters, fabric structures, finishes, and softeners treatment on the moisture management properties of various knitted fabric structures of plain jersey fabric like all knit, fleece, honeycomb, and pique. However, as per the best of our knowledge, no work has been done yet on the effect of softeners on the moisture management properties of terry knitted fabric. These fabrics are widely used as activewear, where moisture management is the key requirement to maintain body comfort. Researchers have developed weft-knitted structures of natural fibers for sustainable textiles [18] and biomedical applications [19].

As the terry fabrics are commodity items, their utilization is in abundance. Therefore, herein, we have developed a polyester/cotton blended knitted terry fabric structure with sandwich polyester filaments, to enhance fabric moisture management and studies the effect of different type of softeners and their concentration on the moisture management of developed fabrics so that, these could provide optimum results for applications where sweat is a problem. For this purpose, six softeners were selected that were commercially applied in various textile industries and then applied them in different concentrations on terry fabrics to check their effect on the fabric's moisture management properties.

2. Materials and Methods

2.1. Materials

Herein, 30/1 polyester/cotton (55/45%) blended main yarn, 50 denier polyester binding yarn, and 12/1 polyester/cotton (55/45%) blended terry yarn were purchased from Xinxiang Kejie Textile Co. Ltd. (Xinxiang, China). Hydrogen peroxide (bleaching agent) and reactive dye were purchased from Hangzhou Emperor Chemical Co., Ltd. (Hangzhou, China). Non-ionic softeners (Siligen SIM Liq, Siligen BH Liq conc., and Siligen SIH Liq), cationic softener (Cepreton UA Liq), and anionic softeners (Solusoft L-VC Liq and Solusoft MW liquid conc.) were purchased from Archroma Pakistan Ltd. (Faisalabad, Pakistan).

2.2. Method

2.2.1. Knitted Fabric Preparation

Single jersey terry fabric was developed using a circular knitting machine with a diameter/gauge of 34/24. The fabric was manufactured of 30/1 polyester/cotton (55/45%) blend as the main yarn, 50 denier polyester filament yarn as a binding yarn, and 12/1 polyester/cotton (55/45%) blended yarn as a terry yarn. Stitch lengths were kept 2.57 mm, and the overall fabric aerial density was recorded as 320 g per square meter.

2.2.2. Bleaching and Dyeing of Fabric

Grey fabric contains oil stains, which can cause uneven dying of the fabric. To overcome this issue, the fabric was bleached with a solution that includes the recipe caustic soda NaOH Flakes (2 g/L), felosan RGN (0.5 g/L), hydrogen peroxide H_2O_2 (4 g/L), and acetic acid CH_3COOH (0.5 mL/L). A gas burner was used for bath heating. The temperature was gradually increased by the rate of 2 °C/min. The bleaching process takes place at 95 °C for 45 min. After completion of bleaching time, the fabric was washed with ordinary water, squeezed, and dried. The bleached fabric was then dyed using recipe 2% reactive dye, 1 g/L leveling agent, 10 g/L soda ash, and 40 g/L salts. The temperature was gradually increased by the rate of 3 °C/min. The dyeing process takes place at 60 °C for 20 min, and the fabric was washed.

2.2.3. Softeners Application

Six different softeners (Solusoft VC (liquid), Cepreton UA liquid, Solusoft MW, Siligen BH (liquid), Siligen SIH (liquid), and Siligen SIM (liquid) each with three concentrations 10 g/L, 15 g/L, and 20 g/L and 1 g/L acetic acid were padded on the fabric separately for 15 min. Then the samples were dried at 110 °C for 3 min and finally cured at 130 °C for 1 min. Overall, nine samples were exposed to each softener, having 3 replicates for each concentration. Softener names, concentrations, and its codes are given in Table 1.

2.3. Characterization

To check the moisture management behavior of the developed samples, all necessary characterizations are crucial. Different tests were performed to analyze the moisture management capability, physical and chemical properties of fabrics as mentioned below.

2.3.1. Moisture Management Tester (MMT)

A tool was developed in conjunction with a test method named Moisture Management Tester (MMT) (model M290 by SDL Atlas, Shenzhen, China) to replicate the diffusion of sweat from the human body and its actions on the surface (inner and outer). MMT consists of two combined sensors. The bottom and top of the fabric to be examined are mounted between sensors to contact the upper sensor into the side that touches the human skin. It can be used to obtain various indices to characterize moisture management. To test samples on moisture management tester, AATCC standard method 195-2000 was followed, and samples were prepared accordingly. A sodium chloride solution (1 L distilled water having 9 g NaCl) was used as sweat.

Table 1. Softeners names, codes, and concentrations.

