Egyptian Journal of Chemistry
http://ejchem.journals.ekb.eg/

Analytical Study of Comfortability, Dyeability, and UPF of Sports Wear Interlock Fabrics

Mona Mohamed Shawky [1], L. K. El-Gabry [2], Manar Y. Abd El-Aziz [1]*

[1] Clothing and Knitting Industrial Research Department, Textile Research and Technology Institute, National Research Centre, Dokki, 12622, Cairo, Egypt
[2] Proteinic and Man-Made Fibres Department, Textile Research and Technology Institute, National Research Centre, Dokki, 12622, Cairo, Egypt

In Loving Memory of Late Professor Doctor ""Mohamed Refaat Hussein Mahran""

Abstract

Sport wears almost preferred with knitted fabrics especially interlock construction. However, there is a need for higher comfortability and functional properties for fabrics to be more fitted to this application. This study compared cotton and polyester microfibers and blended them to improve the functional activity of interlock in sport wear by mercerization, also fabrics dyeability are affected by mercerization. Knitted cotton, polyester microfiber fabrics and polyester microfibre cotton blend are knitted on interlock knitting machine. Then fabrics have been mercerized with sodium hydroxide to enhance many functional properties. This process improves dyeability with both reactive and cationic dyestuffs. The dyeing process providing all treated fabrics many functional properties such as UPF protection. The changes in different mechanical as well as physical properties were investigated. The washing fastness properties of the dyed fabrics are also given. The overall moisture management capacity (OMMC), burst strength, air permeability, coefficient of friction, surface roughness, and thermal conductivity were measured for blank fabrics, after washing, after washing and mercerizing, after dyeing washed fabrics, and after dyeing washed mercerized fabric. Significant differences for overall moisture management capacity (OMMC), bursting strength, air permeability, coefficient of friction, surface roughness, and thermal conductivity were found between blank fabrics and all different finished fabrics under study. 100%cotton fabric has the highest thermal conductivity, and flexural rigidity in blank stage and all finishing and dyeing stages, while microfiber polyester fabric has the highest air permeability and coefficient of friction in blank stage and all finishing and dyeing stages .

Keywords: Interlock; Sports wear; Knitted Fabrics; Mercirization; Dyeability; Function properties; Moisture management".

1. Introduction

Sportswear garment production plays a significant part in the apparel industry, and the demand for these types of garments has been growing recently. When creating this kind of clothing, sportswear with certain functional requirements like comfort features should be taken into account [1]. In general, people must choose their clothes according to their needed properties [2], as Depending on the fabric used, the fibre composition, the moisture content, and the type and concentration of the dye, clothes can shield the skin [3]. Leading sportswear garment manufacturing firms have done a lot of study in this area. High-performance fibrosis fabric with enhanced functional qualities is best suited for sports activity. Weft knitted fabric is mostly used to make sportswear clothes since it has a low production cost and many pattern options such as interlock structure. The qualities of knitted fabric are improved by different materials in the face, back, and inlay [1]. It is known that knitted fabrics have good characteristics related to their good stretch ability according to their looped structure of it [4].

Due to the distinctive qualities and properties of each fibre, a variety of natural and synthetic fibres are being used in double-layered fabrics, activewear, innerwear, and sportswear. Synthetic fibres are preferred for high activity levels while natural fibres are thought to be ideal for low activity levels. However, neither a single fibre nor various fibre blends can guarantee optimal apparel that is appropriate for a variety of uses. Depending on how the fabric will be used, the proper sort of fibre must be used in the appropriate spot. The most significant natural fibre of the 20th century is still without a doubt cotton. It is distinguished by its easy handling and hygienic qualities. Additionally, cotton fibre is

*Corresponding author e-mail: Manar_Yahia@hotmail.com.; (Manar Y. Abd El-Aziz).
Receive Date: 23 December 2023, **Revise Date:** 24 January 2024, **Accept Date:** 28 January 2024
DOI: 10.21608/ejchem.2024.227403.9025

ideal for summer clothing due to its good water vapour and air permeability. Due to skin clinginess and a chilling sensation when wet, it is not a favoured choice as a next to skin layer. Additionally, cotton garments take a long time to dry, especially in environments where liquid perspiration production is high [5, 6]. Because polyester fibre absorbs less moisture, base fabrics for active clothing are advised to have these easy-care qualities. Other qualities of polyester fibre include exceptional dimensional stability, outstanding heat resistance, and durability [7].

Additionally, it is widely acknowledged that moisture is the primary cause of discomfort [8- 11]. Therefore, the three main functional criteria for high-activity sports clothes are sweat absorption, quick drying, and cooling [8, 12]. High stretch and recovery are also necessary to ensure a proper fit and the wearer's freedom of movement [8, 13].

One of the most significant characteristics of materials for consumers is their thermal comfortability. To maintain a suitable microclimate for the body and clothes, sports apparel should have great thermal and moisture transfer qualities [14].

The most well-known technique for improving the physical and colouring characteristics of cotton fibre is mercerization. The surface morphology, nodal structure (i.e. crystallinity), crystal size, etc. of cotton fibre are altered by meccarization [15-17]. It changes the cellulose chain from cellulose I to cellulose II [13, 18, 19, 20]. The mercerization of cotton fabric resulted in a notable improvement in dye affinity, colour strength, sheen, tensile strength, and smoothness [15, 16, 21, 22]. The degree of change relies on a variety of factors, including caustic soda content, processing time, temperature, tension, and others [15, 23].

When compared to the reference sample the interlock knitted fabric that had been treated with silicone softener, and several types of enzymes improved the surface characteristics and hand [24]. Asta and others in their research prepared knitted fabrics with differentiation in yarn loop length, fabric structure, and the fibre used to make the yarn all directly affect how air moves through the knitted fabric [1]. Sampath et al., discovered that the comfort qualities of knitted fabric are inversely correlated with the filament fineness of yarn [25].

The weft knitted fabrics manufactured from Micro denier polyester have superior comfort qualities when compared to knitted fabrics made from regular denier polyester [26]. Ajmeri et al. said that cotton-based knitted fabrics have better thermal comfort characteristics than modal-based materials [27]. The type of fibre, yarn structure, fabric dynamics, and finishing applications all play a significant impact in determining the comfort and handle value of knitted fabric [28]. Ertekn et al. is used mono-filament spacer yarn to knit fabrics to increase their thermal insulation and properties [29]. Salman et al found that Interlock structure has higher protection from UV radiation [30]. The material type affected on both dyeing and finishing comfortability properties of blended cotton fabrics [31], [32].

Eight sets of sportswear fabrics were examined using MMT in a study and it was found that these fabric samples had significant liquid moisture management capabilities. Exercise-related moisture feeling measurements were compared with subjective measurements. It was determined that when the running time grew, both moisture sensations' ratings had gone up [33].

Polyester fabrics were treated with different conditions with sodium hydroxide to impart cationic dyeability as well as imparting silk-like. Many chemical and physical properties were studied. The alkali hydrolysis of polyester fabrics was studied to improve handles, and wettability [34, 35]. Polyester fabrics are treated with nanomaterial to enhance UV protection [36, 37].

This work aims to study the effect of mercerization (NaOH modification) on different interlock knitted fabrics (cotton, polyester and their blend on different physical and functional properties. Apply an analytical study to evaluate the relation between material, treatment and dyeing which were carried out and their effect on physical, mechanical and functional properties of sportswear interlock knitted fabrics by ANOVA analysis.

2. Experimental Work

2.1. Producing Samples

Cotton Yarns (30/1 NE) and polyester Microfiber (150/1/144) were used for producing 100% PE, 100% cotton, and 50% Cotton: 50% polyester Microfiber Fabrics. The blending of materials was done on the knitting machine, by arranging yarns on feeders 1 cotton yarn:1 Polyester microfiber yarn. An interlock structure with gage 20 needles/ Inch was used.

2.2. Chemicals

- Sodium hydroxide, and acetic acid of laboratory grade were used.
- A cationic dye (methylene blue, C.I. Basic blue 9) Methylthioninium chloride was applied as shown in figure (a).
- A reactive dye (Lanasol Blue, Reactive blue 69) anthraqunones, bromoacrylamide benzene sulfonic as shown in figure (b).

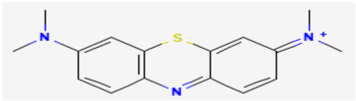


Figure a. Cationic dye Structure

Figure. b. Reactive dye Structure

2.3. Washing

The cotton fabrics were pre-washed with a nonionic detergent solution (2 g/l) for 45 min at 60ºC, thoroughly rinsed and dried at room temperature. Polyester and blend fabrics were also washed with a nonionic detergent solution (2 g/l) for 45 min at 45ºC, thoroughly rinsed and dried at room temperature

2.4. The treatment

The cotton, polyester and cotton/polyester blend knitted were treated with sodium hydroxide NaOH solutions, liquor ratio of 1:25. Concentrations of 0. 5 N were used for all fabrics. The treatment was carried out at 95°C for 30 min. After treatment, the fabrics were washed thoroughly with warm and then cold water and dried at room temperature.

2.5. Dyeing

2.5.1. Dyeing Reactive dyes

Exhaust dyeing of untreated and treated cotton fabric and treated cotton/Polyester Blend using 1% (o.w.f.) of C.I. Reactive blue 69 was started at 60 ºC then the temperature of the dyeing bath was raised to 90ºC within one hour, using liquor ratio 1:100. The pH of the bath was adjusted to 7, with occasional shaking for 60 min. After dyeing, fabric samples were withdrawn, rinsed thoroughly with water and air-dried.

2.5.2. Polyester and Cotton/Polyester Blend

The treated Polyester and treated cotton/Polyester blend fabrics were dyed with C.I. Basic blue (methylene blue), 1% (o.w.f.), liquor ratio 1:100 at 90ºC for 60 min. The dye bath was adjusted to pH 4 with the use of acetic acid. After dyeing, the samples were withdrawn, rinsed several times with warm and cold water, and then air dried at room temperature.

The experimental work of the blank, washed, washed mercerized, washed dyed, and washed mercerized dyed samples is shown in Table 1.

2.6. Characterization

Interlock fabrics' stitch density was measured according to ASTM D8007-15, mechanical properties (weight according to, ASTM-3776, thickness according to ASTM D1777 – 96, burst according to ASTM D3787-16, and stiffness according to ISO 9073-7) were tested and comfort properties (air permeability according to ASTM D737, roughness, friction by the KES-F module (Kawabata, 2020), thermal conductivity by KES-F7 Thermo Labo, and moisture management according to AATCC 195-2017) were determined for blank, washed, washed mercerized, washed dyed, and washed mercerized dyed samples to compare their properties and determine the effect of each finishing process on sportswear fabrics properties. Also, Colorimetric analysis of the dyed fabrics was recorded using a spectrophotometer with pulsed Xenon lamps as a light source (Ultra Scan Pro, Hunter Lab, USA) All measurements occurred at λmax wavelength.

Table 1. Experimental work

Sample Code	Material	Finishing		
		Washing	Mercerization	Dyeing
1blank	Polyester - Microfiber	Non-washed	Non-mercerized	Non-dyed
2blank	50% Polyester -Microfiber / 50% Cotton	Non-washed	Non-mercerized	Non-dyed
3blank	Cotton	Non-washed	Non-mercerized	Non-dyed
1W	Polyester - Microfiber	Washed	Non-mercerized	Non-dyed
2W	50% Polyester -Microfiber / 50% Cotton	Washed	Non-mercerized	Non-dyed
3W	Cotton	Washed	Non-mercerized	Non-dyed
1WT	Polyester - Microfiber	Washed	Mercerized	Non-dyed
2WT	50% Polyester -Microfiber / 50% Cotton	Washed	Mercerized	Non-dyed
3WT	Cotton	Washed	Mercerized	Non-dyed
1WD	Polyester - Microfiber	Washed	Non-mercerized	Dyed
2WD	50% Polyester -Microfiber / 50% Cotton	Washed	Non-mercerized	Dyed
3WD	Cotton	Washed	Non-mercerized	Dyed
1WTD	Polyester - Microfiber	Washed	Mercerized	Dyed
2WTD	50% Polyester -Microfiber / 50% Cotton	Washed	Mercerized	Dyed
3WTD	Cotton	Washed	Mercerized	Dyed

1: polyester microfiber fabric, 2: cotton polyester blend fabric, 3: cotton fabric, Treated =mercerized

The corresponding colour strength (K/S) was assessed by applying the Kubelka- Munk [38] Finally UV protection factor (UPF) was measured according to (AATCC 183-2004, ASTM-D6603-00) to verify functional performance enhancement by mercerization and dyeing.

3. Result and discussion

After conducting the applied tests, the results were calculated and the ANOVA test was applied to analyze the effect of the material type and the effect of the finishing type on the physical and functional properties of the interlock fabrics for sport wear.

3.1. Effect of Material Type

3.1.1. Stitch density

Applying one-way ANOVA for stich density between polyester microfiber fabric, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 2.

Table 2. P values of significant differences in stitch density between fabrics

Samples	P value
Blank	2.46E-06
Washed	3.26E-05
Washed treated	2.47E-07
Dyed washed	3.77E-07
Dyed washed treated	2.44E-07

From Figure 1 (A, B, C, D, and E) it is obvious that cotton fabric has the lowest stitch density then comes cotton polyester blend fabric then polyester microfiber fabric.

