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INVESTIGATION OF ACRYLIC/COTTON SINGLE JERSEY KNITTED FABRICS TREATED WITH TITANIUM DIOXIDE (TiO_2) NANOPARTICLES

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Abstract

Acrylic fibers have advantageous properties such as durability, wear resistance, and high ultraviolet resistance. Its blends with cotton are becoming increasingly common in the textile field. However, new antimicrobial substances are of great interest. Metal oxide nanoparticles such as titanium dioxide (TiO2) are considered an attractive antimicrobial compound. Nevertheless, treatment with TiO2 is expected to affect the properties of the treated fibers, yarns, and fabrics. Wicking properties for fabrics produced with treated Acrylic fibers are hence expected to be influenced. This paper is dedicated to studying the effect of changing the blending ratios of Acrylic fibers blended with cotton fibers and the effect of the addition of TiO2 on the fiber properties, the yarn properties, and the knitted fabric wicking properties. It is shown that the mechanical properties of the yarns are affected by the blending ratio and the addition of the TiO2. The wicking abilities of fabrics increased with the increase in Acrylic content in the blends, either with or without the addition of TiO2¬. Furthermore, a utility concept system for the development and evaluation of the multi-criteria fabrics selection of the best blend is used and tested. The research work presents a significant contribution to study the comfort of fabrics especially for sportswear, where cotton/acrylic blends show an increasing importance.

Keywords: capillary; wicking; knitted fabric; Titanium dioxide (TiO_2); fiber blending

1. Introduction

Comfort is one of the most important aspects of textile products. It strongly affects the choice of customers when selecting clothes [1]. Since the raw materials used to produce yarns and fabrics stand as the primary factor in deciding the comfort of the product, an accurate selection of raw materials is crucial. Neither natural nor man-made fibers are optimally suited to certain fields of use, but a blend of the two fiber categories can give the required characteristics. The proportion of products made of blended yarns is therefore continually increasing [2]. Cotton/Acrylic blends are one of the most common blends used in garments. Acrylic fibers are known to have low thermal conductivity, retention, durability, and easy-care properties. Its softness of touch and bulk make it attractive for use in the knitwear sector. They are quick drying, resilient, retaining shape, and resistant to moths, sunlight, oil, and chemicals [3]. When blended with cotton, Acrylic fibers add warmth, are lightweight, wrinkle resistant and supply shrink resistance, resilience, and shape retention [4]. Cotton fibers supply strength, increase absorbency, and lower the cost of the fabric.

Moisture-wicking refers to the process by which moisture is drawn away from the skin to the fabric's outer surface and into the air. Fabrics with moisture-wicking properties are most used in activewear [5]. Acrylic in knitted fabrics has a much higher wicking rate when compared to that of cotton, making them more right for vigorous activity, in active sportswear [6]. Vertical wicking heights for bulked yarns are higher than comparable 100% cotton yarn [7, 8]. For yarn counts of 20Ne, the percentage increase in the wicking heights varied from 344% to 400% in course and wale directions respectively [6]. Nevertheless, the acrylic proportion in blended cotton-acrylic yarns had little effect on the wicking heights [7]. It was proved that the bulking process supplied more capillary space which in turn increased the wicking performance of the yarns. When wicking takes place in a material whose fibers can absorb liquid the fibers may swell as the liquid is taken up, so reducing the capillary spaces between fibers, and potentially altering the rate of wicking [9,10,11]. Experimental examination of the rates of transport of liquid water along yarns supports the view that water travel occurs by capillary action. Yarn construction features, such as size, number of fibers, fiber size, and twist, all affect the rate of water transport as far as they control the size of the inter-fiber capillaries [12]. Yarn properties including wettability, twist level, and hygroscopic nature affect the wicking behavior. Capillary action is influenced by the increased

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filaments, absence of spaces, and yarn packing which in turn is affected by the twist level of yarn. Increasing twist level and decreasing linear density in yarns reduces inter-yarn spaces, leading to a lower capillary radius [13]. Wicking property is also slightly affected by fabric parameters. But major effects are noticed by the yarns and fibers. Low weaves or knit density of the fabric produces slackness factor in the fabrics that alters wicking property due to ease of water flow in the spaces. Lower thread spacing causes higher wicking provided that inter yarn spaces are filled for better transfer wicking [14,15].

On the other hand, it is observed that the interest in new antimicrobial substances is gradually increasing. It has recently been focused on metal oxide nanoparticles. Specifically, titanium dioxide (TiO_2) has been considered as an attractive antimicrobial compound due to its photocatalytic nature and because it is a chemically stable, non-toxic, inexpensive, and generally recognized as a safe (GRAS) substance [16,17]. The application of nano- TiO_2 on textile fabrics imparts various valuable functionalities such as: wettability, antimicrobial activity, UV protection functional properties. photocatalytic self-cleaning, hydrophobicity, thermal stability, flame retardancy, and electrical conductivity [18,19]. TiO_2 exhibits intrinsically strong absorption of ultraviolet (UV) light. It has been therefore utilized in a variety of applications, such as environmental purification/sterilization, health care and energies [20]. The self-cleaning capability of TiO_2 has been the subject of many research works. Carbon-containing titania nano-composites and TiO_2 nanoparticles prepared using bacterial cellulose (BC/TiO_2 hybrid nano-composite) showed high antimicrobial and photocatalytic activity (self-cleaning effect) and proved to be promising for the application in medical and industrial purposes [21,22]. However, when titanium dioxide was added to acrylonitrile copolymer and wet spun, the resulting fiber displayed insufficient photocatalytic activity [23]. Synthetic fibers, and acrylic fibers specifically are normally extremely shiny and transparent when extruded. A common additive to acrylic fibers during their production is titanium dioxide. Adding powdered titanium dioxide causes the surface of the fibers to be rougher, reducing the sheen; at the same time, being opaque reduces the transparency of the fiber. To be effective as a dull-luster, titanium dioxide must be powdered 0.1-1.0 µm, depending on the size of the fibers, and varying amounts (up to about 2%) can be used depending on the level of luster needed [24, 25, 26].