Sr.	Softener Name	Code	Concentration (g/L)
1 2 3	Solusoft VC (liquid) *Anionic*	A10 A15 A20	10 15 20
4 5 6	Cepreton UA liquid *Cationic*	B10 B15 B20	10 15 20
7 8 9	Solusoft MW *Anionic*	C10 C15 C20	10 15 20
10 11 12	Siligen BH (liquid) *Non-Ionic*	D10 D15 D20	10 15 20
13 14 15	Siligen SIH (liquid) *Non-Ionic*	E10 E15 E20	10 15 20
16 17 18	Siligen SIM (liquid) *Non-Ionic*	F10 F15 F20	10 15 20

2.3.2. Overall Moisture Management

This index is used for the quantitative measurement of the overall liquid moisture transport capacity of the fabric. This test measures the change in the electrical resistance value when moisture passes through the fabric based on a difference in the electrical resistance concerning water content in the cloth [11]. It has a rating from 0 to 1, a rating of 1 means excellent OMMC.

2.3.3. Accumulative One-Way Transport Capability (AOTC)

The AOTC measures the one-way liquid transfer capability of the fabric from the top surface to the bottom surface. It is the accumulative moisture content difference between the two surfaces of the fabric [20].

2.3.4. Wetting Time

Wetting time of WT and WB represents the time in second (s) in which the top surface and bottom surface of the fabric begin to get wetted after the test is started and the slope of total water contents at the top and bottom surfaces become greater than tan (15°) respectively [20].

2.3.5. Absorption Rate

Water absorption is a phenomenon that shows the interaction of the molecules of the water and the fiber substance. AT and AB's absorption rate represents the average moisture absorption capability of the pump time's fabric's top and bottom surfaces, respectively [21].

2.3.6. Spreading Speed

Spreading speed is defined as the accumulative spreading speed from the center to the maximum wetted radius [21].

2.3.7. Rubbing Fastness

The rubbing color fastness refers to the ability to keep dyed textiles in the original color without fading. Dry color rubbing refers to the state of color fading and dyeing if rubbed with a regular white cloth.During rubbing with white cloth the quickness in wet colors refers to fading and staining white cloth, whose water content is 95–105%. Rubbing colorfastness divides into 5 grades, the highest of which is grade 5, and the worst is grade 1. Following standard method AATCC 8-2016 [22], Rubbing fastness tests were carried out on a crock meter (model M238 AA, by SDL Atlas).

3. Results and Discussion

3.1. Effect of Softeners on OMMC

Liquid (sweat) transportation through the micropores of the treated knitted fabrics surface can be calculated by an index called OMMC. Softeners are finishing agents for textiles to improve fabric smooth or slippery feel. These are some types of lubricants and may block pores when applied to the fabric surface. That is why optimum concentration is necessary for softeners; otherwise, they reduce OMMC negatively in moisture handling. Moisture management capability is classified according to the OMMC indices, as follows [23].

- 0–0.2 Very poor
- 0.2–0.4 Poor
- 0.4–0.6 Good
- 0.6–0.8 Very Good
- 0.8–1 Excellent

The OMMC results show the effect of various softeners and their concentrations on OMMC at 20 °C. OMMC value of plain sample (untreated) is 0.50 given in Table 2. The OMMC values of A10, A15, and A20 were found 0.57, 0.66, and 0.58, respectively, as shown in Table 2 and Figure 1. These values indicate that by increasing softener A's concentration beyond 15 g/L, the value of OMMC shows deterioration because this finish blocks the surface pores, which reduces the moisture handling property. Optimum concentration is necessary to balance OMMC with fabric finishing. When the concentration was increased from 10 to 15 g/L, the OMMC shows increase, and the fabric showed better moisture management with an initial rise of softener A's concentrationFurther increase in the concentration from 15 to 20 g/L decreased the OMMC from 0.66 to 0.58. The decrease in the OMMC with further increase in softener's concentration could be explained based on pore-clogging as the softener tends to form a layer. Thus, it could be concluded that there is no linear relationship between the OMMC and the concentration of softener A.

For softener B, the values of B10, B15, and B20 were recorded as 0.54, 0.52, and 0.47, respectively, as shown in Figure 1. Results show that initially, by increasing concentration from 10 g/L to 20 g/L, the OMMC value shows a gradual decrease because higher concentrations block the surface pores, which deteriorates the overall OMMC value. The decreased value of the B softener treated fabrics could be due to the softener's cationic nature. The cationic softeners have a natural tendency towards anionic cellulosic materials. The available hydroxyl groups decrease with such softeners' application, resulting in fewer to almost no functional groups. Therefore, when the water has limited access to the fabric's water-loving groups, the absorbency decreases, ultimately influencing the OMMC values. The results follow the previously published literature where it was highlighted that such softeners tend to reduce the absorbency of the cotton fabrics [24].