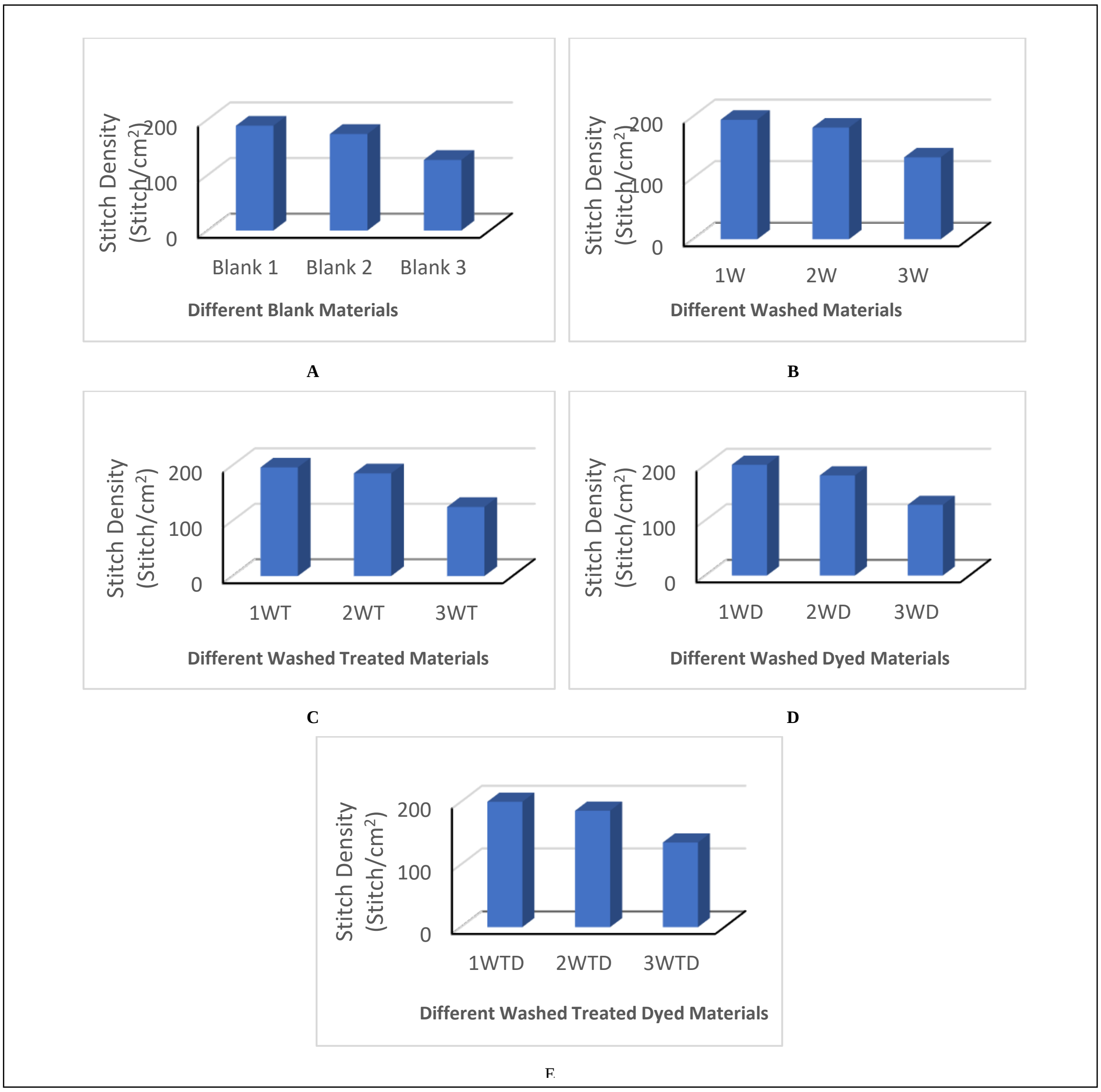


Fig. 1. Effect of the Material Type on the Stitch density

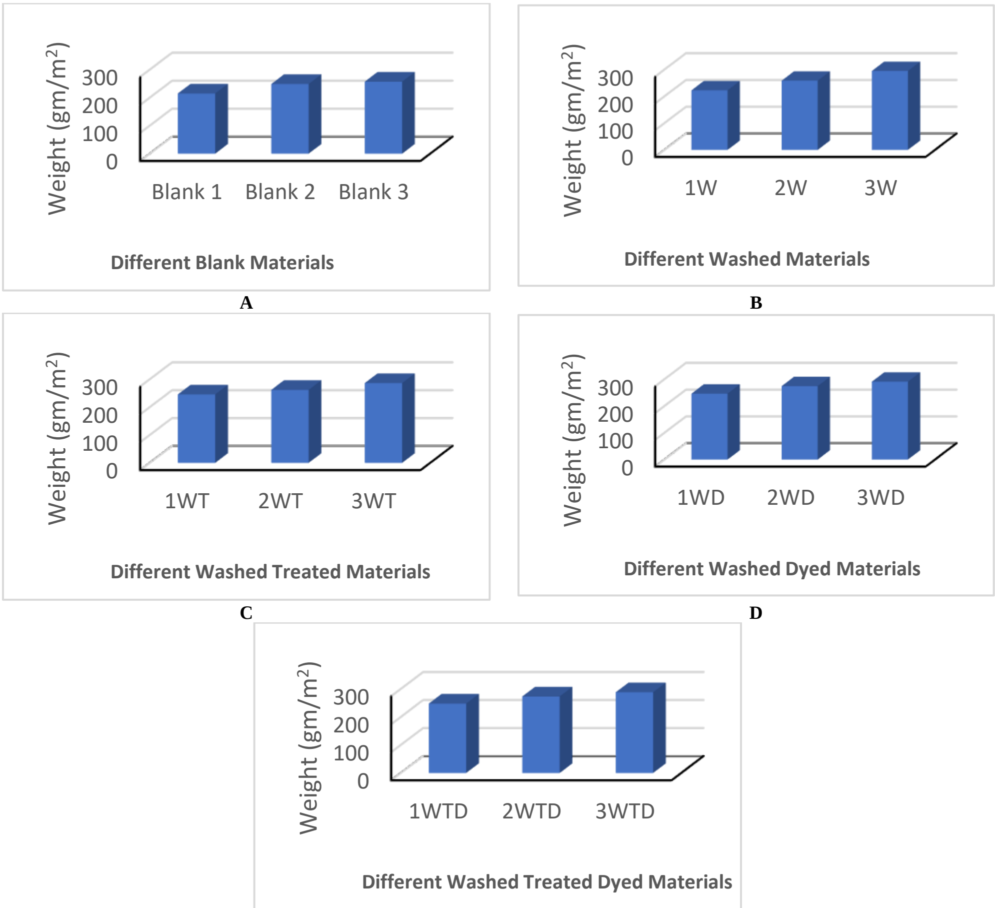
3.1.2. Fabric Weight

Applying one-way ANOVA for gram per square meter between polyester microfiber, cotton polyester blend fabric, and cotton fabrics for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 3.

From Figure 2 (A, B, C, D, and E) it is obvious that cotton fabric has the highest gram per square meter, then comes cotton polyester blend fabric then polyester microfiber fabric.

Table 3. P values of significant differences in fabric weight between fabrics

Samples	P value
Blank	5.1E-06
Washed	1.58E-07
Washed treated	0.004494
Dyed washed	0.003497
Dyed washed treated	0.048815



E

Fig. 2. Effect of the Material Type on Fabric Weight

3.1.3. Fabric Thickness

Applying one-way ANOVA for fabric thickness between polyester microfiber, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 4.

From Figure 3 (A, B, C, D, and E) it is obvious that cotton fabric has the biggest thickness then comes cotton polyester blend fabric then polyester microfiber fabric.

Table 4. P values of significant differences in fabric thickness between fabrics

Samples	P value
Blank	1.76E-06
Washed	6.77E-07
Washed treated	2.99E-05
Dyed washed	0.000127
Dyed washed treated	2.16E-05

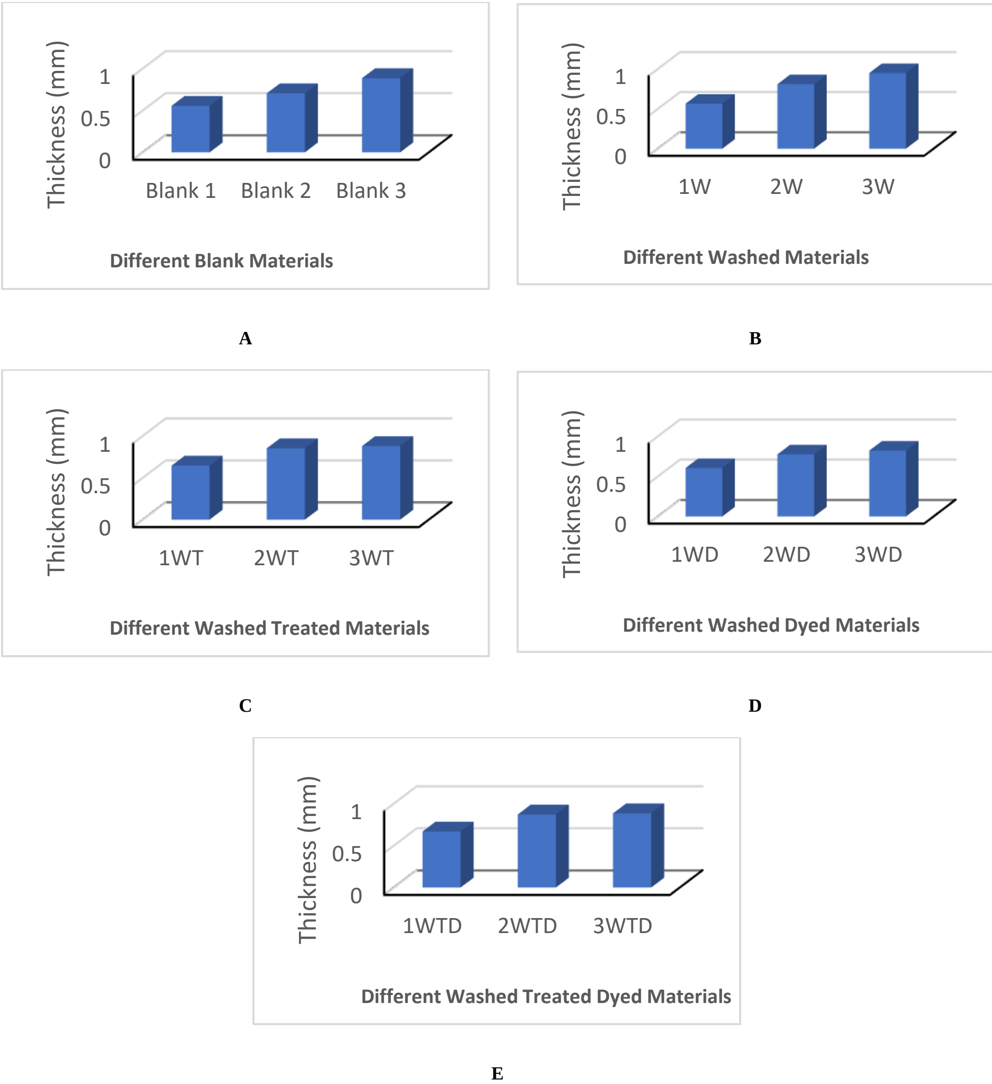


Fig. ٣. Effect of the Material Type on Fabric Thickness

From Figure 3 (A, B, C, D, and E) it is obvious that cotton fabric has the biggest thickness then comes cotton polyester blend fabric then polyester microfiber fabric.

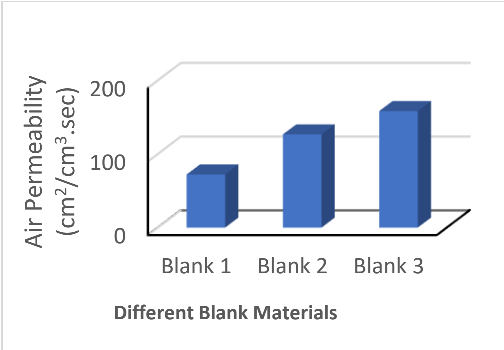
3.1.4. Air permeability

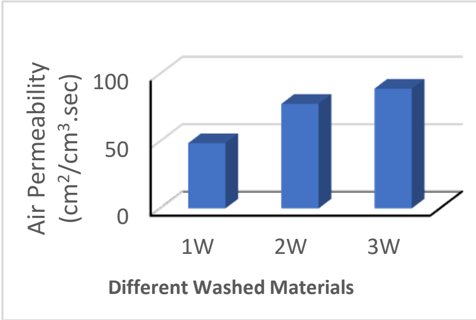
Applying one-way ANOVA for fabric air permeability between polyester microfiber, cotton polyester blend fabrics, and cotton fabrics for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values shown in Table 5.

From Figure 4 (A, B, C, and D) it is obvious that cotton fabric has the highest air permeability then comes the cotton polyester blend fabric then comes the polyester microfiber fabric this could be attributed to the highest stitch density of polyester microfiber fabrics as mentioned before and shown in Figure 1.