The wicking properties of rotor yarns and their influence on the wicking behavior of cotton-Acrylic knitted fabrics have been investigated. The results showed that the presence of acrylic fibers had a significant impact on the wicking performance of single jersey knitted fabrics [27]. It is, therefore, important to investigate the effect of the addition of TiO_2 on the properties of the fibers, yarns, and fabrics produced from cotton/Acrylic blends and to investigate its effect on the comfort of the fabrics produced. The objective of this work is to study the effect of treating acrylic fiber with TiO_2 used for cotton/acrylic blend on the yarn's mechanical properties and knitted fabric wicking.

2. Materials and Methods

2.1 Acrylic fibers

2.1.1 Preparation of untreated Acrylic fibers

The manufacturing process of acrylic fiber can be divided into two processes, namely chemical process, and fiber production. The chemical process consists of polymerization, dope making, and solvent recovery. The polymer is produced by aqueous suspension polymerization of acrylonitrile (AN), methacrylate (M35), and sodium methyl sulfonate (M37). Polymer suspended in water slurry is dissolved with sodium thiocyanate (PRS) for dope making in case of producing bright acrylic fiber. The monomer ratio of AN:M35:M37 in the preparation of untreated acrylic fibers varies according to the desired properties of the final product. However, a common ratio is 85:10:5. On the other hand, TiO_2 is added to the dope in order to produce semi-dull acrylic fiber.

Wet spinning is adopted and diluted PRS is used as a coagulant. Crimp is imparted to Acrylic fibers, relaxation is achieved then finish oil is added to the tow. The tow is then cut to a fixed length of 38 mm to be suitable for blending with cotton fibers.

The properties of acrylic fibers are shown in table 1.

Table 1. Properties of Acrylic fibers

Cotton like Acrylic	Fiber Denier	Fiber cut length Mm	Crimp Number/cm	Finish percentage "Normal finish"	Shrinkage %	Specific density g/cm^3
	1.5	38	4	0.35 %	3%	1.2

2.1.2 Preparation of Modified Acrylic Fibers

In the case of the production of semi-dull Acrylic, TiO2 is added to the dope before fiber formation. In this case, preparation of TiO2 liquid is necessary. Deionized water (DW) is fed using the head pressure, then metered by a flow meter, and finally fed into the TiO2 preparation tank. In the preparation tank, TiO2 is stirred with DW by the homo-mixer for 2 hours. TiO2 suspension liquid is then stirred with a proper agitator to prevent cohesion and precipitation of TiO2. The TiO2 suspension liquid is directly added to the bright filtered dope just before the fiber extrusion using a feed pump with a concentration of 0.3 % in proportion to the dope flow rate. The dope is completely mixed through a dispersing machine and fed to the spinning machine. The titanium dioxide average particle size is 0.19 microns. The specifications of the TiO2 are given in Table 2.

2.2 Cotton fibers.

Egyptian cotton Giza 86 is used to be blended with the acrylic fibers prepared. The specifications of the cotton fibers are given in Tables 3.

2. 3 Production of Cotton/Acrylic yarns and fabrics

In the ring spinning mill, Acrylic and cotton fibers are opened in separate blowing room units. Blending cotton with Acrylic takes place on the first drawing frame with the following percentages: 100% A, 100% C, 50%A/50%C, 80%A/20%C, and 20%A/80%C. Where A stands for Acrylic, and C stands for cotton fibers. The different blends are prepared from bright

Acrylic as well as from semi-dull acrylic fibers treated with TiO2.

Table 2. Characteristics of TiO_2

Molecular weight	79.9 g/mol
Appearance	Colorless Crystal
Specific gravity	3.9
Melting point	1640° C

Table 3. The properties of cotton fiber used

Cotton Type	Egyptian cotton Giza 86
Staple length mm	32.7
Uniformity Index	86.2
Micronair u/inch	4.3
Maturity	88%
Tenacity g/tex	43.9
Tenacity C.V%	6
Breaking elongation %	5.2
Elongation C.V%	8
Hair-Weight millitex	162
Specific density g/cm^3	1.54
Spinning Consistency Index	199

Spun yarns of the count 20 tex and twist 720 tpm are produced on a ring spinning machine, using two types of acrylic fibers with different blending ratios with the Egyptian cotton G 86, as given in Figure 1. Single Jersey Knitted fabrics (140 g/m2) are produced on a flat knitting machine with gauge number 8. The wicking tests for the fabrics are conducted in the wale and course directions according to ISO 9073 for all the knitted fabric produced. Figure 1 shows the plan of the experimental work.