We can see in Figure 1, that softener C's effect on the OMMC of surface-treated knitted fabric is like solusoft VC. The impact of change in concentration is more prominent. The 5-point increase in softener C concentration (from 10 g/L to 15 g/L), OMMC value shows a significant increase from 0.65 to 0.76, very prominent important from an industrial point of view. Hence, softener C has a drastic effect on the finishing of fabric concerning concentration. Moreover, a higher value of OMMC (0.76) can be achieved at an optimum concentration (15 g/L). The solusoft VC is an anionic softener. Thus, it does not reduce the treated fabrics' absorbency as water can make a hydrogen bond with anionic species.

Table 2. OMMC Values of softeners applications against different concentrations.

Softener Codes	OMMC	SD (±)
Plain	0.50	0.003
A10	0.57	0.009
A15	0.66	0.004
A20	0.58	0.015
B10	0.54	0.007
B15	0.52	0.003
B20	0.47	0.004
C10	0.65	0.015
C15	0.76	0.007
C20	0.70	0.008
D10	0.50	0.004
D15	0.54	0.016
D20	0.49	0.009
E10	0.52	0.008
E15	0.50	0.004
E20	0.50	0.007
F10	0.51	0.009
F15	0.47	0.009
F20	0.45	0.0015

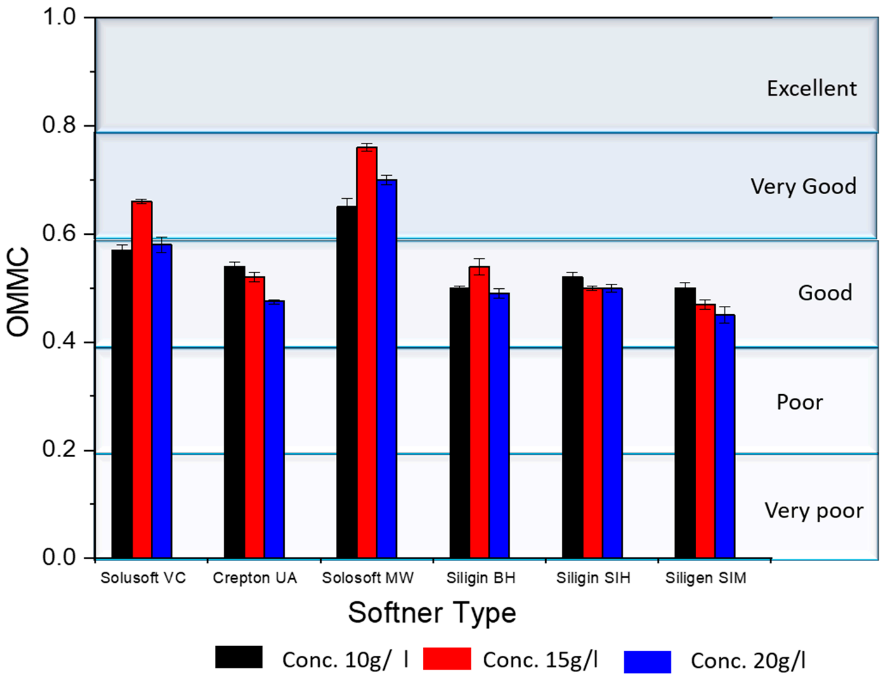

Figure 1. Effect of Softener type and concentration on OMMC of the terry knitted fabric.

In softener D, increasing concentration shows inverse effect initially on OMMC from 10 to 15 g/L, however, this effect has been observed directly by increasing concentration from 15 to 20 g/L because of the availability of cotton content in fabrics. This silicon-based softener will block the pores when we increase concentration from 10 to 20 g/L, causing low moisture content handling through the fabric. So, 10 g/L could be the optimum concentration in softener D when dealing with OMMC. The same trend has been observed with softeners E, and F. Lower quantity of these softeners could improve fabric feel and OMMC. It is also essential in terms of economic and technical aspects. At 10 g/L, the OMMC values for softener D, E, and F are 0.50, 0.52, and 0.51, respectively, which is considerably high concerning finishing quality. The silicone-based non-ionic softeners make a smooth layer on the fabric. The formation of layer blocks the passage and ability of the water molecules to interact as described previously. Therefore, these softeners also reduced the OMMC at higher concentrations. Though, at low concentrations, the effect was not that prominent.