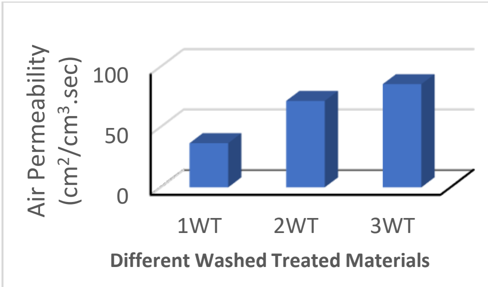
Table 5. P values of significant differences in air permeability between fabrics

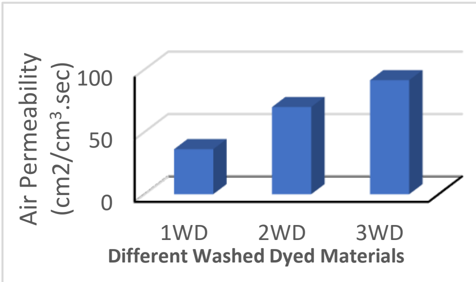
Samples	P value
Blank	1.46E-05
Washed	1.78E-06
Washed treated	6.33E-06
Dyed washed	6.3E-06
Dyed washed treated	1.1E-05



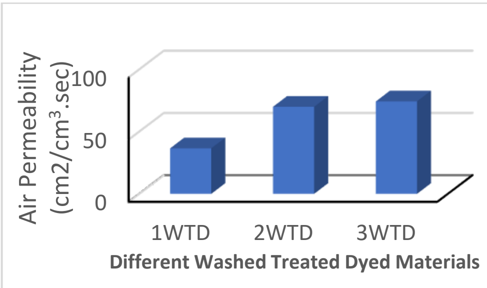


A **B**





C **D**



E

Fig. 4. Effect of Material Type on Air permeability

3.1.5. Burst pressure

Applying one-way ANOVA for gram per square meter between polyester microfiber, cotton polyester blend fabric, and cotton fabrics for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 6.

From Figure 5 (A, B, and D) it is obvious that polyester microfiber fabric has the highest bursting strength then comes cotton polyester blend fabric then comes cotton fabric this happened in the case of blank fabrics, washed fabrics, and washed dyed fabrics while in case of washed mercerized fabric and dyed mercerized fabric Figure 5 (C, and E) bursting strength is the highest for polyester microfiber fabric and cotton fabric (almost the same) and its lower in case of cotton polyester blend fabric this may due to hydrolysis of cotton fabric s' surface by mercerization process which increased its burst strength.

Table 6. P values of significant differences in burst pressure between fabrics

Samples	P value
Blank	1.14E-09
Washed	1.26E-08
Washed treated	0.029047
Dyed washed	9.48E-08
Dyed washed treated	9.44E-05

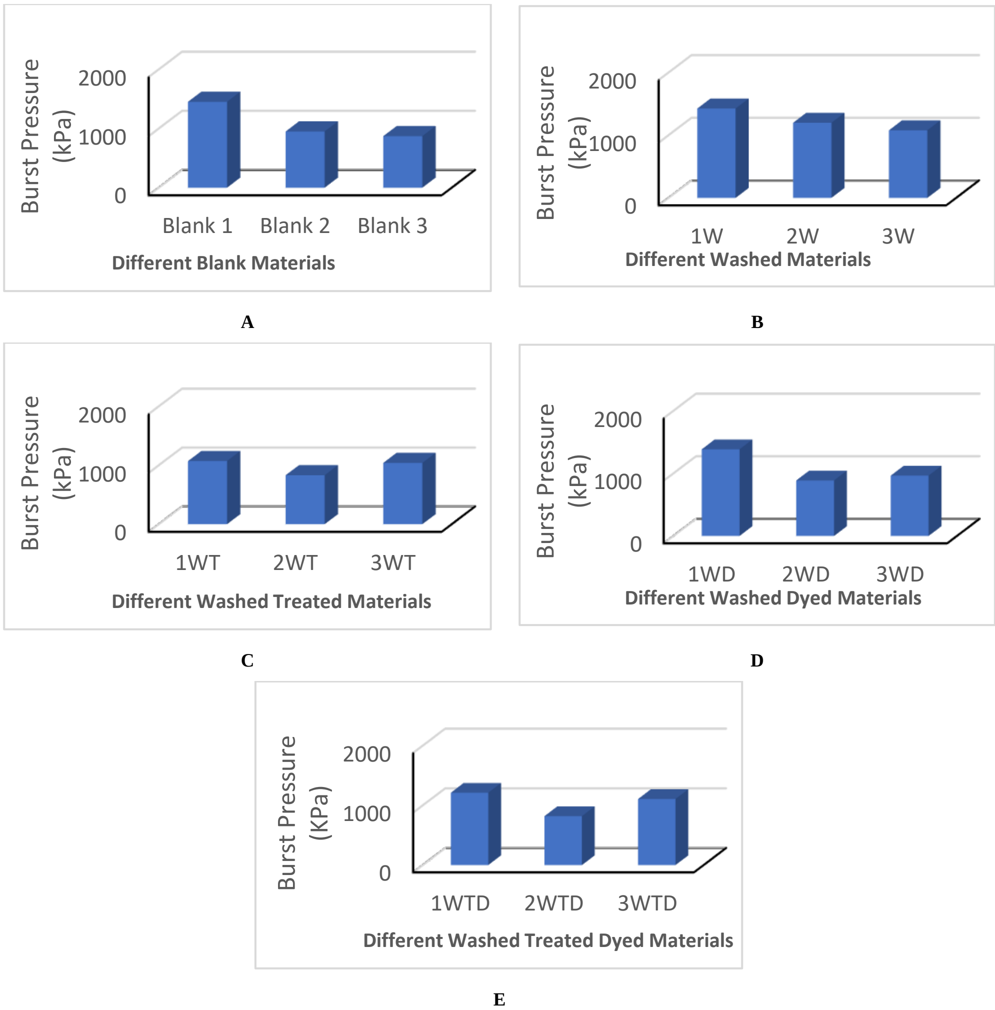


Fig. 5. Effect of Material Type on Burst pressure

3.1.6. Burst detention

Applying one-way ANOVA for gram per square meter between polyester microfiber fabric, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, and after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 7.

Figure 6 (A, B, C, D, and E) shows the displacement before bursting occurs. Figure 6 (A, and B) shows that cotton fabric extends more before bursting. Regarding Figure 6 (C.D, and E) the treatment and dyeing process affected the behavior of extensibility before bursting.

Table 7. P values of significant differences in burst detention between fabrics

Samples	P value
Blank	1.36E-05
Washed	2.39E-05
Washed treated	0.045796
Dyed washed	0.000593
Dyed washed treated	0.015532

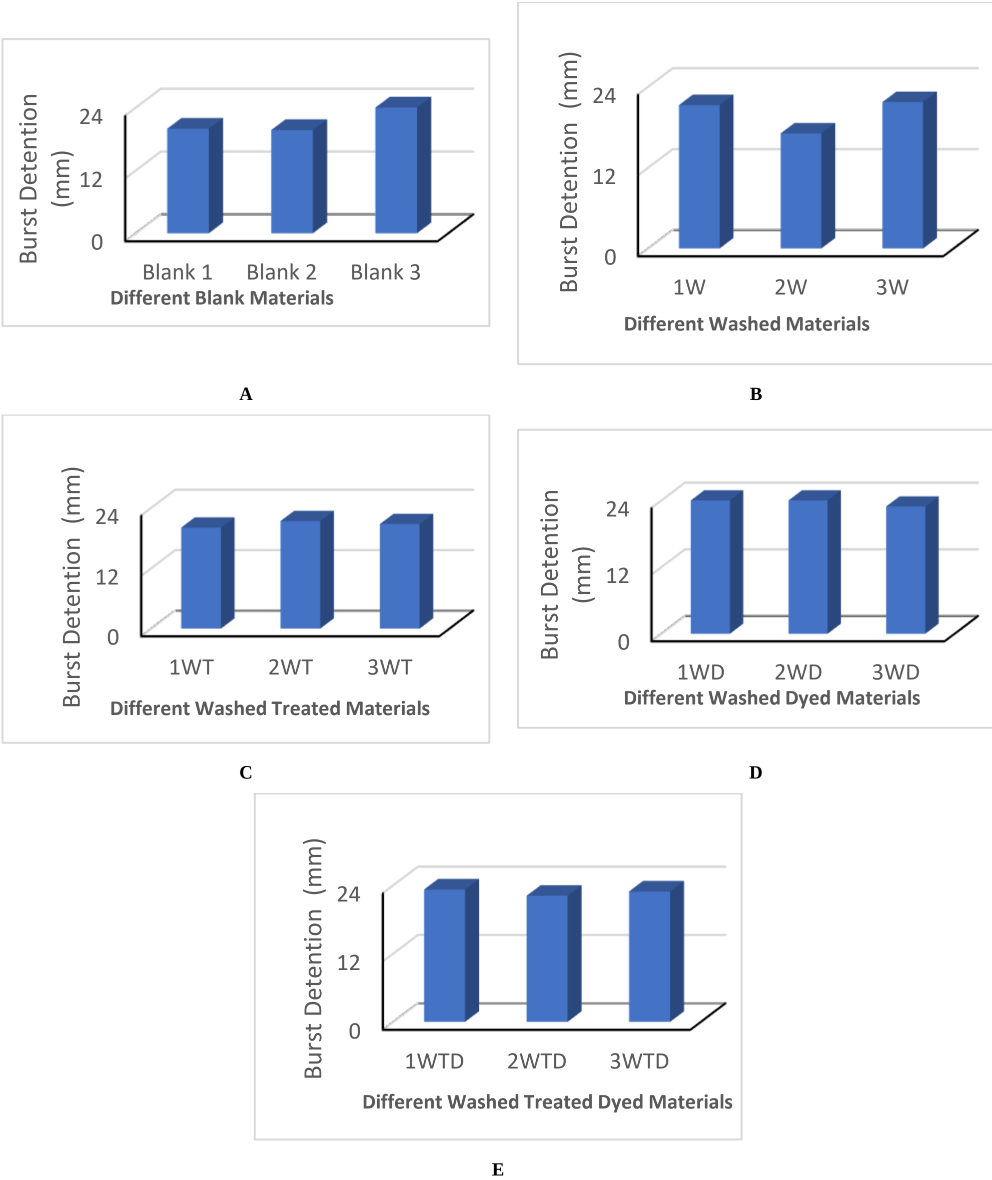


Fig. 6. Effect of the Material Type on the Burst detention

3.1.7. Flexural rigidity

Applying one-way ANOVA for fabric flexural rigidity between polyester microfiber fabric, cotton polyester blend, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 8.

From Figure 7 (A, B, C, D, and E) it can be noticed that cotton fabric has the highest flexural rigidity then comes cotton polyester blend fabric then comes the polyester microfiber fabric. This means that cotton fabric is the stiffest fabric and polyester microfiber is the least stiff fabric this may refer to that polyester yarn consists of microfibers which cause the polyester yarn to be more flexible than cotton yarn as well as it is known as that cotton fiber is stiffer than polyester fiber. Also, the cotton fabric is thicker than polyester fabric as mentioned before.

Table 8. P values of significant differences in flexural rigidity between fabrics

Samples	P value
Blank	0.058739
Washed	0.000134
Washed treated	1.03E-06
Dyed washed	1.22E-05
Dyed washed treated	0.000195

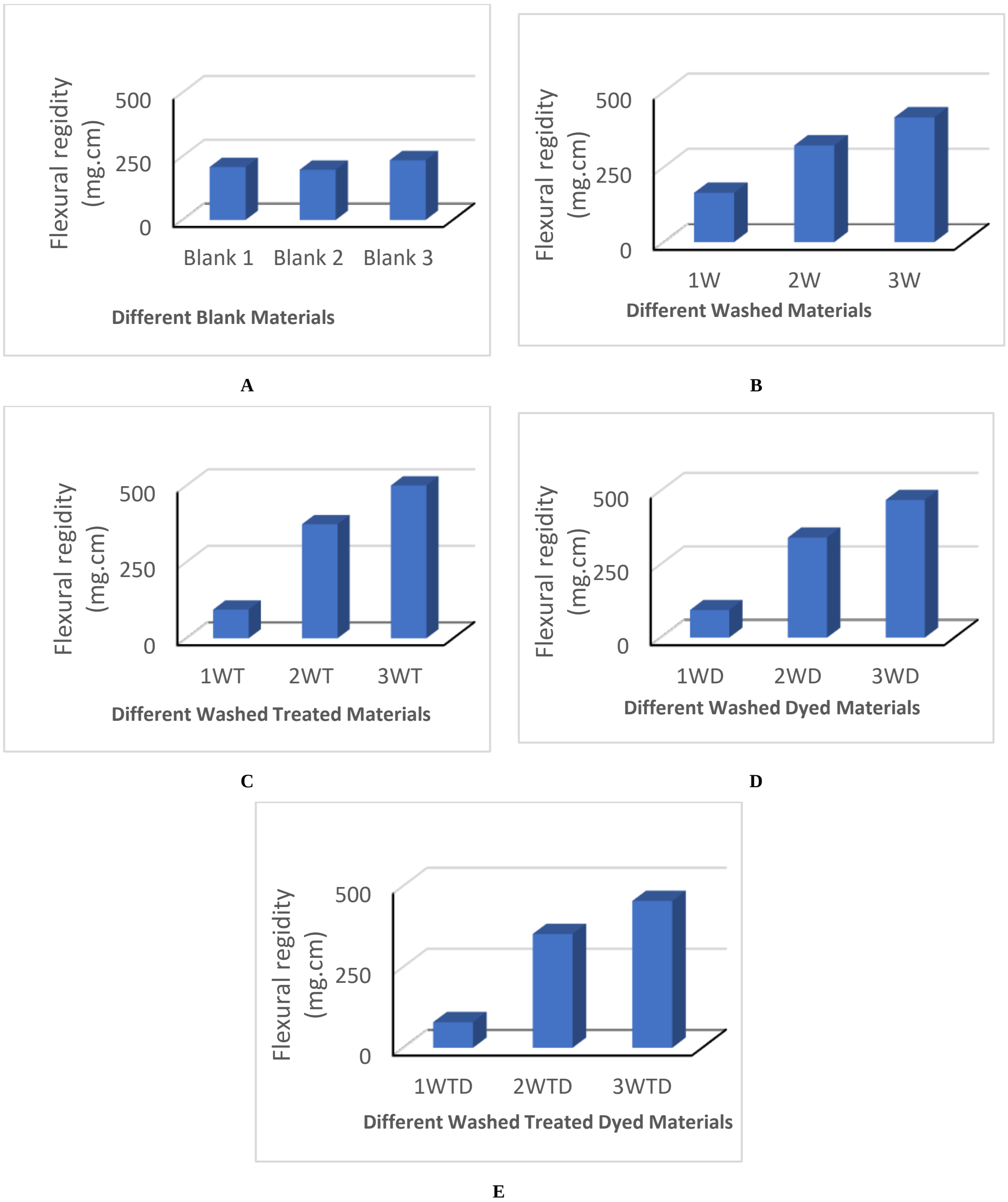


Fig. 7. Effect of the Material Type on the Flexural rigidity

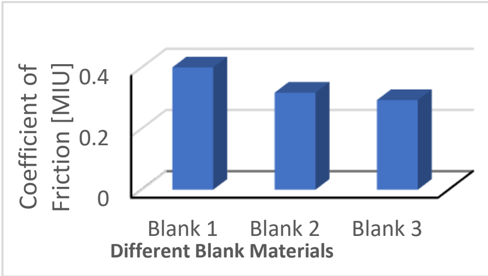
3.1.8. Coefficient of fabric friction (MIU)

Applying one way ANOVA for fabric coefficient of friction MIU between polyester microfiber fabric, cotton polyester blend, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between three fabrics in each case. The significant p values shown in Table 9.