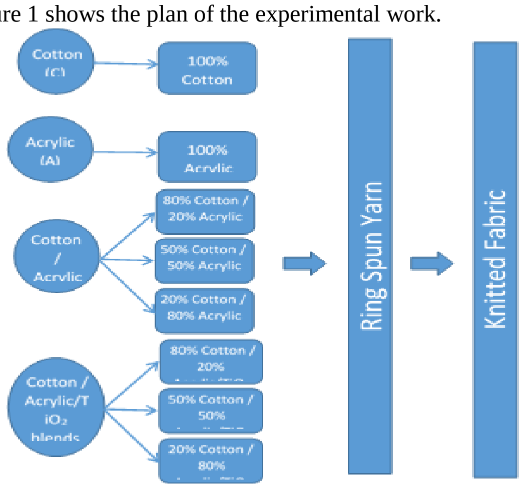


Figure 1: Experimental design

The specifications of the produced knitted fabric are given in Table 4. The tightness of knitted fabric is characterized by the tightness factor (TF). When comparing structures of the same type and yarn in a similar state of relaxation, the following formula can be used [28]:

$$TF = (tex)^{0.5} / l \quad (1)$$

where the tex represents the yarn linear density and l represents the stitch length in mm.

2.4 Vertical Wicking measurement

The determination of fabric wicking is performed using the strip test method on the course and wale sample strips according to AATC TM 197-2011 standards. The schematic diagram of the experimental setup is shown in Figure 2. Fabric specimens of 300 mm × 25 mm in wale and course directions are prepared from the different knitted fabrics produced. The specimens are suspended vertically with their bottom ends dipped in a reservoir of distilled water. To ensure that the bottom ends of the specimens are immersed vertically at a depth of 20 mm under the surface of the water, the bottom end of each specimen is clamped with a 2.5 g clip. The wicking height is measured in cm.

2.5 Statistical analysis

To evaluate the test outcomes, one-factor ANOVA and Two-factor ANOVA are applied, where applicable, to determine the statistical significance of the different variables under investigation. P-values are examined, and the variables are considered significant if the p-value is less than 0.05.

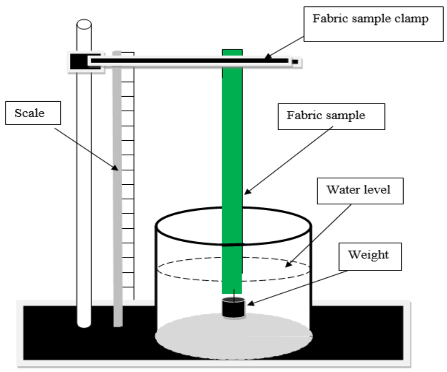


Figure 2: Schematic representation of the vertical wicking setup

3. RESULTS AND DISCUSSION

Moisture transition in textile fabrics is one of the critical factors affecting physiological comfort and is also particularly important, especially for underwear and sportswear. Therefore, in this research work, the wicking ability is chosen to be the determining factor standing for the Cotton/Acrylic knitted fabric comfort. Wicking is often used to express moisture transport. It represents the spontaneous transport of a liquid driven into a porous system by capillary forces [1]. While wettability describes the first behavior of fabric or yarn in contact with liquid, wicking ability describes its ability to support capillary flow [29,30].

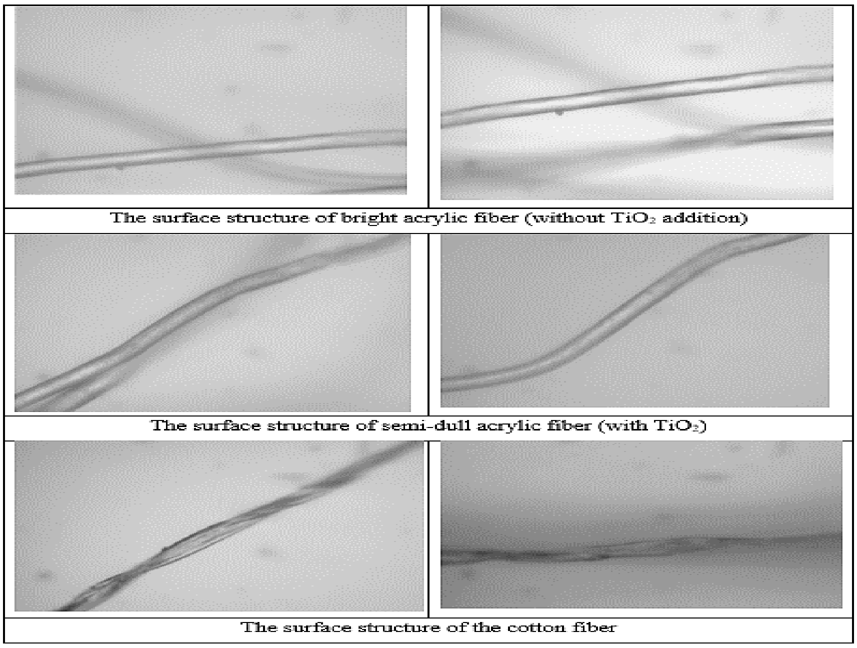
In the designed experimental plan shown in Figure 1, different parameters are measured for yarns and fabrics produced from different blends of Acrylic and cotton fibers. For yarns, yarn strength, elongation, irregularity, imperfection, and hairiness are measured. For single jersey knitted fabrics the wicking height is measured and is considered as a factor reflecting the comfort of the fabrics.