3.2. Wetting Behavior of the Fabric

Figure 2 shows the wetting index of knitted fabrics with the application of different softeners at different concentrations. The softeners A and C (Solusoft VC and Solusoft MW anionic in nature) generally showed the minimum time required for wetting. In contrast to other softeners, softeners A and C showed higher wetting values at the fabric's bottom (outer) surfaces than top (inner) surfaces, as shown in Table 3 and Figure 2. Effect of concentration seems more dominant on softener C (Solusoft MW anionic in nature). It shows the lowest wetting time value of 4.27 at 15 g/L concentration. However, Softener D shows the highest value of wetting time, 22.1 at 20 g/L. Softener D (Siligen BH non-ionic) generally showed the highest wetting times than other softener types at all concentration levels.

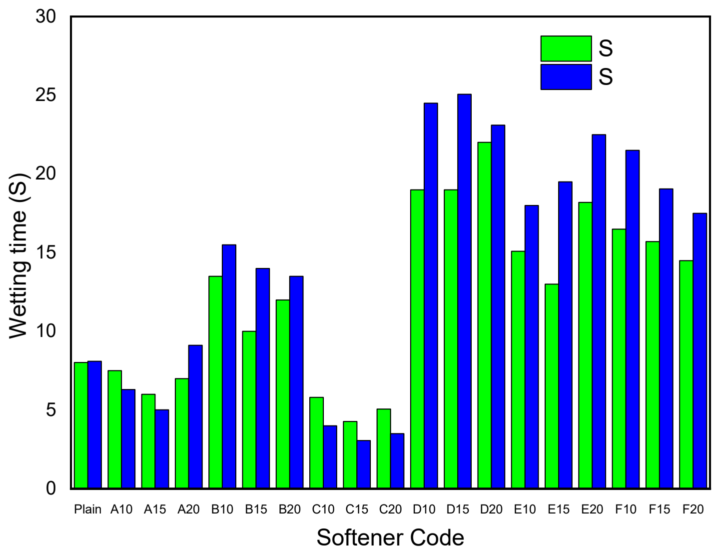

Figure 2. Wetting index of terry knitted fabric with the application of different softeners.

Table 3. Effect of Softener type and concentration on wetting time, absorption, and spreading speed of the fabric.

Softener Code	Wetting Time (Bottom) S	Wetting Time (Top) S	Absorption Rate (Bottom) %/s	Absorption Rate (Top) %/s	Spread Speed (Bottom) Mm/s	Spread Speed (Top) Mm/s
Plain	8.02	8.1	45.17	43.21	1.69	1.58
A10	7.5	6.3	48.02	55.11	2.00	1.74
A15	6.1	5.02	50.1	59.01	2.36	1.90
A20	7	9.11	45.2	49.08	2.25	1.94
B10	13.5	15.5	37	39.04	0.45	0.76
B15	10.1	14	28.03	36.12	1.00	1.26
B20	12	13.5	27.2	32.06	1.48	1.51
C10	5.81	4	57.11	65.27	2.07	1.79
C15	4.27	3.06	45.07	55.63	2.62	2.36
C20	5.07	3.50	39.15	47.23	1.90	1.92
D10	19.02	24.5	44.06	49.11	1.50	1.20
D15	19	25.07	41.31	45.02	1.31	1.21
D20	22.01	23.10	43	45	1.30	130
E10	15.09	18	41.07	46.1	1.10	0.83
E15	13	19.5	39.12	40.07	0.91	0.63
E20	18.2	22.5	38.08	45.13	0.82	0.65
F10	16.5	21.5	37.04	40.08	1.11	0.99
F15	15.7	19.05	43.01	45.1	1.01	0.89
F20	14.5	17.5	37.11	39.03	0.89	0.80

3.3. Liquid Absorption Rate

The absorption rate of knitted fabrics with the application of different softeners is shown in Figure 3. Softener B (Cepreton UA cationic in nature) generally exhibited the lowest absorption values. Other softeners C to F (Solusoft MW, Siligen BH, Siligen SIH, and Siligen SIM) also showed generally excellent to good absorption values, thus can perform well to reduce skin humidity and maintain body comfort. Softener A (Solusoft VC) also showed exceptional absorption values both at the top and bottom. Softener C (Solusoft MW) at the top with 10 g/L concentration showed the highest absorption value, where an increase in the concentration of softener exhibited a decrease in absorption rate.