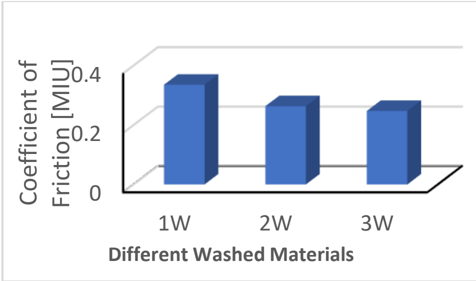
From Figure 8 it is seen that polyester microfiber fabric has the highest coefficient of friction then comes polyester cotton fabric then comes cotton fabric in all cases except case E which is washed mercerized and dyed fabric this may be attributed to fibre surface scraping occurs during hydrolysis of polyester fabrics surface.

Table 9. P values of significant differences in coefficient of friction (MIU) between fabrics

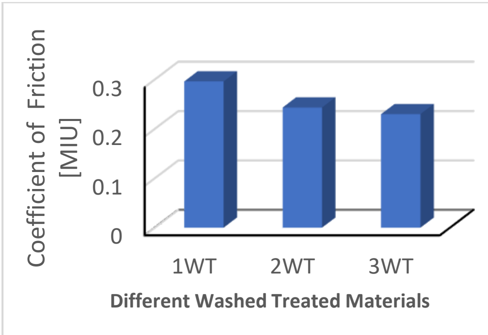
Samples	P value
Blank	1.55056E-05
Washed	0.00434235
Washed treated	7.0986E-05
Dyed washed	1.33711E-05
Dyed washed treated	0.002816402



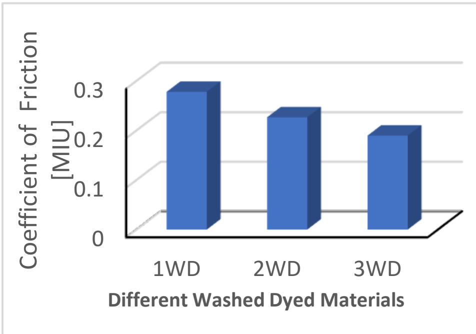
A



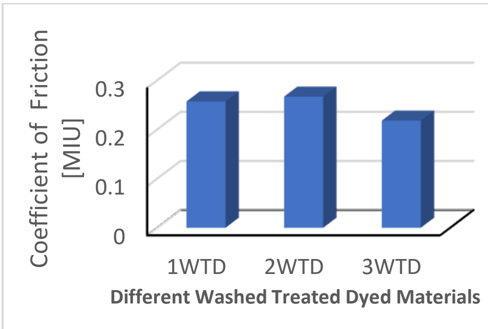
B



C



D



E

Fig. 8. Effect of the Material Type on the coefficient of Friction

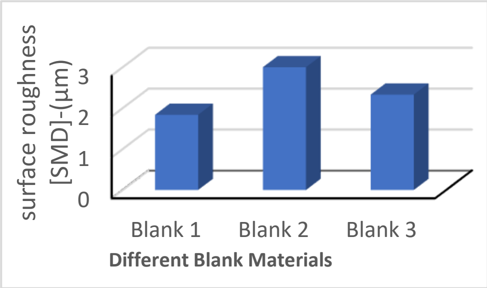
3.1.9. Surface roughness (SMD)

Applying one-way ANOVA for fabric surface roughness between polyester microfiber fabric, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p-values are shown in Table 10.

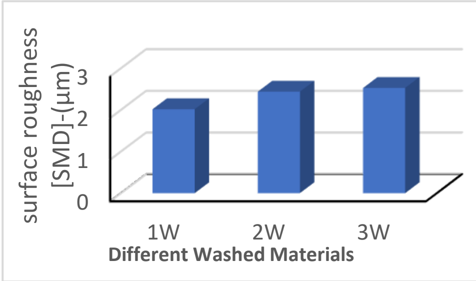
From Figure 9 (A, B, C, D, and E) it is obvious that for blank fabric cotton polyester blend fabric has the highest surface roughness then comes cotton fabric then comes polyester microfiber fabric. This may be attributed to the structure of the microfiber cotton blended fabric. During the knitting process, the machine was fed by one yarn of microfiber polyester and one yarn of cotton. This results in fabric surface un-uniformity (zigzag shape) as cotton yarn diameter differs from polyester microfiber yarn diameter.

Table 10. P values of significant differences in surface roughness (SMD) between fabrics

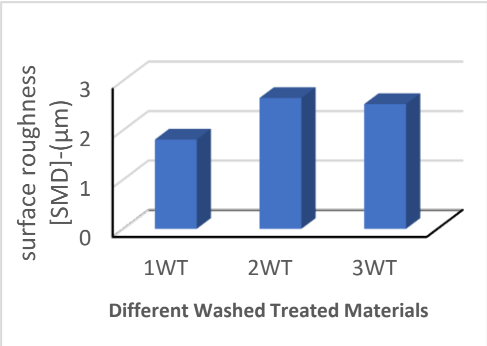
Samples	P value
Blank	0.002690527
Washed	0.002610187
Washed treated	5.71124E-05
Dyed washed	0.000410659
Dyed washed treated	9.65942E-05



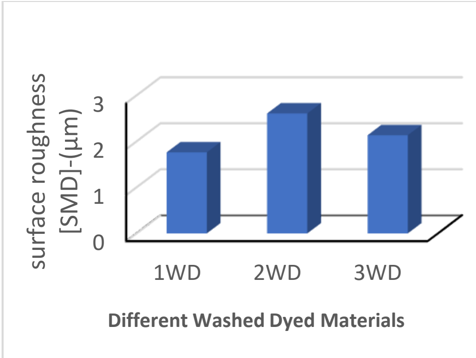
A



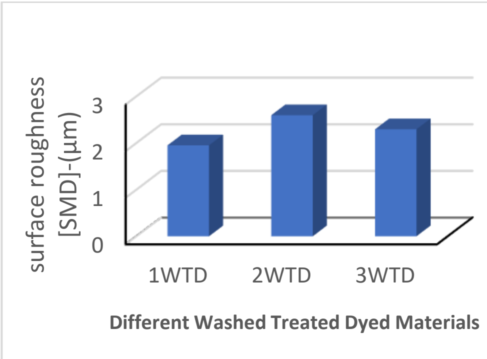
B



C



D



E

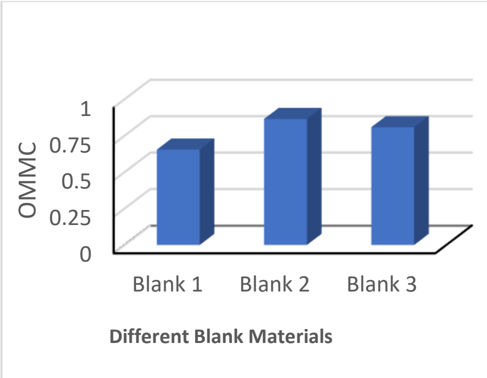
Fig. 9. Effect of Material Type on Fabric surface Roughness

3.1.10. Overall moisture management capacity (OMMC)

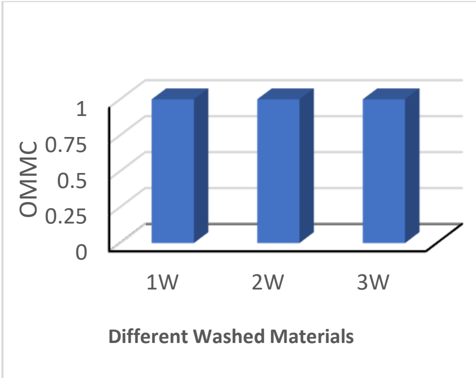
Applying one-way ANOVA for fabric Overall moisture management capacity between polyester microfiber fabric, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, and after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 11. It could be noticed that no available P-values for washed and washed treated could be obtained due to the similar reading of the OMMC in these cases.

Table 11. P values of significant differences in OMMC between fabrics

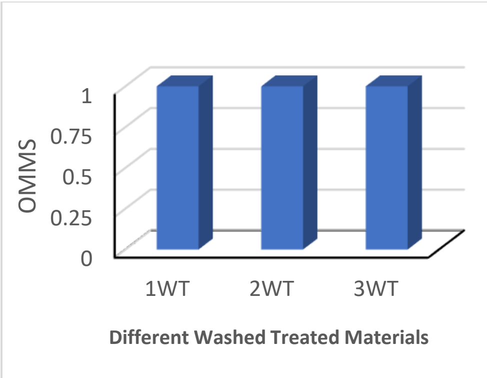
Samples	P value
Blank	0.050867827
Washed	--
Washed treated	--
Dyed washed	0.000118251
Dyed washed treated	0.019167249



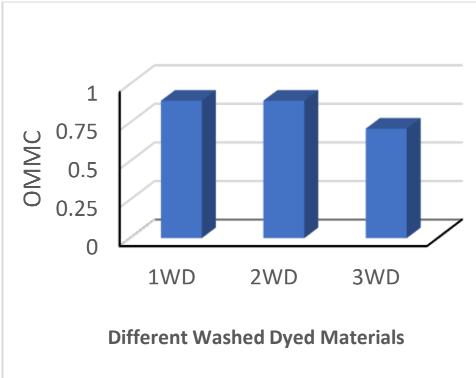
A



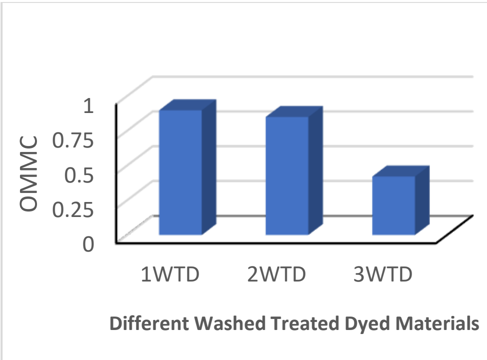
B



C



D



E

Fig. 10. Effect of Material Type on OMMC

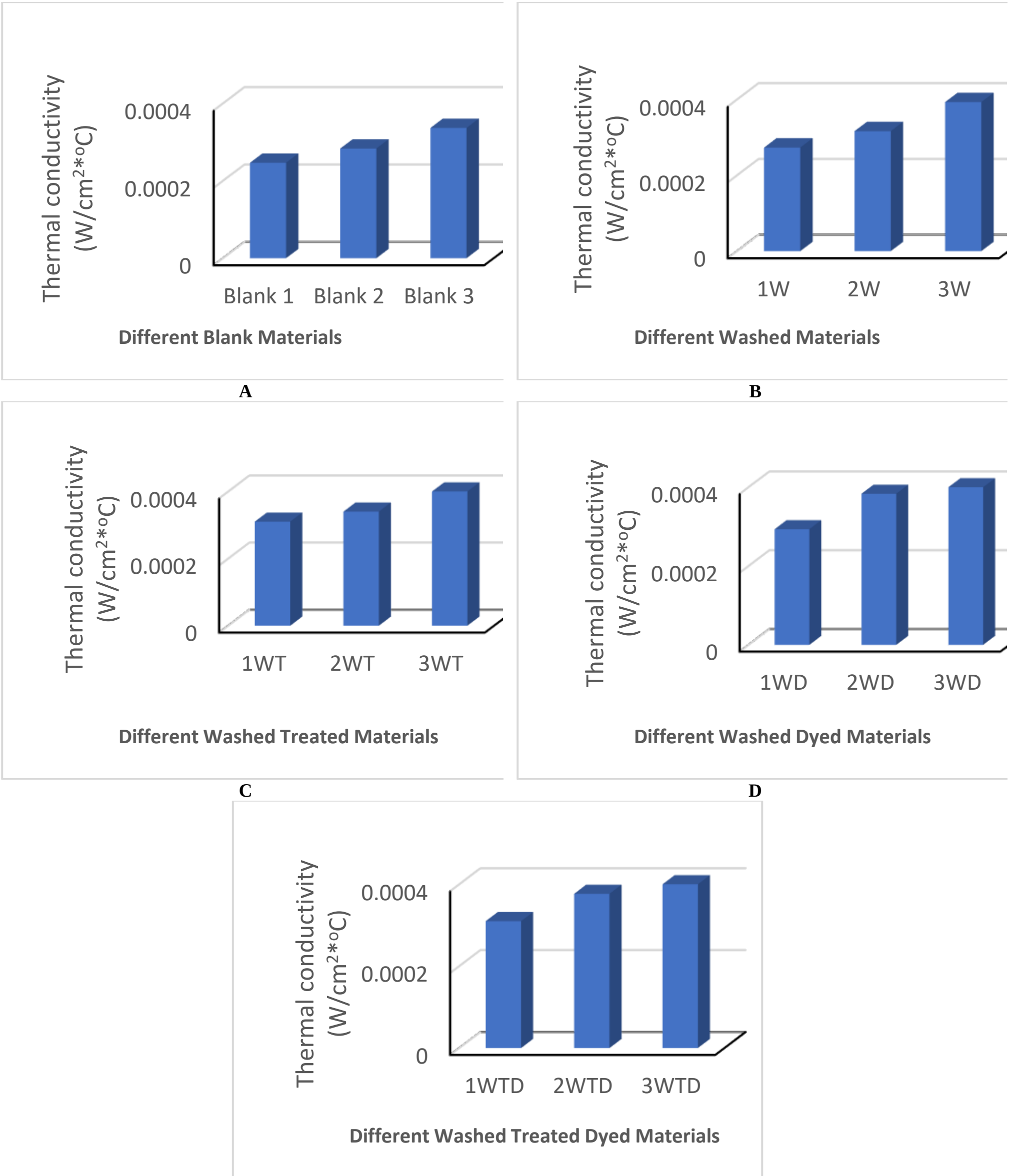
From Figure 10 it could be seen that there were differences in OMMC between three fabrics in the case of blank fabrics, washed fabrics, washed mercerized, and washed mercerized dyed, while in the case of washed fabrics and washed and mercerized fabrics OMMC gives the same values for all fabrics.

