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Alaa Badr

*Textile Engineer Dept., Faculty of Engineering, Alexandria University, alaa300\_2000@hotmail.com*

Ashraf El Nahrawy

*Textile Engineer Dept., Faculty of Engineering, Alexandria University*

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# Comfort Properties of Woven Fabrics Produced From Twist-Less Weft Using PVA Yarns

## خصائص الراحة لأقمشة النسيج المنتجة من خيوط

## لحمة بدون برمات باستخدام خيوط PVA

AlaaArafaBadr&Ashraf El Nahrawy

Textile Engineer Dept., Faculty of Engineering, Alexandria University

[Alaa300\\_2000@hotmail.com](mailto:Alaa300_2000@hotmail.com)

### الخلاصة

خاصية الراحة لأقمشة النسيج التي تحتوي على خيوط لحمة بدون برمات من خامات قطن وتنسيل تم دراستها في هذا البحث. وهذا النوع من الخيوط تم إنتاجه عن طريق الزوى مع خيط PVA أحادي الشعيرة في الإتجاه المعاكس حيث هذا الخيط له قابلية الذوبان في الماء. تم عملية الزوى على ماكينة two for one twister. تم إنتاج جميع عينات القماش باستخدام نفس خيوط السداء من غزل قطن 100% حلقى مفرد. وعموما يتم بناء هذا التركيب micro porous للخيط عن طريق إذابة مادة PVA الموجودة بالقماش بالماء الساخن اثناء التجهيز. وتم إنتاج جميعا لعينات مع تغيير نوع وكثافة الحدقات للقماش. أظهرت النتائج أن استخدام خيوط لحمة بدون برمات لها تأثير كبير على خصائص الراحة للقماش مثل نفاذية الهواء، التوصيل للحرارة ومثانة الشد ومقاومة التمزق. وأوضحت النتائج أن خاصية نفاذية الهواء وإمتصاص الماء قد تحسنت في القماش الناتج بعد استخدام هذا النوع من الخيوط وهذا يرجع الى الإنتفاخ الذي حدث للقماش بعد التخلص من PVA.

### Abstract

Comfort characteristics of microporous plain-woven fabrics, containing cotton staple fiber twistless and Tencel staple fiber twistless yarn in weft, have been reported in the present paper. The twistless yarn was produced without twist by means of plying with water soluble monofilament PVA filament in the opposite direction. This process was done by TFO (Two for one twister) machine. In all these fabrics the same warp yarn, i.e. a single ring spun 100% cotton yarn was used. The microporous structure of the yarn is created by dissolving the PVA fibers using hot washing of the fabrics. All sample types of twistless yarns and reference yarns are made with a variation in fiber material and fabric picks/cm.

The structure of fibrous assemblies in weft has great impact on the comfort related properties, like fabric air permeability, thermal conductivity and also tensile strength and tear resistance. Results indicated that the wickability, and air permeability of the woven fabrics constructed from twistless weft yarn were improved due to the bulkiness of the fabric after dissolving PVA.

### Key words

Twistless yarn, microporous fabric, fibrous assemblies, Tencel, PVA, thermal properties, wicking, gain% and air permeability.

### 1- Introduction:

The most essential property of any clothing is comfort. Comfort is an experience that is caused by combination of impulses passed up the nerves from a diversity of external receptors smell, smoothness and color etc in the brain. Comfort is a qualitative expression and it is one of the main features of apparel.

Many consumer research groups have stated that current consumers take into consideration comfort as one of the most significant aspects in their purchase of apparel products. The clothing comfort is dependent onto the mechanical stress, thermal and moisture transfer properties of the fabrics [1]. Based on fundamental information on heat and moisture properties, continual efforts are done by

many scientists to develop the comfort over engineering fibre and fibre assemblies. In one of the various efforts towards improving comfort, the fabrics are produced using a hollow yarn. Recently hollow/micro-porous yarn spinning system and fabric quality therefrom have attracted attention to many textile yarn and fabric manufacturers [2] and research workers [3-6]. The existence of air space inside the yarn affects the transmission features of fabrics. It is essential to reminder that for making the hollow yarn fabrics; bi-component pre-hollow yarn is used to make the fabric; afterwards one component (e.g. polyvinyl alcohol) is dissolved from the pre-hollow yarn at the fabric stage [7,8]. The Polyvinyl alcohol is a water-soluble high-molecular compound and is soluble in water at about 60°C [7]. Furthermore, Mukhopadhyayet *al.* [8], said that the pre-hollow yarn fabrics were boiled (hot washed) in water for 25 minutes to remove the PVA.

Additionally, elastic recovery of hollow yarn after taking away the lateral compressive force was higher than elastic recovery of typical friction yarn with the same count [9]. Hollow yarn production targets at reducing fiber packing density. The hollow yarn indicates better compressional recovery. The volume of the hollow yarn after compression is also more than that of the traditional cotton yarn. According to the study of cotton-PVA (polyvinyl alcohol) - blended ring spun yarn, Ishtiaque et al. (2008) [10] discovered that the yarn-specific volume of a hollow yarn increases with increase in the PVA percentage. Consequently, the yarn packing factor decreases with the increase in the PVA content, improving yarn thermal comfort, cover factor, smoothness, bulkiness and efficiency in weaving [11,9]. Fabrics built of core spun yarn have superior handling, appropriate dimensional properties and pilling

resistance. Nevertheless this kind of fabric has disadvantages such as unevenness in dye absorption [12].