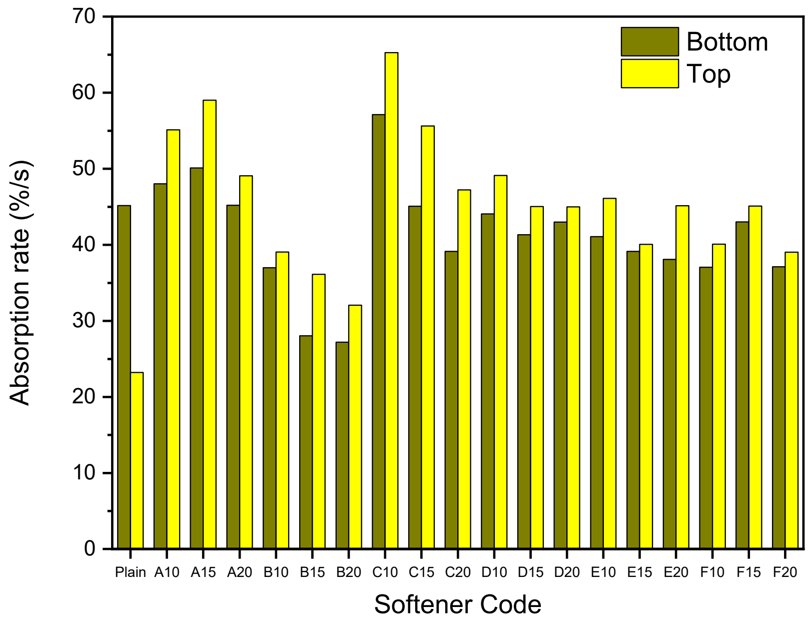

Figure 3. The absorption rate of terry knitted fabric with the application of different softeners.

3.4. Spread Speed

The spreading speed of liquid on the knitted fabrics with different softeners is shown in Figure 4. Softener B (Cepreton UA cationic in nature) generally showed the lowest spread speed values. In contrast, the softener C (Solusoft MW) generally showed the lowest spread speed values. All the other types showed lower spread speed values except softener A (Solusoft VC) and softener C (Solusoft MW). The softener B (Cepreton UA) with 10 g/L concentration exhibited the lowest spread speed value (0.59) at the fabric bottom side. In comparison, the softener C (MW) with 15 g/L concentrations showed the highest spread speed value (2.62) at the fabric bottom side.

3.5. One-Way Transport Capability

Figure 5 showed the accumulative one-way transport capability of knitted fabric samples with the application of different softeners. Softeners A, B, and C generally showed the highest values of one-way transport capability; among these, Softener C (Solusoft MW) showed excellent one-way moisture transport capability. All three non-ionic softeners (Siligen BH, Siligen SIH, and Siligen SIM) showed lower one-way transport capability values, respectively. Thus, their high values of one-way moisture transport capability make them the right choice to be used as sportswear.

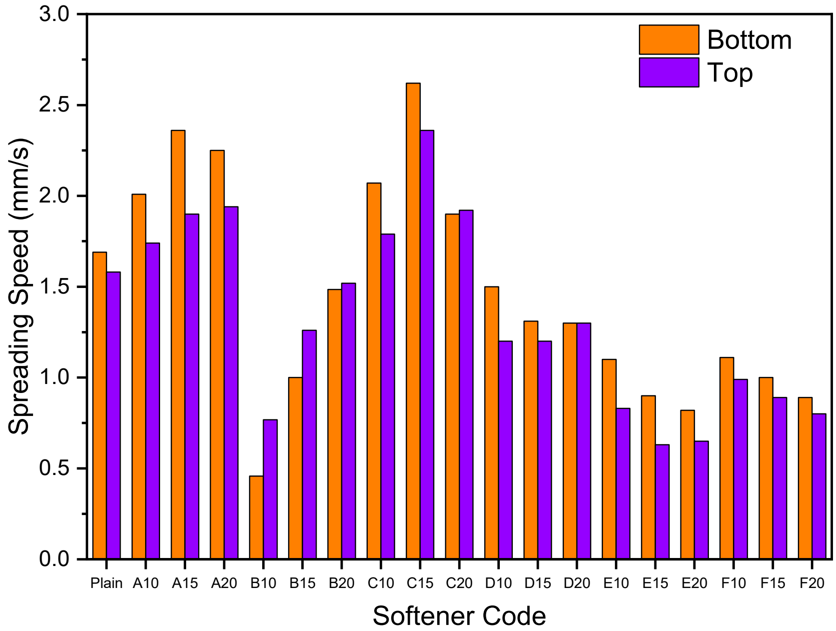

Figure 4. Spreading speed of liquid of the terry knitted fabric with the application of different softeners.

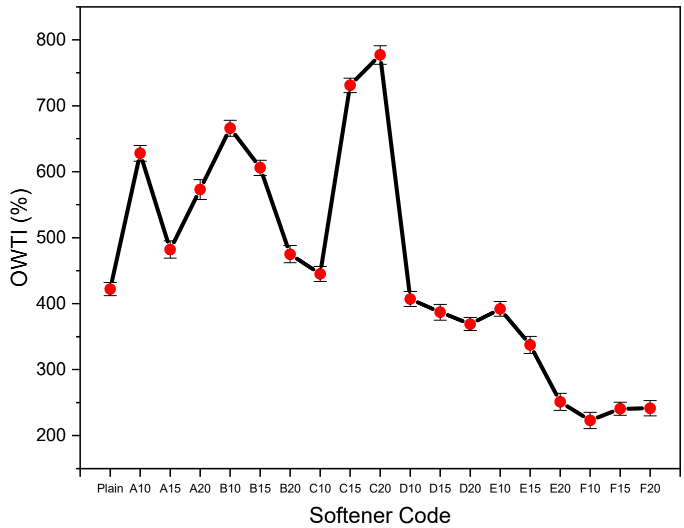

Figure 5. Accumulative one-way transport capability.