3.1.11. Thermal Conductivity

Applying one-way ANOVA for fabric thermal conductivity between polyester microfiber fabric, cotton polyester blend fabric, and cotton fabric for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 12.

Table 12. P values of significant differences in thermal conductivity between fabrics

Samples	P value
Blank	0.000100881
Washed	8.05442E-05
Washed treated	1.50534E-05
Dyed washed	7.84112E-07
Dyed washed treated	7.27908E-07



E

Fig. 11. Effect of Material Type on Thermal Conductivity

From Figure 11 (A, B, C, D, and E) it was found that 100% cotton fabric has the highest thermal conductivity [39] then comes the cotton polyester fabric then comes polyester microfiber fabric. This could be due to the higher hairiness of cotton yarn than microfiber polyester yarn.

2.1.12. Ultraviolet Protection factor (UPF)

Applying one-way ANOVA for fabric UPF between polyester microfiber fabric, cotton polyester blend, and cotton fabric, for the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the three fabrics in each case. The significant p values are shown in Table 13.

Figure 12 (A, B, C, and D) showed that the dyeing with both dyes led to a significant increase in the UPF value than undyed fabrics this may be attributed to the chemical structure of both dyes.

Table 13. P values of significant differences in UPF between fabrics

Samples	P value
Blank	4.1362E-05
Washed	0.056359777
Washed treated	7.41633E-06
Dyed washed	5.22979E-05
Dyed washed treated	0.006298248

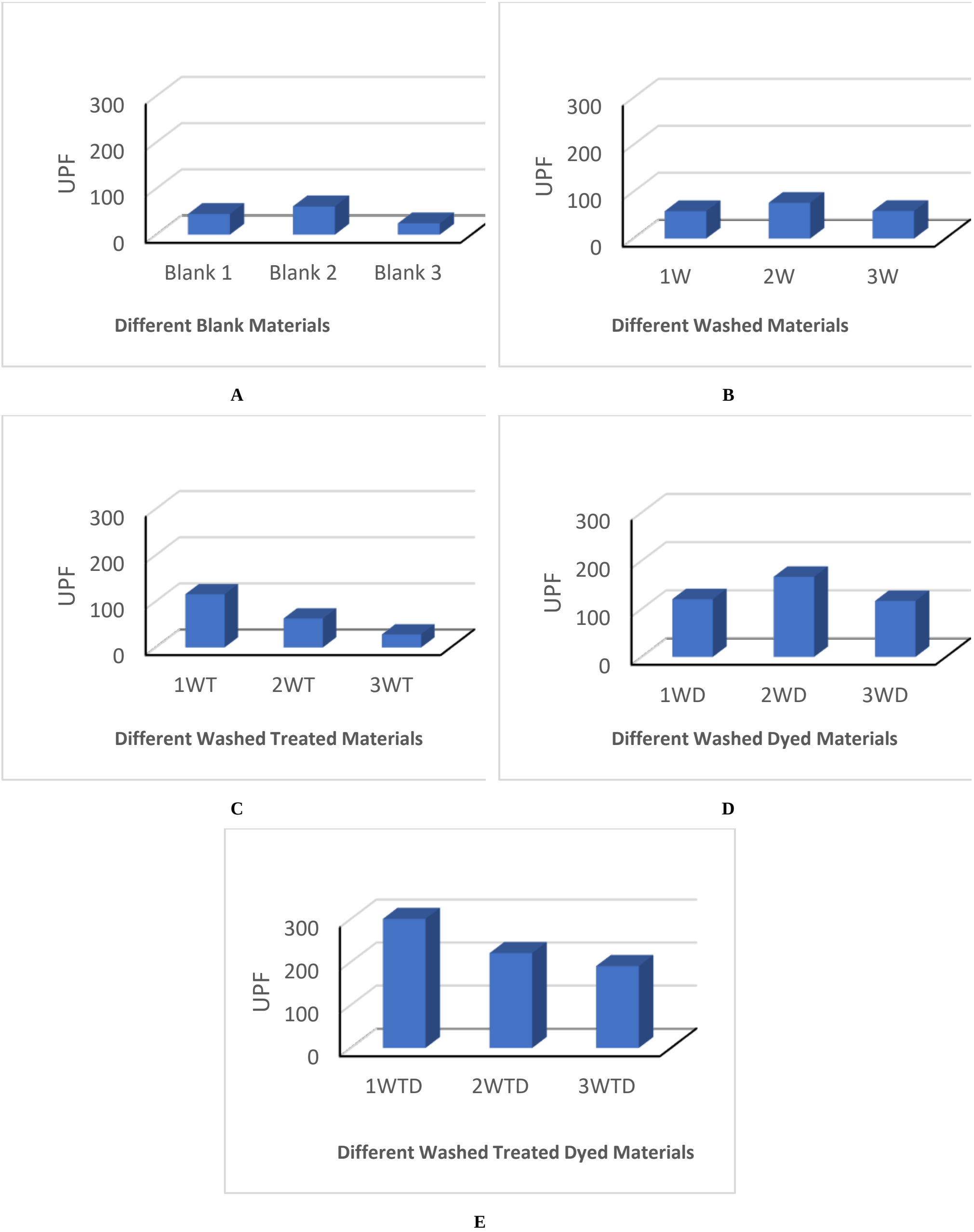


Fig. 12. Effect of Material Type on Fabric UPF

3.2. Effect of Mercerization and Dyeing

3.2.1. Stitch density

Applying one-way ANOVA for the stitch density of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing,

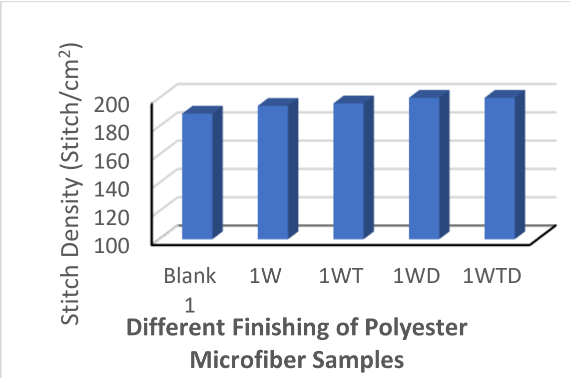
after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between

the previous cases for each fabric type. The significant p values are shown in Table 14.

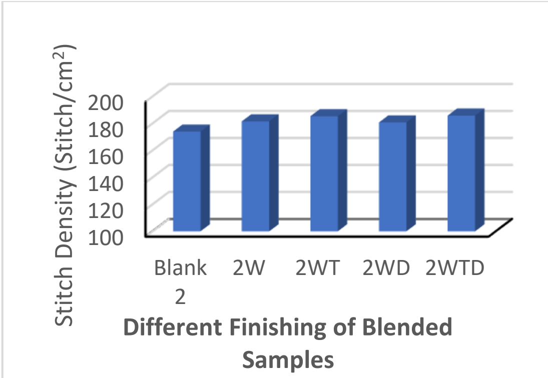
Table 14. P values of significant differences in stitch density for the treatment effect of each fabric

Samples	P value
Blank 1	5.6222E-05
Blank2	0.035027816
Blank3	0.015641202

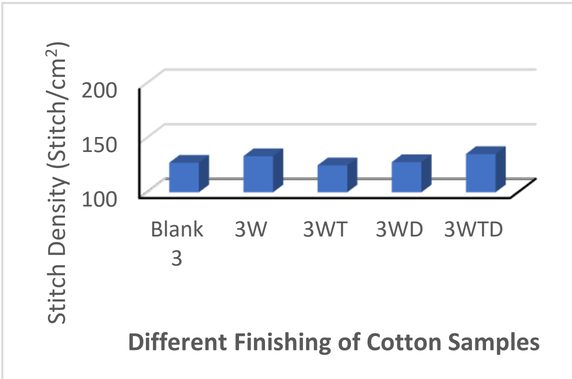
From Figure 13 (A, B, and C) it could be seen that stitch density increased after the four finishing treatments and dyeing for all fabrics this is due to fabric shrinkage that occurred after all finishing processes applied on the fabrics.



A



B



C

Fig. 13. Effect of Finishing Type on the Stitch density

3.2.2. Fabric weight

Applying one-way ANOVA for the gram per square meter of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 15.

Table 15. P values of significant differences in fabric weight for the treatment effect of each fabric

Samples	P value
Blank 1	0.018084248
Blank2	0.052291488
Blank3	1.55425E-06

From Figure 14 (A, B, and C) it was found that gram per square meter increased after all finishing processes applied on the three fabrics this increase was due to shrinkage of the fabrics after finishing processes.

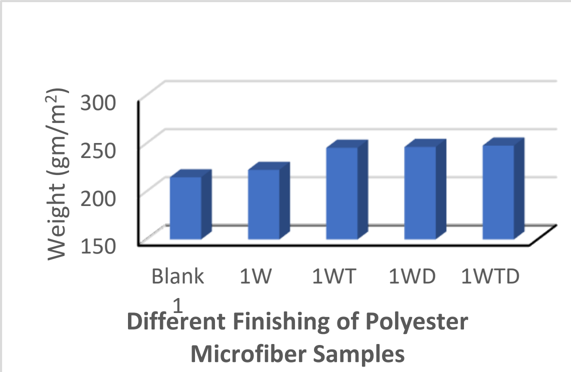
3.2.3. Fabric thickness

Applying one-way ANOVA for the thickness of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 16.

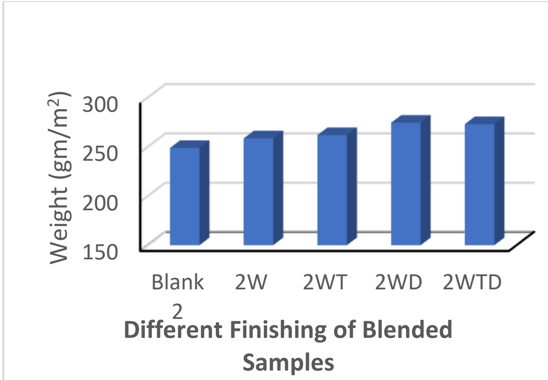
Table 16. P values of significant differences in fabrics' thickness for the treatment effect of each fabric

Samples	P value
Blank 1	0.000131
Blank2	3.58E-06
Blank3	0.00232

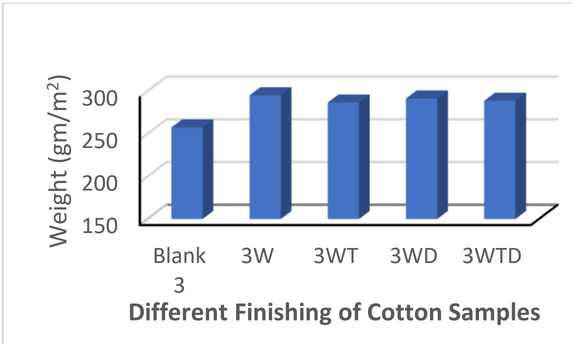
'From Figure 15 (A, B, and C) it was found that fabric thickness increased after all finishing processes applied on polyester microfiber fabric, and cotton polyester fabric, this increase is due to a shrinkage in the dimensions of samples during different processes.