3.1 Effect of the addition of TiO_2 on acrylic fiber properties

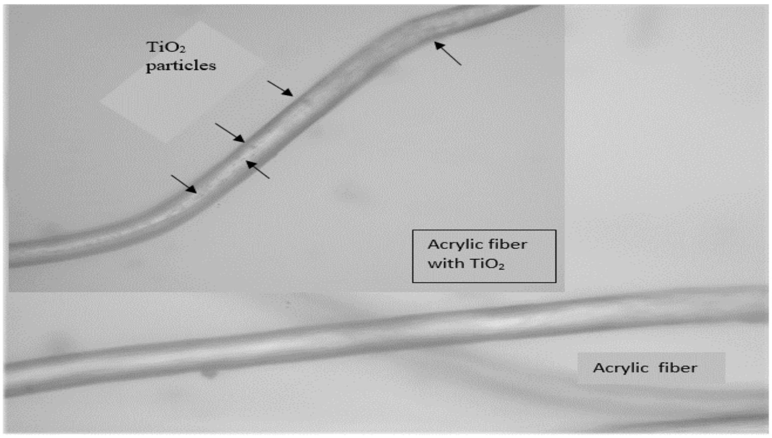
As a first step, the surface structure of cotton and acrylic fibers is investigated using a SEM (SEM-JSM-5300 JEOL) with a magnification of x1000. The average cotton diameter is 20 micron and the average acrylic diameter is 13.3

micron. From the comparison of the surface structure of the Acrylic and the Acrylic with TiO2 fibers, Figure 3, it could be seen that acrylic fibers with TiO2 have a rougher surface than normal acrylic fibers. The presence of TiO2 particles on the surface of the fibers can be distinguished. This plays a significant role in yarn processing and, so, on yarns and fabric properties.

The yarn properties are a function of their fiber properties and the blending ratio of the Cotton /Acrylic. Hence, the addition of TiO2 is expected to affect the properties of the Acrylic fibers and their behavior during drafting. Fiber tenacity and elongation are measured for bright and semi-dull acrylic fibers as shown in Table 5. It can be seen that the fiber tenacity and elongation increased with the addition of TiO2.



a- SEM of the different fibers



b- TiO_2 particles on the surface of the acrylic fibers

Figure 3: Surface structure of cotton, bright and semi-dull Acrylic

3.2 Effect of the addition of TiO_2 on the properties of Acrylic/ Cotton ring-spun blended yarns

Table 6 gives the results of the different produced yarns according to ASTM standards for each property.

Table 4. Knitted fabrics specifications.

Yarn blending %	No of Wales/cm	No of Courses/cm	Fabric density stitches/cm^2	Fabric tightness factor TF
100C	6	8	48	1.72
20A/80C	5	8	40	1.69
50A/50C	5	8	40	1.66
80A/20 C	6	8	48	1.60
100A	5	7	35	1.54

Table 5. Effect of the addition of TiO_2 on Acrylic fiber tenacity and elongation

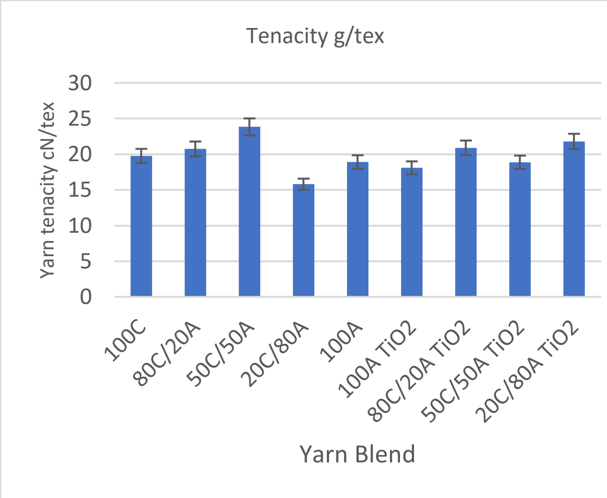
	Tenacity cN/tex	Elongation %
Acrylic	21.6 (CV% = 10.15)	45
Acrylic treated with TiO_2	22.5 (CV% = 8.5)	50

Table 6. Properties of the Yarns

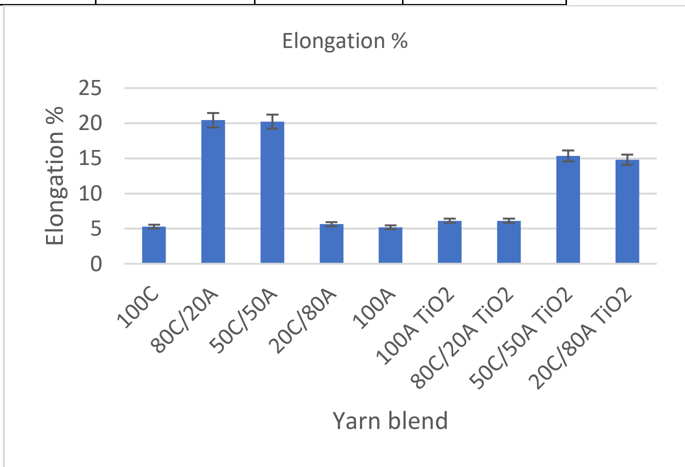
Sample Index	CV% Uster	Thick places + 50%/ Km	Thin places -50%/ Km	Neps 200%/ km	Hairiness	Tenacity cN/tex	Elongation %
100C	16.3	5	2	125	7.5	19.79	5.3
80C/20A	14.53	20	1	75	6.3	15.8	5.64
50C/50A	15.46	2	0	105	8.5	18.1	6.13
20C/80A	13.24	15	0	50	5.5	18.87	15.33
100A	13.89	10	0	10	4.7	20.75	20.42
100A TiO_2	16.99	15	0	23	5.1	23.85	20.21
80C/20A TiO_2	17.63	18	1	72	5.6	18.91	5.2
50C/50A TiO_2	18.56	0	1	115	7.4	20.89	6.13
20C/80A TiO_2	16.34	16	0	65	6.3	21.79	14.8