3.6. Rubbing Fastness

Rubbing fastness results were obtained for treated samples only with 15 g/L conc. of softener, considering the best moisture management results at this concentration, All the six softeners show full-scale grade 5 of dry rubbing fastness. The effect of different softeners on the wet rubbing fastness of treated fabrics is shown in Figure 6. Out of six, three silicone-based softeners, namely, Solusoft MW, Siligen BH, and Siligen SIH, do not disturb the rubbing fastness too much and showing a grade, 4 out of 5. Two softeners out of these three are non-ionic. These softeners do not interact with other finishing recipes (resins, water-repellents, etc.) due to their compatibility. In Solusoft VC, rubbing fastness decreased and was calculated as 3.5. This decrease in the value of rubbing fastness is the consequence of the ionic character of the softener. The Solusoft VC is an anionic softener. Therefore, it increases the hydrophilicity of the fabric. Increased hydrophilicity increases the water penetration in wet rubbing, leading to impair it. Crepton UA shows a full-scale rating of 5 due to its cationic nature.

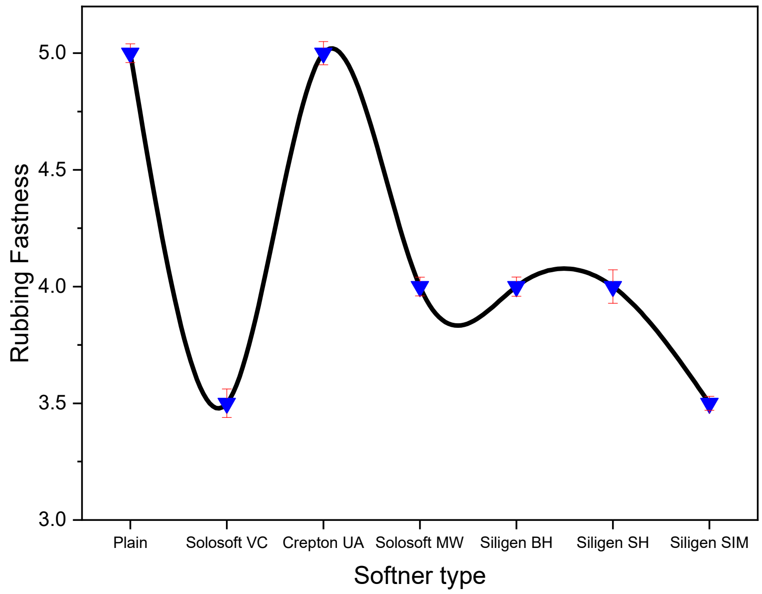

Figure 6. The rubbing fastness of terry knitted fabric with the application of different softeners.

3.7. Mechanism of Anionic Softeners Action on Moisture Management

Here we saw that samples treated with Solusoft MW (anionic) offered the best moisture management values depicted by indices such as OMMC, wetting time, and OWTI (Figures 1, 2 and 5), etc. Anionic softeners have a positively charged hydrophobic head and a hydrophilic tail. [25] As shown in Figure 7, the hydrophobic tail attaches with the negatively charged fabric, and the hydrophilic head is oriented away from fabric and contact with skin. When body sweat, the hydrophilic head synergize the moisture absorption capability of terry loops transported to the fabric's outer surface (face side) via binding yarns layer by wicking action. The binding yarn layer comprises 100% polyester filaments, which offers faster wicking of the moisture [26] to the outward direction. Polyester has less moisture content and regains [27]; therefore, the presence of polyester in the middle layer of fabric structure provides moisture wicking from the wetted fabric (next to the skin) and transfers that moisture to the top layer (hydrophilic) while restricting the re-wetting of the lower surface from top one. Thus, it would increase the wearer's comfort and would keep the body dry.