A

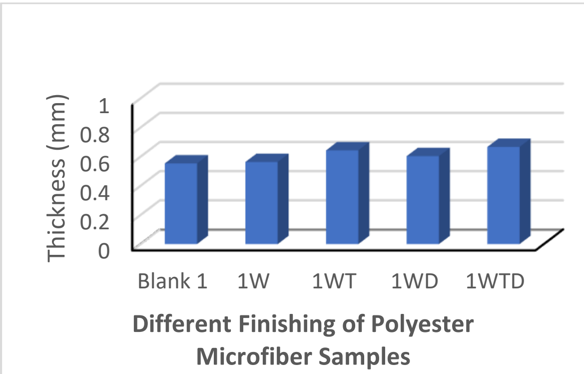


B

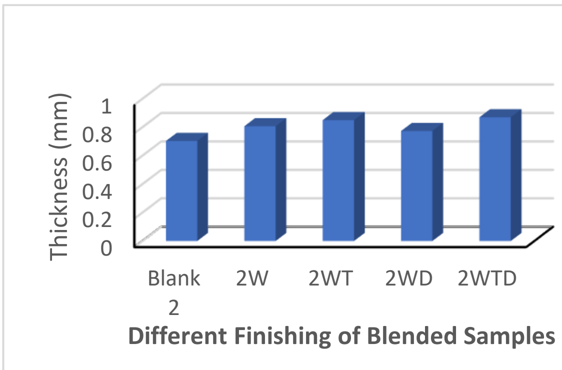


C

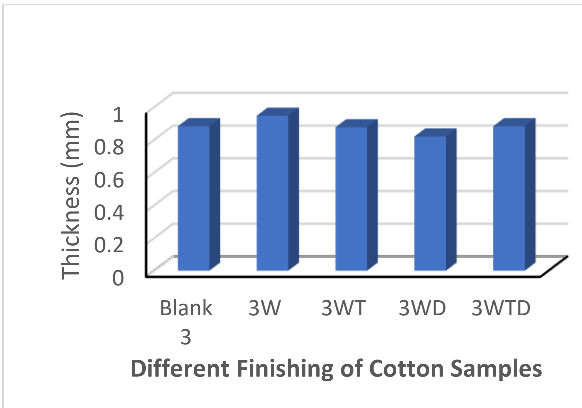
Fig. 14. Effect of Finishing Type on Fabric Weight



A



B



C

Fig. 15. Effect of Finishing Type on Fabric Thickness

3.2.4. Air permeability

Applying one-way ANOVA for the air permeability of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 17.

Table 17. P values of significant differences in fabrics' air permeability for the treatment effect of each fabric

Samples	P value
Blank 1	4.03956E-06
Blank2	4.56467E-09
Blank3	2.76363E-09

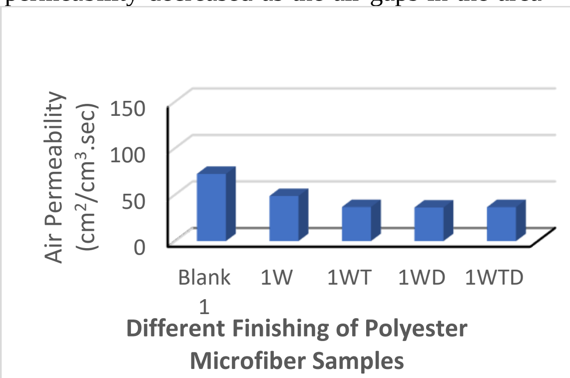
From Figure 16 (A, B, and C) it could be seen that air permeability decreased after washing, mercerizing and dyeing this could be explained as stitch density increased after washing, mercerizing and dyeing the air permeability decreased as the air gaps in the area of measuring air permeability decreased. It is also known that increasing the thickness of the fabrics affects the air permeability property.

3.2.5. Burst pressure

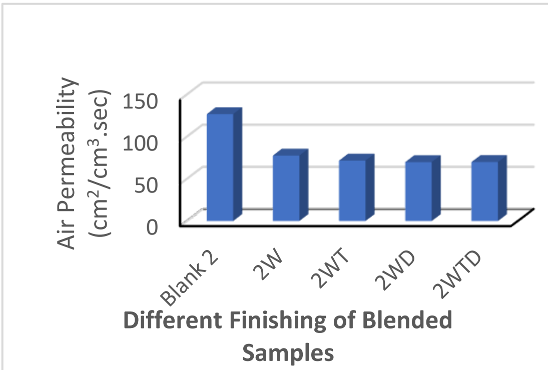
Applying one-way ANOVA for the bursting strength of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, and after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 18.

Table 18. P values of significant differences in fabrics' burst pressure for the treatment effect of each fabric

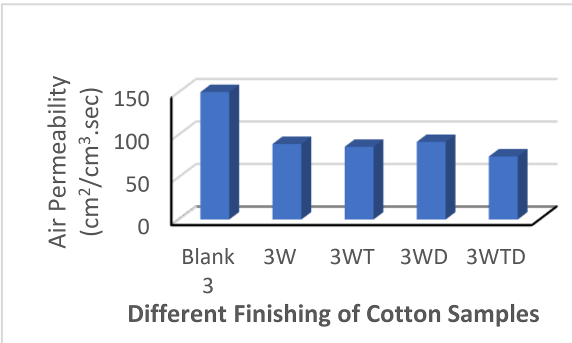
Samples	P value
Blank 1	0.0004345
Blank2	7.66542E-11
Blank3	9.20188E-09



A

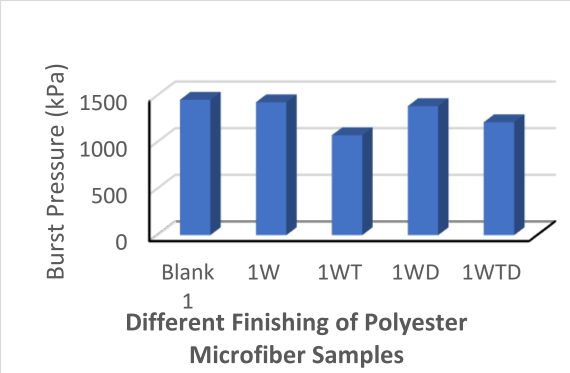


B

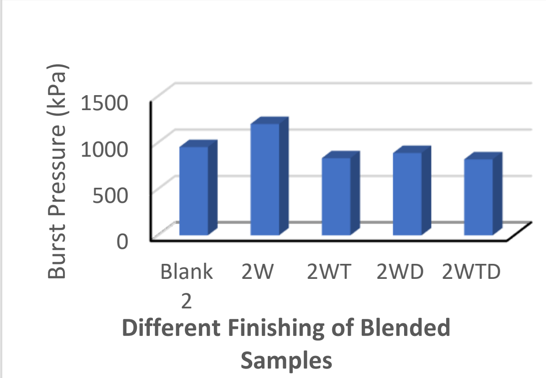


C

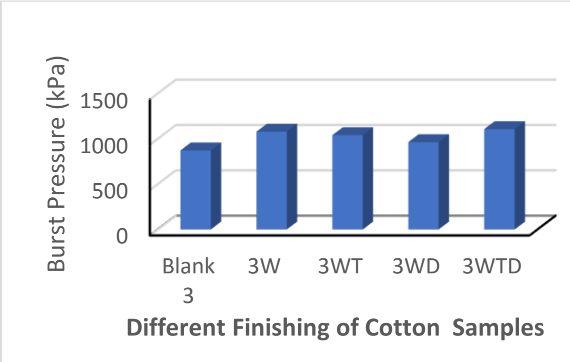
Fig. 16. Effect of Finishing Type on the Air permeability



A



B



C

Fig. 17. Effect of Finishing Type on Burst pressure

From Figure 17 (A, and B) it could be seen that bursting strength decreased for washed mercerized fabrics and washed mercerized dyed in both polyester and cotton blended with polyester fabric while Figure 17 (C) shows for cotton fabric; the washed mercerized and washed mercerized dyed fabric bursting strength increased. This is due to the hydrolysis process of polyester material, which leads to weight loss and loss of strength.

3.2.6. Burst detention

Applying one-way ANOVA for the burst detention of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the prev\ious cases for each fabric type. The significant p values are shown in Table 19.

Table 19. P values of significant differences in fabrics' burst detention for the treatment effect of each fabric

Samples	P value
Blank 1	4.03956E-06
Blank2	4.56467E-09
Blank3	2.76363E-09

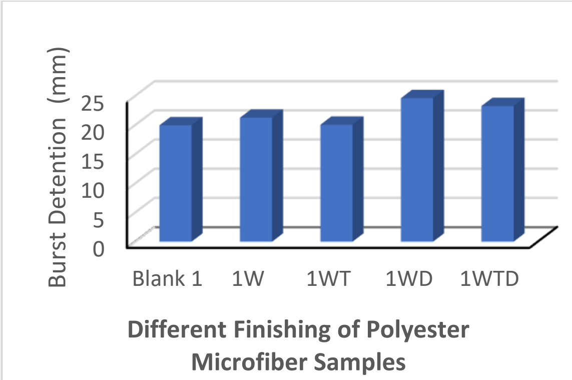
From Figure 18 (A, B, and C) it could be seen that displacement before bursting increased after finishing processes for polyester and cotton polyester fabrics which means that these fabrics become more extensible after finishing. While it decreased in cotton samples, as a result of the polyester hydrolysis during these finishing.

3.2.7. flexural rigidity

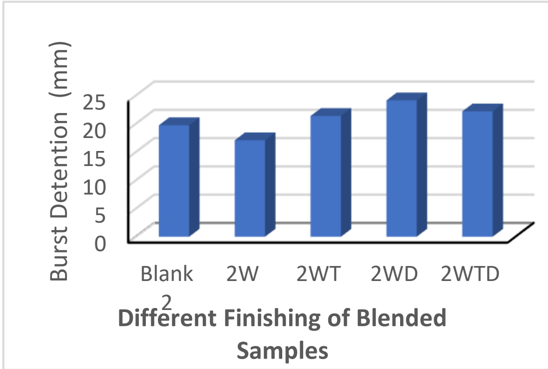
Applying one-way ANOVA for the flexural rigidity of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 20.

Table 20. P values of significant differences in fabrics' flexural rigidity for the treatment effect of each fabric

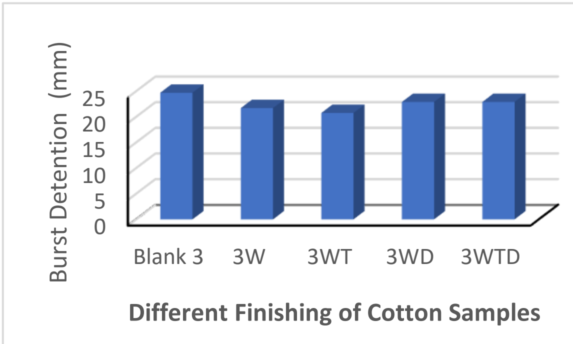
Samples	P value
Blank 1	0.000205427
Blank2	0.000669718
Blank3	9.74447E-06



A

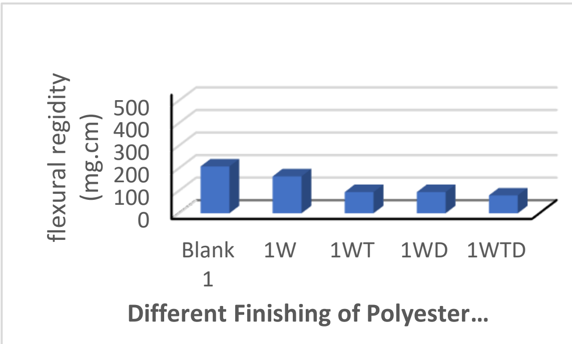


B

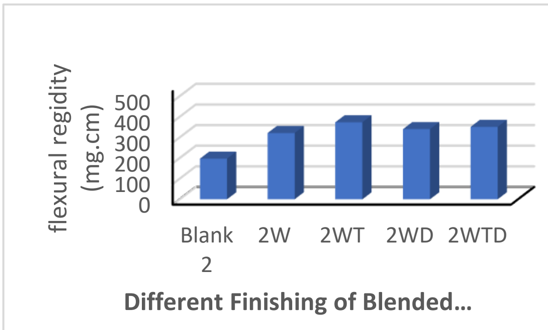


C

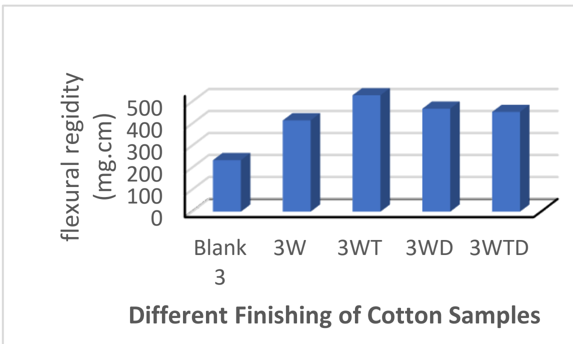
Fig. 18. Effect of Finishing Type on Burst detention



A



B



C

Fig. 19. Effect of Finishing Type on Flexural rigidity

From Figure 19 (A, B, and C) it could be seen that flexural rigidity decreased for polyester microfiber fabric after the finishing process. While it increased for cotton polyester blend and cotton fabric after finishing processes, this may be attributed to an increase in weight, thickness and fabrics' shrinkage.

3.2.8. Coefficient of Fabric Friction (MIU)

Applying one-way ANOVA for the coefficient of friction (MIU) of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 21.

Table 21. P values of significant differences in fabrics' MIU for the treatment effect of each fabric

Samples	P value
Blank 1	1.53311E-06
Blank2	1.53525E-07
Blank3	9.90428E-06

From Figure 20 (A, B, and C) it was found that the coefficient of friction decreased after finishing processing for all fabrics [40]. For polyester microfiber fabric. Figure 20 (A) the coefficient of friction decreased after mercerizing, and dyeing mercerized fabric due to the scraping that occurs on the surface of the polyester fabric as a result of the hydrolysis process. However, it was noticed that; in the case of cotton polyester fabric and cotton fabric Figure 20 (B, and C) in the case of washed mercerized dyed fabric MIU is higher than case of washed dyed fabric as a result of swelling of the cotton yarns in the fabric, which may lead to nonuniformity in the fabric surface.

3.2.9. Fabric surface roughness (SMD)

Applying one-way ANOVA for the surface roughness (SMD) of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 22.

From Figure 21 (A, B, and C) it was found that surface roughness decreased after dyeing for cotton and polyester cotton blend fabrics Figure 21 (B, and C), while it increased after dyeing mercerized polyester fabrics as shown in Figure 21 (A).