3.2.1 Effect of the addition of TiO_2 on blended Acrylic/ Cotton ring spun yarn tenacity

Figures 4-a and 4-b show the effect of the TiO2 addition on the tenacity of Cotton/Acrylic ring spun yarns with different blending ratios. It can be observed that the tenacity and the breaking elongation of the blends of cotton and acrylic fibers change with the change of the blending ratio. The work of rupture of the blended yarn is higher than that of cotton yarn. Moreover, the addition of TiO2 leads to a significant increase in the yarn tenacity as the amount of acrylic in the blends increases. A single factor ANOVA showed that the treatment of Acrylic with TiO2 significantly affects the tenacity and breaking elongation of the yarns with p-values of 0.0004 and 0.0082 respectively. This increase is mainly due to the increase in the friction between the fibers associated with the treatment with TiO2.



(a) Effect of the TiO_2 addition on the yarn tenacity



(b) Effect of the TiO_2 addition on the yarn elongation

Figure 4: Effect of the TiO_2 addition on the yarn tenacity and elongation

3.2.2 Effect of the TiO_2 addition on yarn Young's modulus

Young's modulus for cotton fibers (E=3.47 GPa) is generally higher than that of Acrylic fibers (E=0.9/GPa). The addition of TiO2 increases the Acrylic fiber Young's modulus by about 7%. This is clearly illustrated in figure (5). A two-Factor ANOVA showed that the blending ratio of Acrylic/Cotton and the treatment with TiO2 significantly affect Young's modulus of the Cotton/ Acrylic blended yarn giving p-values of 0.0288 and 0.00089 respectively. It is believed that the addition of TiO2 to acrylic fibers increases Young's modulus due to the strong interfacial interaction between the TiO2 and the acrylic matrix. This interaction leads to improved fiber-matrix adhesion, resulting in enhanced mechanical properties of the composite material. Moreover, the fact that TiO2 is a stiff and strong material is also crucial. When added to acrylic fibers, it reinforces its structure and improves its mechanical properties.

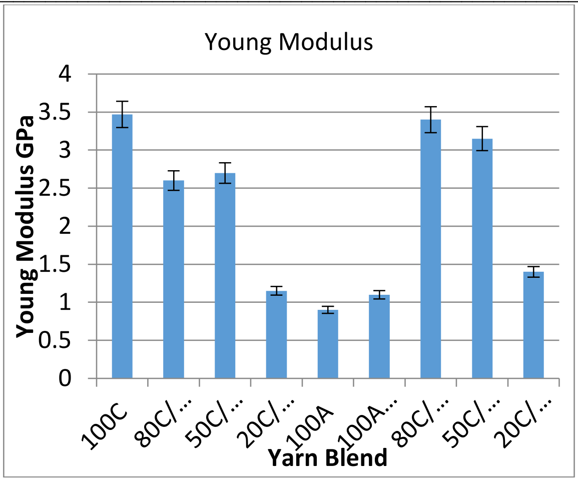


Figure 5: Effect of the TiO_2 addition on Cotton/Acrylic blended yarns Young's modulus

3.2.3 Effect of the TiO_2 addition on yarn evenness

The yarn irregularity depends primarily on the behavior of the drafted fibers during the drafting process. This behavior depends on the value of the coefficient of friction of the different fibers in the blend as well as on the respective fiber extensibility. Drafting force is the direct and sensitive factor resulting from the fiber motion within a drafting zone. It starts with the interfacial friction between the fibers and interaction of the roller and the outer layer of fiber assembly to overcome the cohesive friction of drafted fiber strands [31]. In the drafting process, a fiber's motion behavior at the drafting zone depends on the frictional force and, more specifically, on the variation of frictional force among the surrounding fibers [32]. In the case of blending fibers of different fibers lengths and different coefficients of friction, it is expected that the drafted product's irregularity (CV%) will be correlated with the blending ratio. However, it was revealed that the mass CV% increases with the increase in cotton fiber % in any blend [33]. As shown in Figure 6, increasing the percentage of cotton in the blend increases the corresponding yarn irregularity. Figure 6 also shows that the blends of Cotton/Acrylic treated with TiO2 blend give higher yarn irregularity. A single-factor ANOVA shows that the addition of TiO2 has a significant influence on the values of yarn irregularity (CV %) with a p-value of 0.003. This is justified by the higher surface friction of Acrylic fibers treated with TiO2 nanoparticles compared to the untreated Acrylic fiber.