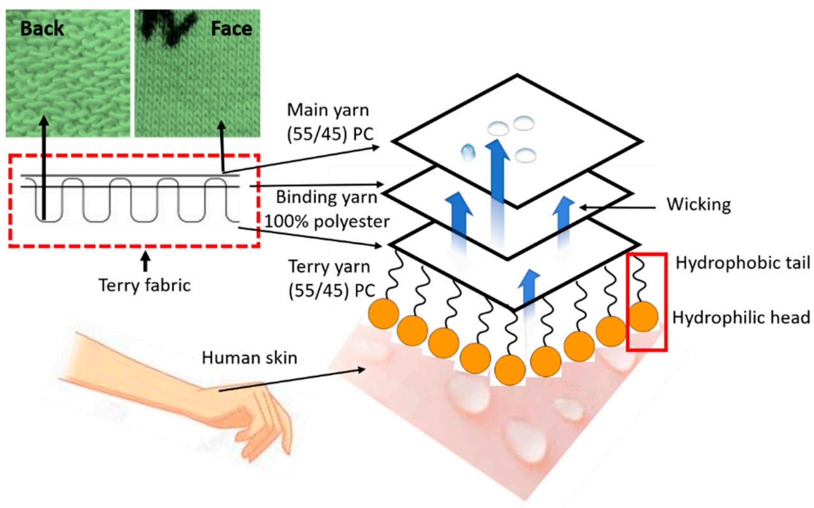

Figure 7. Graphical illustration of the action of anionic softener on moisture management.

4. Conclusions

Moisture management test (MMT) is the best tool to evaluate hydro-mobility through the fabric. It is concluded that increasing the softener concentration, irrespective of its nature, beyond a certain concentration results in impairing fabric moisture management performance caused by pore-blocking. It is worth mentioning that softener's physical and chemical interaction with fabric is critical which confirmed the concentration dependency. However, the dependence of moisture management on non-ionic softeners such as Siligen SIH concentration is not prominent as a 5 unit increase in concentration results 0.2 unit decrease in OMMC. On the other hand, other softners caused a significant increase or decrease in the OMMC values. It was observed that OWTC and OMMC values are higher for Solusoft MW with 20 g/L and 15 g/L concentration, respectively, indicating the suitability of developed terry knitted fabric for beneficial moisture management properties required in outdoor activewear and sportswear applications.

It was concluded from this study that selection of an appropriate softener and its concentration are critical as it determines the final OMMC of the terry fabrics. However, there is no linear relationship between the concentration of softner and OMMC. Furthermore, the construction and quality of fabric (gsm, fiber type, blend ratio, structure, etc.) are important parameters that could alter the OMMC. Hence, for a different fabric, the results could vary and preliminary trials are recommended, however, these results are true for the selected fabric only.

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References

1. D'Silva, A.P.; Greenwood, C.; Anand, S.C.; Holmes, D.H.; Whatmough, N. Concurrent determination of absorption and wickability of fabrics: A new test method. *J. Text. Inst.* **2000**, *91*, 383–396. [CrossRef]
2. Benisek, L.; Harnett, P.R.; Palin, M.J. Influence of fibre and fabric type on thermophysiological comfort. *Melliand Textilber. Eng.* **1987**, *68*, 878.
3. Hu, J.; Li, Y.; Yeung, K.W.; Wong, A.S.; Xu, W. Moisture Management Tester: A Method to Characterize Fabric Liquid Moisture Management Properties. *Text. Res. J.* **2005**, *75*, 57–62. [CrossRef]
4. Öner, E.; Atasağun, H.G.; Okur, A.; Beden, A.R.; Durur, G. Evaluation of moisture management properties on knitted fabrics. *J. Text. Inst.* **2013**, *104*, 699–707. [CrossRef]
5. Parthiban, M.; Ramesh Kumar, M. Effect of fabric softener on thermal comfort of cotton and polyester fabrics. *Indian J. Fibre Text. Res.* **2007**, *32*, 446–452.
6. Peršin, Z.; Stana-Kleinschek, K.; Sfiligoj-Smole, M.; Kre, T.; Ribitsch, V. Determining the Surface Free Energy of Cellulose Materials with the Powder Contact Angle Method. *Text. Res. J.* **2004**, *74*, 55–62. [CrossRef]
7. Bedek, G.; Salaün, F.; Martinkovska, Z.; Devaux, E.; Dupont, D. Evaluation of thermal and moisture management properties on knitted fabrics and comparison with a physiological model in warm conditions. *Appl. Ergon.* **2011**, *42*, 792–800. [CrossRef]
8. Fangueiro, R.; Goncalves, P.; Soutinho, F.; Freitas, C. Moisture management performance of functional yarns based on wool fibres. *Indian J. Fibre Text. Res.* **2009**, *34*, 315–320.
9. Sampath, M.B.; Mani, S.; Nalankilli, G. Effect of filament fineness on comfort characteristics of moisture management finished polyester knitted fabrics. *J. Ind. Text.* **2011**, *41*, 160–173. [CrossRef]