Table 22. P values of significant differences in fabrics' SMD for the treatment effect of each fabric

Samples	P value
Blank 1	0.013508684
Blank2	0.003575675
Blank3	0.007815241

3.2.10. Overall moisture management capacity (OMMC)

Applying one-way ANOVA for the Overall moisture management capacity of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 23.

Table 23. P values of significant differences in fabrics' OMMC for the treatment effect of each fabric

Samples	P value
Blank 1	0.000574671
Blank2	0.010807786
Blank3	0.001260737

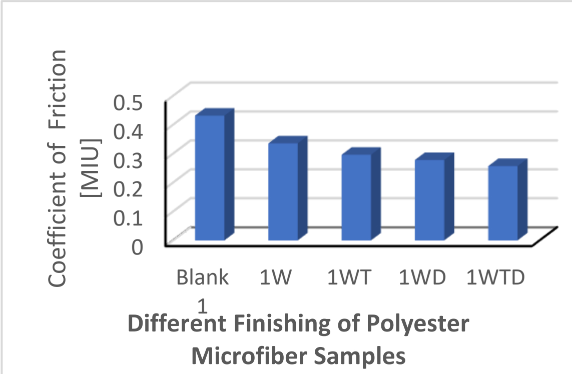
From Figure 21 (A, B, and C) it was found that surface roughness decreased after dyeing for cotton and polyester cotton blend fabrics Figure 21 (B, and C), while it increased after dyeing mercerized polyester fabrics as shown in Figure 21 (A).

3.2.11. Overall moisture management capacity (OMMC)

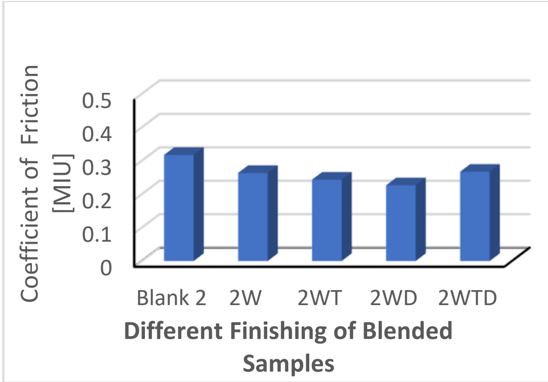
Applying one-way ANOVA for the Overall moisture management capacity of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 23.

Table 23. P values of significant differences in fabrics' OMMC for the treatment effect of each fabric

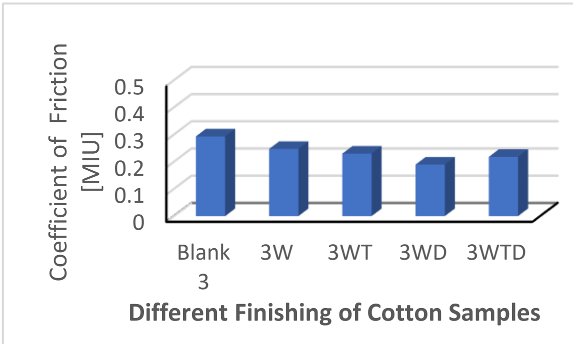
Samples	P value
Blank 1	0.000574671
Blank2	0.010807786
Blank3	0.001260737



A

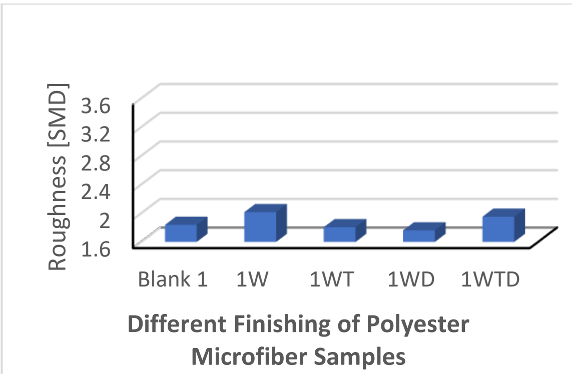


B

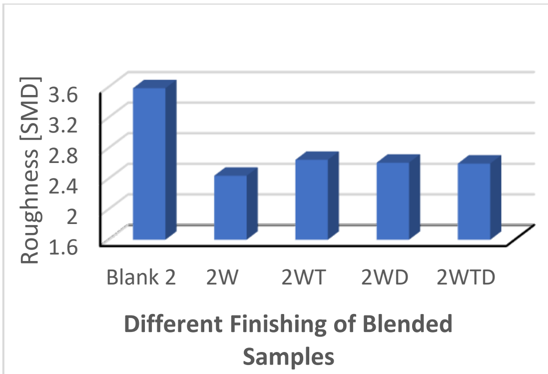


C

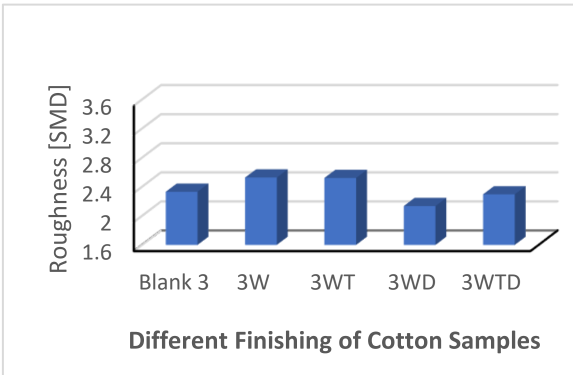
Fig. 20. Effect of Finishing Type on Fabric Coefficient of Friction



A

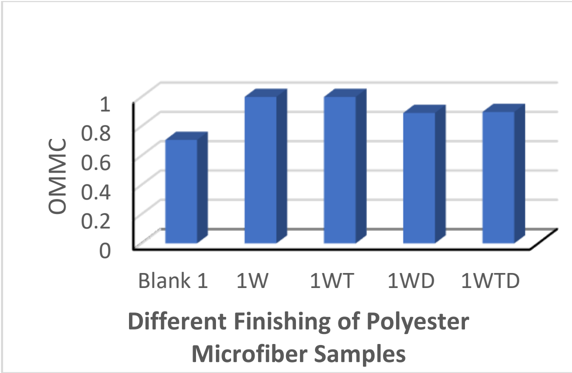


B

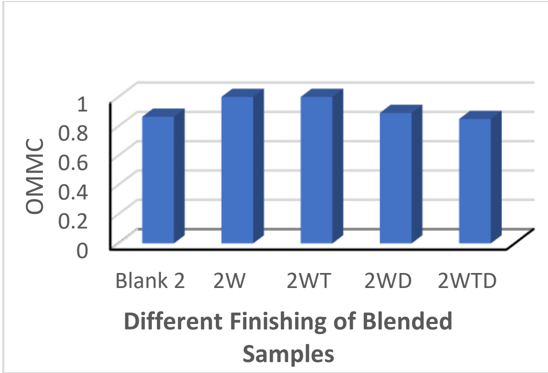


C

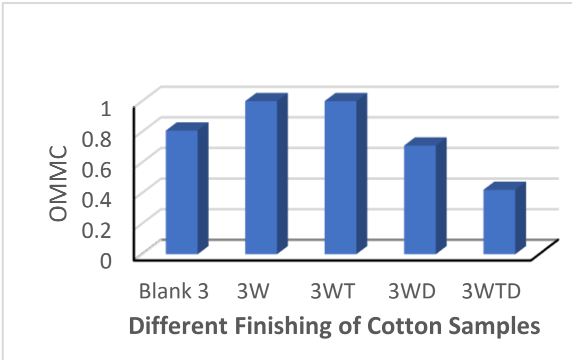
Fig. 21. Effect of Finishing



A



B



C

Type on the Roughness

Fig. 22. Effect of Finishing Type on OMMC

From Figure 22 (A, B, and C) it could be seen that Overall moisture management increased after all finishing processes for the three fabrics, except in Figure 22 (C) sample 3WT (cotton mercerized dyed fabric) decreased in OMMC due to the cooperation between functional group of cotton fibre and functional group of reactive dye.

3.2.12. Thermal Conductivity

Applying one-way ANOVA for the thermal conductivity of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 24.

Table 24. P values of significant differences in fabrics' thermal conductivity for the treatment effect of each fabric

Samples	P value
Blank 1	9.31447E-07
Blank2	1.86956E-09
Blank3	0.000179244

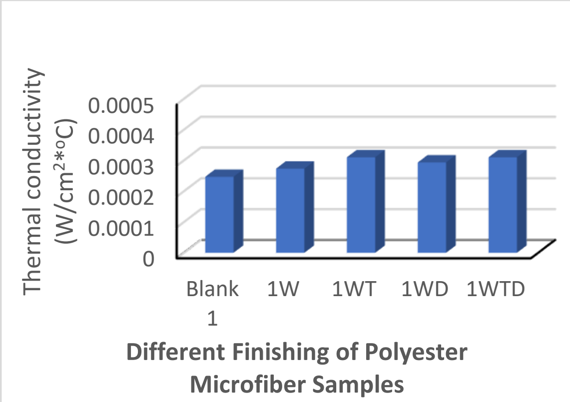
From Figure 23 (A, B, and C) it is noticed that thermal conductivity increased after the finishing process for the three fabrics this is due to the increase in stitch density after the finishing processes which means a higher percentage of material in the same area.

3.2.13. Ultraviolet Protection (UPF)

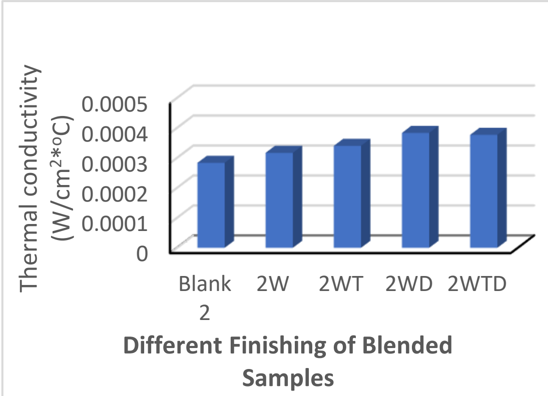
Applying one-way ANOVA for Ultraviolet protection of each fabric separately (polyester microfiber fabric, cotton polyester blend fabric, and cotton fabrics) in the following cases blank fabrics, after fabrics washing, after mercerization treatment, after dyeing of washed fabrics, and after dyeing of washed mercerized fabrics. A significant difference was found between the previous cases for each fabric type. The significant p values are shown in Table 25.

Table 25. P values of significant differences in fabrics' UPF for the treatment effect of each fabric

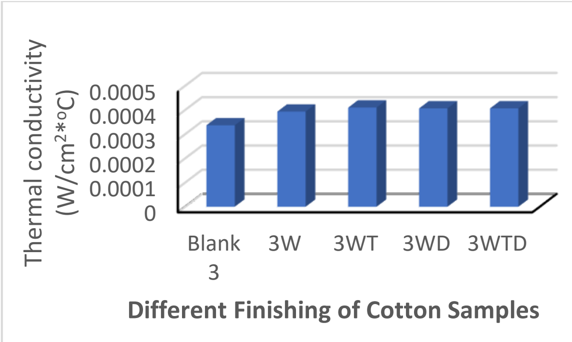
Samples	P value
Blank 1	9.38782E-07
Blank2	1.47789E-09
Blank3	4.23821E-14



A

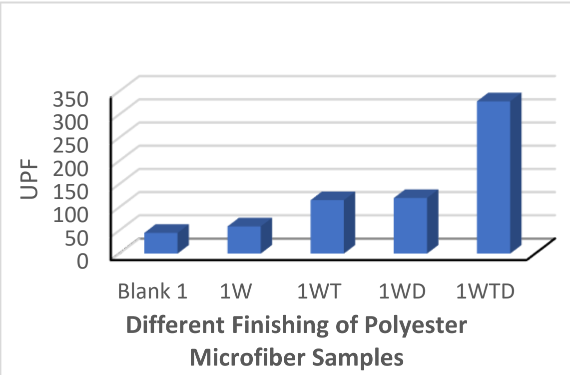


B

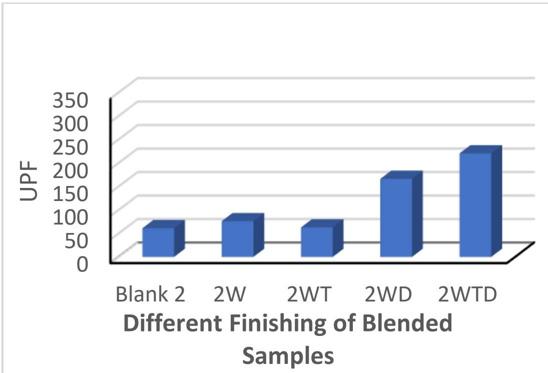


C

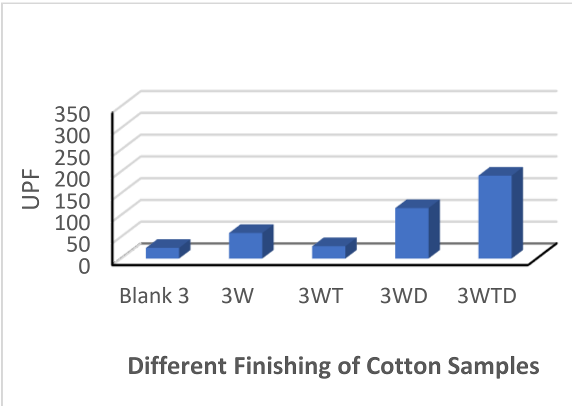
Fig. 23. Effect of Finishing Type on the Thermal conductivity



A



B



C

Fig. 24. Effect of Finishing Type on the UPF

Table 26. Effect of Treatment on washing fastness

Sample condition	K/S	Alt	St_A	St_C	St_P
W Polyester	1.03	2-3	4	4	4-5
W Polyester/Cotton	3.2	3	4-5	3-4	4
W Cotton	4.8	4	4-5	3-4	3-4
W Treated Polyester	3.3	3-4	4	3-4	4
W Treated Polyester/ Cotton	5.1	4	4	3-4	4
W Treated Cotton	5.8	4	4-5	4	4

*Dyeing condition: 1% (o.w.f) dye

From figure 24; it is obvious that fabric Ultraviolet Protection increased after finishing processes for all three fabrics this may refer to the increase in stitch density after finishing processes. The percentage increase in UPF was the highest in the case of dyed mercerized fabric which means that this process may improve the UPF of the fabric.