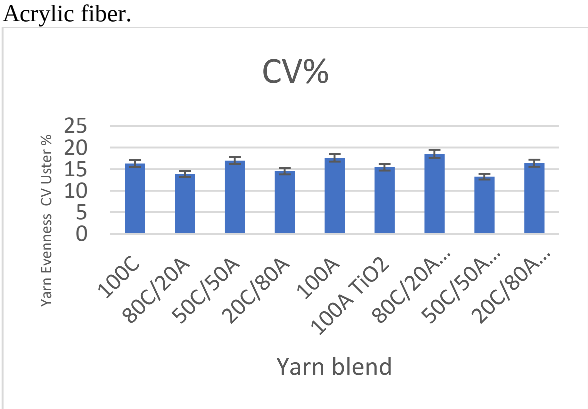
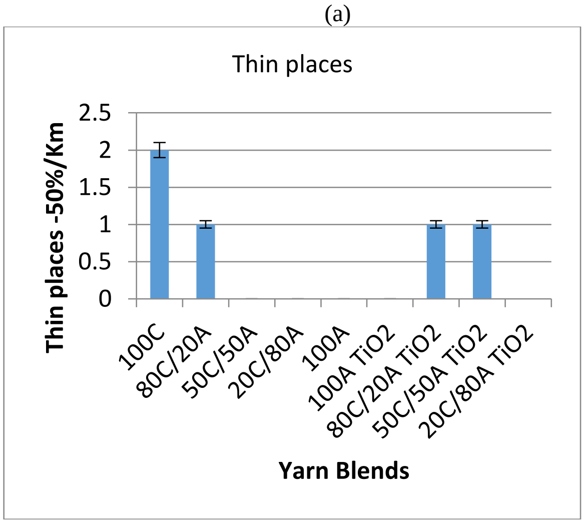


Figure 6: Effect of the TiO_2 addition on the yarn irregularity CV%

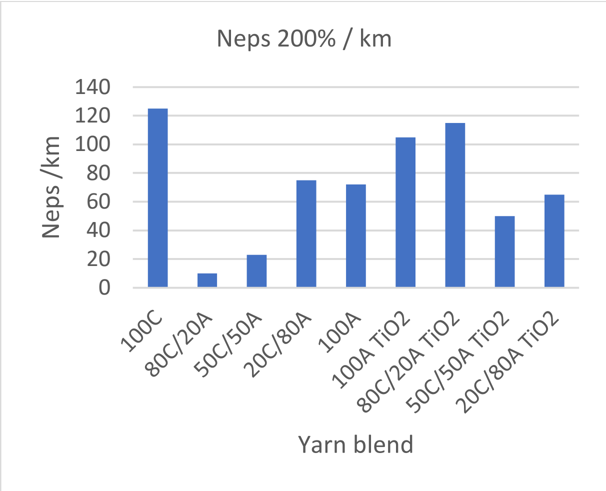
3.2.4 Effect of the TiO_2 addition on yarn imperfections

The heterogeneity in the properties of the components of blended yarns has an effect on the yarn imperfection. The behavior of the drafting process which varies according to the fiber types to be drafted leads to a change in the yarn imperfection: thin places, thick places, and neps. The treatment of acrylic fibers with TiO2 also has a considerable effect on yarn imperfection. Fiber clustering is highly expected when the coefficient of friction of one fiber component is higher than the other. The blending ratio is therefore expected to have an effect on the yarn imperfection. Figure 7-a shows the effect of the TiO2 addition on the number of thick places/km for Cotton/Acrylic yarns. The addition of TiO2 increases the number of thick places/km in unblended yarns but reduces the number of thick places/km in the blended yarns, especially at 50C/50A. This is due to the change in the surface roughness of the fibers which changes the movement behavior of the fibers in the drafting zone. Figure 7-b and Figure 7-c show the effect of adding TiO2 on the number of thin places and neps/km for Cotton/Acrylic blended ring spun yarns. However, single-factor ANOVA showed that the effect of applying TiO2 on acrylic fibers has a non-significant effect on the number of thick places and neps with p- values of 0.936 and 0.805 respectively.

(a)



(b)



(c)

Figure 7: Effect of applying TiO_2 on Acrylic blended yarns, (a) Thick places , (b) Thin places and (C) Neps

3.2.5 Effect of the TiO_2 addition on yarn hairiness

Figure 8 shows that increasing the acrylic percentage in the yarn slightly decreases the amount of hairiness till the blending ratio of 50C/50A is reached. A further addition of TiO2 decreases the amount of hairiness. However, applying a single factor ANOVA showed that this variation is non-significant as the p-value was found to be 0.889.

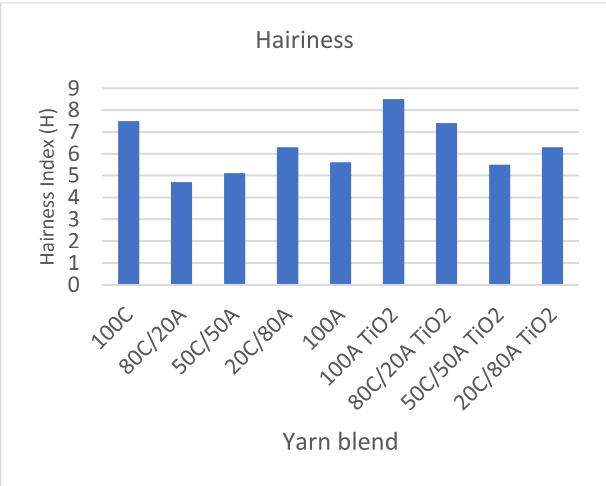


Figure 8: Effect of the TiO_2 addition on yarn hairiness

3.2.6 Effect of the TiO_2 addition on the Yarn Quality Index

While assessing the quality of a yarn, it is more practical to compare one descriptive number rather than several parameters. Therefore, the three properties (Tenacity, elongation, and irregularity) have been combined in a total quality index defined as follows:

TQI = [(Yarn tenacity (cN)/ tex) x Elongation %] / CV% (2)

This index has been used to compare the overall quality of the different yarns produced.