10. Fangueiro, R.; Filgueiras, A.; Soutinho, F.; Meidi, X. Wicking Behavior and Drying Capability of Functional Knitted Fabrics. *Text. Res. J.* **2010**, *80*, 1522–1530. [CrossRef]
11. Özdil, N.; Süpüren, G.; Özçelik, G.; Pruchova, J. A study on the moisture transport properties of the cotton knitted fabrics in single jersey structure. *Tekst. Konfeksiyon* **2009**, *19*, 218–223.
12. Nazir, A.; Hussain, T.; Ahmad, F.; Faheem, S. Effect of knitting parameters on moisture management and air permeability of interlock fabrics. *AUTEX Res. J.* **2014**, *14*, 39–46. [CrossRef]
13. Sampath, M.B.; Senthilkumar, M. Effect of Moisture management finish on comfort characteristics of microdenier polyester knitted fabrics. *J. Ind. Text.* **2009**, *39*, 163–173. [CrossRef]
14. Sampath, M.B.; Aruputharaj, A.; Senthilkumar, M.; Nalankilli, G. Analysis of thermal comfort characteristics of moisture management finished knitted fabrics made from different yarns. *J. Ind. Text.* **2012**, *42*, 19–33. [CrossRef]
15. Balci, O.; Kinoglu, G.Ö.; Sancar Besen, B. Silicone oil based softeners including different additives: Part II: Investigation of effects of silicone softeners on the comfort properties of the fabrics. *Int. J. Cloth. Sci. Technol.* **2019**, *31*, 16–31. [CrossRef]
16. Cimilli Duru, S.; Şahin, U.K. Effects of yarn type, process history, softener type and concentration on wicking and drying properties of cotton plain knitted fabrics. *J. Text. Inst.* **2020**, *111*, 1166–1175. [CrossRef]
17. Hassan, T.; Khan, M.Q.; Salam, A.; Hassan, N.; Raza, A.; Bukhsh, N.; Javed, Z.; Kim, I.S. The assessment of finishing properties on the mass per unit area, pilling, bursting strength, and wicking behavior of polyester weft-knitted jersey fabric. *Coatings* **2020**, *10*, 723. [CrossRef]
18. Ferrándiz, M.; Fages, E.; Lema, S.R.; Martinez, J.I.; Caturla, J.G.; Giner, S.T. Development and Characterization of Weft-Knitted Fabrics of Naturally Occurring Polymer Fibers for Sustainable and Functional Textiles. *Polymers* **2021**, *13*, 665. [CrossRef] [PubMed]
19. Hinchliffe, J.D.; Parassini, A.; Syed Mohamed, D.; Roy, I. Biomedical Applications of Bacteria-Derived Polymers. *Polymers* **2021**, *13*, 1081. [CrossRef]
20. Basuk, M.; Bait, S.; Maiti, S.; Adivarekar, R.V. Effect of Plasma Treatment on Moisture Management Properties and Drying Behavior of Polyester and Blend Fabrics for Sportswear Application. *Curr. Trends Fash. Technol. Text. Eng.* **2018**, *3*, 105–112.
21. Basuk, M.; Choudhari, M.; Maiti, S.; Adivarekar, R.V. Moisture Management Properties of Textiles and Its Evaluation. *Curr. Trends Fash. Technol. Text. Eng.* **2018**, *3*, 50–55. [CrossRef]
22. *AATCC 8-2016 Colorfastness to Crocking: Crockmeter Method*; American Association of Textile Chemists and Colorists: Research Triangle Park, NC, USA, 2016.
23. De Vasconcelos, F.B.; Monteiro de Barros, L.M.; Borelli, C.; De Vasconcelos, F.G. Moisture Management Evaluation in Double Face Knitted Fabrics with Different Kind of Constructions and Fibers. *J. Fash. Technol. Text. Eng.* **2017**, *s3*, 3–8. [CrossRef]
24. Reddy, N.; Salam, A.; Yang, Y. Effect of structures and concentrations of softeners on the performance properties and durability to laundering of cotton fabrics. *Ind. Eng. Chem. Res.* **2008**, *47*, 2502–2510. [CrossRef]
25. Role of Softeners in Textile Wet-Processing. Available online: https://www.textiletoday.com.bd/role-of-softeners-in-textile-wet-processing/ (accessed on 28 January 2021).
26. Chatterjee, A.; Singh, P. Studies on Wicking Behaviour of Polyester Fabric. *J. Text.* **2014**, *2014*, 1–11. [CrossRef]
27. Su, C.I.; Fang, J.X.; Chen, X.H.; Wu, W.Y. Moisture Absorption and Release of Profiled Polyester and Cotton Composite Knitted Fabrics. *Text. Res. J.* **2007**, *77*, 764–769. [CrossRef]