3.3. Colorimetric measurements

The colour strength and washing fastness properties of dyed fabrics were further evaluated and reported in Table (26). The colour strength of mercerized fabrics increased than washed fabrics on overall. The alkaline treatment on polyester fabrics led to hydrolyses which increased the active groups on surface polyester fabrics. It can be seen that the colour strength was comparatively enhanced by the alkali pre-treatment for both polyester and cotton fabrics. The washing fastness results ranged from well to very well with reactive and basic dyestuffs.

4. Conclusions

There are significant differences in stitch density, gram per meter square, and fabric thickness in each of the blank fabrics, washed fabrics, washed and mercerized fabrics, washed dyed, and washed mercerized dyed fabrics as a result of fabric shrinkage.

There were significant differences in flexural rigidity, bursting strength, fabric surface roughness, coefficient of friction, air permeability, and thermal conductivity between polyester microfiber fabric, cotton polyester blend, and cotton fabric for blank and all different finished fabrics under study.

The coefficient of friction decreased after finishing processes.

There were differences in OMMC between three fabrics in the cases of blank and all different finished fabrics under study as it increased after washing and washing and mercerizing for three fabrics and then decreased for dyeing washed fabrics or dyeing washed and mercerized fabrics.

There were differences in fabric UPF for each of the polyester microfiber fabric, cotton polyester blend, and cotton fabric for blank and all different finished fabrics under study as it increased after finishing processes for all three fabrics this may refer to the increase in stitch density after finishing processes.

Air permeability decreased after washing, mercerizing, and dyeing this could be due to increasing of stitch density after washing, mercerizing, and dyeing.

The Mercerization process enhanced the dyeability of all fabrics under the study.

Te mercerization increased the ultraviolet protection factor, especially for the dyed mercerized fabrics.

100%cotton fabric has the highest thermal conductivity, and Flexural rigidity then comes the cotton polyester fabric then comes polyester microfiber fabric for blank and all different finished fabrics under study.

Microfibre polyester fabric has a higher bursting strength, and coefficient of friction then comes cotton polyester blend then comes cotton fabric for blank and all different finished fabrics under study.

5. Conflicts of interest

"There are no conflicts to declare".

6. Formatting of funding sources

Authors funded this research work on their own for producing samples, treatment and testing.

7. Acknowledgments

The researchers would like to acknowledge the labs of the National Research Centre for the availability of test apparatus needed for this research.

8. References

[1] S. Sundaresan, K. J. Sivanganam, and A. S. Kuma. (2019) . Detailed Investigation of Weft Knitted Interlock Fabrics for Comfort Properties to Suit for Active and Sportswear Application," International Journal of Engineering and Advanced Technology (IJEAT), 8(5), 713–721 [Online]. Available: https://www.researchgate.net/publication/334163443.

[2] Z. M. Abdel-Megied, K.M. Seddik, Manar Y. Abd El-Aziz. (2018). Improve UV Protection Property of

Single Jersey for Summer Protective Clothes, *Journal of Textile & Apparel Technology & Management (JTATM)*, 10(3),1- 9.

[3] H. T. E. S. Abo El Naga and M. Y. I. Abd El-Aziz. (2023). Eco-friendly materials knitting by different yarn ply for high-performance garments, *Research Journal of Textile and Apparel*, doi: 10.1108/RJTA-03-2023-0038.

[4] Z. M. Abdel-Megied, K.M. Seddik, Manar Y. Abd El-Aziz, L.K. El-Gabry. (2020). The Enhancement of the Functional Properties of Polyester Microfiber Single Jersey Using Some Nano-materials, *Egyptian Journal of Chemistry*, 63(1), 145–154. doi: 10.21608/ejchem.2019.2868.1804.

[5] Y. Jhanji, D. Gupta, and V. K. Kothari. (2015). Comfort properties of plated knitted fabrics with varying fibre type, *Indian J Fibre Text Res*, 40, pp. 11–18.

[6] Oglakcioglu N, Celik P, Ute B, Marmarali A & Kadoglu H, Text Res J, 79 (2009) 888.

[7] Chaudhari S S, Chitnis R S & Ramakrishnan R, Water proof breathable active sports wear fabrics http://www.sasmira.org/ sportswear.pdf (accessed on 24October 2013).

[8] Y. Teyeme, B. Malengier, T. Tesfaye, S. Vasile, and L. Van Langenhove. (2020). Comparative analysis of thermophysiological comfort-related properties of elastic knitted fabrics for cycling sportswear," Materials, 13(18), doi: 10.3390/ma13184024.

[9] Li, Y. (2005). Perceptions of temperature, moisture and comfort in clothing during environmental transients. Ergonomics, 48, 234–248. [CrossRef] [PubMed]

[10] Yi, K.F. Effect of Heat and Moisture Transfer Properties of T-Shirts on Comfort Sensations; The Hong Kong Polytechnic University: Hong Kong, China, 2006.

[11] Theses, M.; Wigboldy, K. The Effects of a Moisture-Wicking Fabric Shirt on the Physiological Responses during Acute Exercise in the Heat; Wester Michigan University: Kalamzoo, MI, USA, 2013.

[12] Uttam, D. (2013). Active Sportswear Fabrics. Int. J. IT Eng. Appl. Sci. Res., 2, 34–40.

[13] Bhatia, D.; Malhotra, U. Thermophysiological Wear Comfort of Clothing: An Overview. *J. Text. Sci. Eng.* 2016, 6, 250. [CrossRef]

[14] Y. Yang, X. Yu, L. Chen, and P. Zhang. (2021). Effect of knitting structure and yarn composition on thermal comfort properties of bi-layer knitted fabrics," *Textile Research Journal*, 91(1–2), 3–17, doi: 10.1177/0040517520932557.

[15] R. Ahmed, S. Mia, N. Nabijon, M. N. Morshed, and Q. Heng. (2013). Knit Fabric Mercerisation through the Use of High-Concentration NaOH in a Scouring and Bleaching Bath using an Exhaustion Method," Tekstilec, 60(4), 324–330, doi: 10.14502/Tekstilec2017.60.324-330.

[16] SAAPAN, A. A., KANDIL, S. H., HABIB, A. M. (1884). Liquid ammonia and caustic mercerization of cotton fibers using X-ray, infrared, and sorption measurements. *Textile Research Journal*, 54(12), 863–867, doi: 10.1177/004051758405401212.

[17] WAKIDA, Tomiji, KIDA, Kyoko, LEE, Muncheul, BAE, Soyeung, YOSHIOKA, Hiromu, YANAI, Yuichi. (2000). Dyeing and mechanical properties of cotton fabrics treated with sodium hydroxide/liquid ammonia and liquid ammonia/sodium hydroxide. *Textile Research Journal*, 70(4), 328– 332, doi: 10.1177/004051750007000408.

[18] ROUSSELLE, M., A., NELSON, M. L., HAS SENBOEHLER, C. B., LEGENDRE, D. C. (1976). Liquid-ammonia and caustic mercerization of cotton fibers: changes in fine structure and mechanical properties. Textile Research *Journal*, 46(4), 304–310, doi: 10.1177/ 004051757604600412.

[19] HAGA, T., TAKAGISHI, T. (2001). Structural change in mercerized cotton fibers on cellulase treatment. *Journal of Applied Polymer Science*, 80(10), 1675–1680, doi: 10.1002/app.1262.

[20] BERTONIERE, Nelie R., KING, Walter D. (1989). Effect of scouring/bleaching, caustic mercerization, and liquid ammonia treatment on the pore structure of cotton textile fibers. *Textile Research Journal*, 59(2), 114–121, doi: 10. 1177/004051758905900209.

[21] HAGA, T., MORI, R., WAKIDA, T., TAKAGISHI, T. (2000). Hydrolysis of mercerized cotton fibers due to cellulase treatment. *Journal of Applied Polymer Science*, 78(2), 364–370, doi: 10. 1002/1097-4628(20001010)78:23.0.co;2-4.

[22] SAMEII, N., MORTAZAVI, S. M., RASHIDI, A. S., SHEIKHZADAH-NAJAR, S. (2008). An investigation on the effect of hot mercerization on cotton fabrics made up of open-end yarns. Journal of Applied Science, 8(22), 4204–4209, doi: 10. 3923/jas.2008.4204.4209.

[23] WAKIDA, Tomiji, LEE, Muncheul, PARK, Sun Ji, HAYASHI, Aya. Hot. (2002). mercerization of cottons. Sen'i Gakkaishi, 58(8), 304–307, doi: 10.2115/ fiber.58.304

[24] S. Jevšnik, Z. Stjepanovič, L. Heikinheimo, and K. Gotlih, (2012). Changes in a Knitted Fabric's Surface Properties Due to Enzyme Treatments, *Fibers and Polymers*, 13(3), 371–379, doi: 10.1108/09556221111096741.

[25] Sampath, M. B., Anton Aruputharaj, Mani Senthilkumar, and G. Nalankilli. (2012). Analysis of thermal comfort characteristics of moisture management finished knitted fabrics made from different yarns. *Journal of industrial textiles*, 42(1), 19-33.

[26] El-Hady, Rasha A. Abd. (2014). Enhancing the functional properties of weft knitted fabrics made from polyester microfibers for apparel use. *International Design Journal*, 4 (4), 219-227.

[27] Bhattacharya, S. S., and J. R. Ajmeri.. (2013). Investigation of air permeability of cotton & modal knitted fabrics. International Journal of Engineering Research and Development, 6(12)` , 1-6.

[28] Asta Bivainytė. (2012). Influence of the Knitting Structure of Double-Layered Fabrics on the Heat Transfer Process" *FIBRES & TEXTILES in Eastern Europe*, 2(91), 40-43.

[29] Ertekin, Gözde, and Arzu Marmarali. (2011). Heat, air and water vapor transfer properties of circular knitted spacer fabrics. *Textile and Apparel*, 21(4) , 369-373.

[30] Salman, Ahmed Ali and Manar Y. Abd El-Aziz. (2015). Influence of Weft Knitted Fabrics Construction for Protection against Ultraviolet Radiation. *International Journal of Science and Research.* 4(12), doi:10.21275/v4i12.nov152400.

[31] A. M. El-Moursy, O. A. Hakeim, Z. M. Abdel-Megied, M. Y. Abd El-Aziz and N. A. H. Asser. (2022). Impact of Hollow Cellulosic Fiber-Based

Polyester / Cotton / Bamboo Hybrid Composites on Physical and Some Comfort Properties. *Egyptian Journal of Chemistry*, 65(13), 909-918.
[32] A. M. El-Moursy, Z. M. Abdel Mageid, M. Y. I. Abd El-Aziz, N. Asser and O. Hakeim. 2023. Evaluating fabrics produced by blending hollow fibres and bamboo with cotton/polyester wastes using the Kawabata system. *Research Journal of Textile and Apparel*, doi: 10.1108/RJTA-01-2023-0005.
[33] J. Hu. (2005). Moisture Management Tester: A Method to Characterize Fabric Liquid Moisture Management Properties. *Text. Res. J*., 75(1), 57–62.
[34] L.K. El-Gabry and A. Bendak. (2006). Dyeing Characterization of Alkoxide Pretreated Acrylic, Polyester Fibres Blend Using Cationic Dyes. *Polish Journal of Applied Chemistry*, (3-4), 83-94
[35] S. E. Shalaby, N. G. AL-Balakocy, and S. M. Abo EL-Ola. (2007). ALKALINE TREATMENT OF POLYETHYLENE GLYCOL MODIFIED POLY (ETHYLENE TEREPHTHALATE) FABRICS" *Journal of the Textile Association* , (5-6)
[36] Z. M. Abdel- Megied; K. M. Seddik; M. Y .Abd El-Aziz and L. K. El-Gabry (2020). The enhancement of the functional properties of polyester microfiber single jersey using some nano-materials. *Egypt. J. Chem*. 63(1), 145- 154.
[37] A. Abou El-Kheir, N. A. Abd El-Ghany, M. M. Fahmy, S. E. Aboras and L. K. El-Gabry. (2020). Functional Finishing of Polyester Fabric Using Bentonite Nano Particles" Egypt. J. Chem. 63, 1, pp. 85-99 .
[38] L. Jing, X. Min, C. Shuilin. (2003). Synthesis and characterization of nonformaldehyde releasing and low-temperature curable binder, *AATCC review*, 3, 29-32.
[39] Pran Krisna Saha, Md. Anamul Haque, Tarikul, Debasree Paul and Joy Krishna Saha. (2019). A Study on Thermal Comfort Feeling Properties of 60%/40% and 80%/20% Cotton/Polyester and 100% Cotton Fleece. *Journal of Textile Science& Fashion technology*, 4(3).
[40] Mohamed Ezzat , Fatma Bassyouni , Lamiaa Kamal El Gabry, Mona Mohamed Shawky . (2022). Effect of New Functional Dye on Some Comfort Attributes of Suiting Wool Fabrics Using Kawabata Evaluation System. *Egypt. J. Chem.* 65(13), 71-80.