Figure 9 shows that as the percentage of acrylic increases in the blended yarn, the quality index increases significantly. The addition of TiO2 to the Acrylic fiber has a rather negative effect. The index decreases as the amount of acrylic treated with TiO2 increases. However, performing a two-factor ANOVA analysis showed that while changing the blending ratio of acrylic fibers had a significant effect on the quality index giving a p-value of 0.000178, the addition of TiO2 had no significant effect giving a p-value of 0.1394.

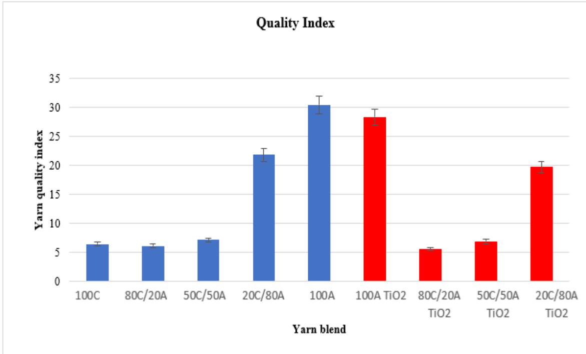


Figure 9: Effect of the TiO_2 addition on yarn Quality Index

3.3 Wicking properties of knitted fabrics

Wicking in a fabric is a phenomenon representing the moisture transmission in this fabric. It influences the comfort which the fabric can provide. An easy and effective transportation of moisture away from the body improves comfort significantly. The rate of transfer of moisture/liquid is a function of fabrics' wicking properties. The wicking height for the different blends is shown in Figure 10.

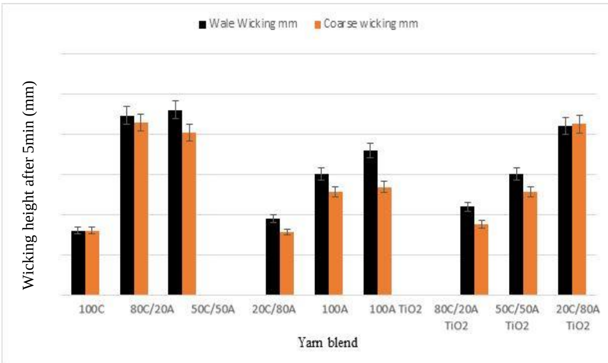


Figure 10: Knitted fabric wicking height for different blends

The wicking properties of the knitted fabrics were found to be a function of different blending ratio as well as the type of fibers. Figure 10 shows that the fabrics knitted from Acrylic fibers give a higher value of wicking height for both wale and coarse directions. The Acrylic fiber with TiO2 addition gives better wicking when blended with cotton fibers. This is due to the fact that the addition of TiO2 to acrylic fibers changes the texture of the fibers and hence changes the capillarity of the fibers which affects the wicking height especially in the wale direction. Cotton fibers have a high affinity to water and therefore absorb water as soon it reaches the spaces between the fibers in the yarn structure preventing the capillary flow along the channel formed by the fiber surfaces, resulting in less height of water in the fabric, which is not the case with Acrylic fibers which offer higher wicking [14]. The 100%

Acrylic fabrics give the highest wicking values. The better wicking ability of the Acrylic yarns is due to the lower moisture absorption capability of the regular Acrylic fiber which does not allow water to penetrate inside. As a result, water movement and absorption occur only on the Acrylic fibers' surface. The influence of fabric wicking in the wale direction is higher than in the course direction. This is due to the fact that in the course direction, the yarn loop shape helps the water to flow in the capillaries easier than in the course direction. A two-factor ANOVA is performed to check the statistical significance of the results obtained. No significant difference is detected between wicking in wale and course directions with a p-value of 0.061. The blending ratios Acrylic/Cotton also have a non-significant effect on the wicking properties with a p-value of 0.114. However, the treatment of acrylic fibers with TiO_2 has a significant effect on the wicking properties with a p-value of 0.0195.

3.4 Effect of fabric tightness on wicking properties

In general, wicking height values decrease with the increase in the tightness of knitted fabrics regardless of the types of raw materials processed [34,35]. Figure 11 shows the wicking height as a function of the fabric tightness.

3.5 Multi-criteria decision analysis

Analysing the results obtained throughout the research work, it can be monitored that the addition of TiO_2 to the Acrylic fiber changes the blended Cotton/Acrylic yarns and fabric properties. The accurate selection of raw material (types and blending ratios) together with the accurate determination of the relevant yarn properties have a great effect on the fabric properties; e.g. fabric wicking. Diverse multi-criteria decision-making methods have been proposed in material choice, many of which require quantitative weights for the attributes [19, 33]. The efficiency of the material to perform its function is the sum of the individual performance characteristics (attributes/criteria) of a particular product. Yj is the measure of performance of jth attribute (criterion) and there are alternatives in the entire property selection space. A utility concept system is the measure of the characteristic of a product to meet the customers' requirements and its serviceability. The fabric serviceability Pj is the sum of the individual performance characteristics (attributes/criteria) of a particular product. The fabric's overall index value (U) can be calculated as follows:

$$U = \Sigma \ Pj \ W j \quad (3)$$

Where Wj is the quantitative weight of the attribute (property), the relative importance of the element subjected to the constraint that Σ Wj should equal to one. Pj is the value of the attributes in the entire property selection space. The overall index value (U) can now be calculated as follows:

$$U = \sum wj \ Pj \quad (4)$$

$$Pj = (\log (yj/ y'j)) \quad (5)$$

Where: yj and yj' are the measured and acceptable values of each property.

For example, the values of wj and y'j are given in Table 7.

Table 7. Weight of different fabric properties for fabric wicking

Criteria	Fabric wicking	Yarn strength	Elongation %	CV% Uster	Thick places + 50% / Km	Thin places -50% / Km	Neps 200% / km	Hairiness Index
Pj'%	0.35	0.15	0.10	0.10	0.05	0.05	0.10	0.10
y_j'	8	10	5	17	2	1	125	8.5

Figure 12 shows the calculated U values for the different samples under investigation. It shows that when considering fabric wicking as the main target, the 100% Acrylic yarns with and without the addition of TiO_2 give the best and the highest overall index U followed by the 20C/80A samples. Pure cotton samples have the worst overall index U. It is possible to rank fabrics from the best to the worst according to the selected criteria and weights of each criterion as shown in Figure 12.

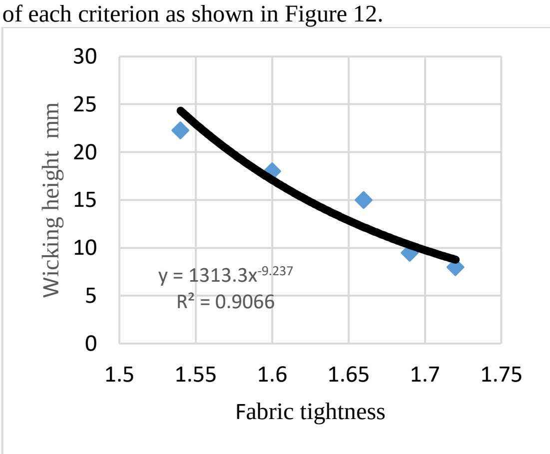


Figure 11: Knitted fabric wicking height versus fabric tightness.

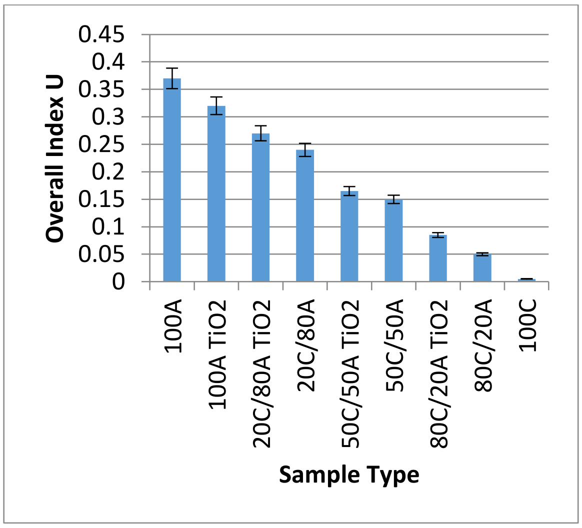


Figure 12: Overall Index U for different samples.

4 CONCLUSION

The treatment of Acrylic fibers with TiO_2 and their blending with cotton fibers with different blending ratios represent the core of this research work. The effect of the

different blending ratios and the addition of TiO2 on the fibers, yarns, and fabric properties were thoroughly studied. The increase of acrylic fiber strength associated with the treatment of TiO2 was recorded. For the ring spun yarns produced with different blends of cotton/acrylic both treated and untreated with TiO2, ANOVA tests showed that the yarn tenacity, elongation, Young's Modulus, yarn irregularity, and yarn Quality-Index are significantly affected by the treatment of acrylic fibers with TiO2. The blending ratios showed a significant effect on Young's modulus and the Quality Index. ANOVA tests showed that the increase in the cotton percentage in a blend leads to a significant increase in Young's Modulus while the increase in the percentage of acrylic leads to a subsequent increase in the Quality Index. For single jersey knitted fabrics, the wicking properties represented by wicking heights were measured for both wales and course directions. It was established that while for acrylic fabrics, water molecules are not absorbed by the fibers because of their hydrophobic characteristics, they contribute to the wicking of the liquid quickly. This phenomenon begins to disappear gradually with the increase of cotton fibers blending ratios. The tests performed showed that while the blending ratio had no significant effects on the wicking properties, the treatment of acrylic fibers with TiO2 increased the fabrics' wicking heights significantly.
A utility concept approach to measure a product characteristic's ability to meet the customers' requirements was adopted and it showed that the blends of Cotton/Acrylic treated with TiO2 give the highest fabric Overall Index U. The paper represents an important contribution to the researches concerned with the comfort of fabrics especially for sportswear, where cotton/acrylic blends are highly appreciated for their ultimate performance.

5. Conflict of interest

There is no conflict of interest of any kind.

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