Das, Ishtiaque, & Singh, 2009 [13] also exhibited that plain woven fabrics with micropores have improved thermal resistance and moisture vapour transmission as compared with 100% cotton fabrics. The removal of water-soluble PVA fibres makes the yarn porous; therefore, fabrics become more compressible. Moreover, there is dearth of literature on the impact of structurally different pre-hollow/ microporous yarns on yarn tensile and physical properties. Researchers [6] found that the strength of pre-hollow/pre-microporous yarns is better than that of equivalent (normal) cotton yarns which as a result leads to improve spinning and weaving efficiency. Natural and synthetic cellulose fibres give clothing and apparels the highest comfort: softness, strength, good look and functionality [14-15]. Lyocell "Tencel" is a cellulose fibre and has the advantage of being used in a less contaminant spinning process than the one for conventional viscose. It absorbs water perfectly and provides hygienic properties to textile products, has a higher breaking strength, either wet or dry and is commonly used in the apparel industry like underwear. Tencel can also be used in technical textiles and nonwovens. Also, huge differences exist between Lyocell and cotton in both thermal transmission and vapour permeability [16]. Lyocellfibres absorb more moisture than cotton.

Dziworska et al. [17] discovered that fabrics with Lyocell and Tencelfibre wefts were characterized by better air permeability and crease resistance in comparison with fabrics with cotton and viscose wefts.

The comfort characteristics of fabrics primarily depend on the structure and types of yarn used. The development of

new yarn materials raises questions about the nature and quality of fabrics produced from these new yarns.

The main aims of this research study is to investigate the comfort characteristics of woven fabrics made out of Tencel staple twistless assemblies using two-for-one twister. Our particular objective is to evaluate the ability of these yarn types of distinctive materials to improve the comfort characteristics.

## 2- Material and Methods

### 2-1 Material:

In this study 100% Tencel LF, 100% Egyptian cotton Giza 86 (100 % C) and PVA monofilament (100 Ne) yarns were used to produce twistless woven fabrics. The Polyvinyl alcohol (PVA) is a water-soluble high-molecular compound, white solid, mould ability and excellent electrical insulation. The properties of yarns were given in Table 1. Also, the properties of the Egyptian cotton Giza 86 cotton used in this research work are obvious in the Table 2. For the properties of the Tencel fibers, the fiber length is 38 mm and the fineness is 1.3 dtex.

### 2-2 Fabric Manufacture:

All fabric samples were woven on a Sulzer loom machine with 4 heald shafts and with fabric width 300cm "WIR".

The fabric picks density was changed at two different levels such as low and high to represent a range of light and medium woven fabrics.

All fabric samples were desizing, washing, bleached in the same dyeing bath and then dried using drying cylinders and finally all the fabrics were put in the flat form using width setting technique.

### 2-3 Methodology

The details of the accomplished design of experiment and sample specifications are shown in Table 3.

### 2-4 Fabric Testing:

After finishing, all the fabric properties were measured after leaving the samples 72 hours in standard conditions (Relative humidity =  $65 \pm 2\%$  - Temperature =  $20 \pm 2^\circ\text{C}$ ) to give them the chance to relax without any existing stresses.

The fabric count, fabric weight, thickness and air permeability were measured according to ASTM D3775, ASTM D 3776, ASTM D 1777 and ASTM D737 respectively. Furthermore, the thermal properties of the samples were measured on the Alambeta testing instrument (in USA) where, in this device the fabric is placed between a hot and a cold plate, the amount of heat flow from the hot plate to the cold plate through the fabric is measured by heat flux sensors. Also the thickness of the fabric is measured (h), which is used to determine the thermal resistance ( $r=h/\text{thermal conductivity}$ ) and the thermal absorptivity (b).

The wicking behavior of the sample (1\*1 inch) was measured using a 0.2% soap solution. The samples were dropped from 1cm into the solution "Textile testing by Jewel, Jewel Raul, 2005, page 58, sinking test".

Additionally, gain % was evaluated according to BS 3449. The percentage gain of the sample "20\*20cm" were measured by dipping it into water for five minutes, the time taken for complete sinking of the sample was measured in minutes. Then, the sample was hung vertically to allow extra water to drip for another. Finally, Water vapor permeability was measured using ASTM E 96 - "Standard Test method for Water Vapor Transmission of materials" - cup method.

**Table 1. Yarn Properties**

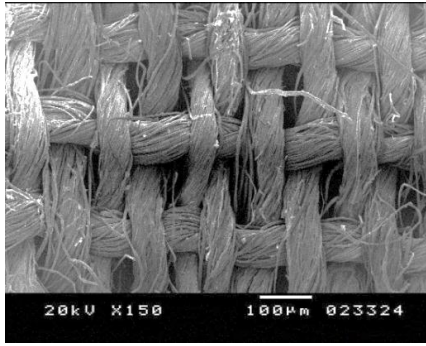
	<b>100% Cotton Giza 86</b>	<b>100% Tencel LF</b>
<b>Count (Ne)</b>	40	40.01
<b>Twist (Turns/inch)</b>	22.8	21.89
<b>Uster (CV %)</b>	12	13.02
<b>Thin places (-50%)</b>	1	0
<b>Thick places (+50%)</b>	31	15
<b>Neps + 200</b>	60	42
<b>RKM (CN/tex)</b>	18	21.93
<b>Elongation %</b>	4.6	7.37
<b>Hairiness (H)</b>	5.9	5.35

**Table 2. Fiber Properties**

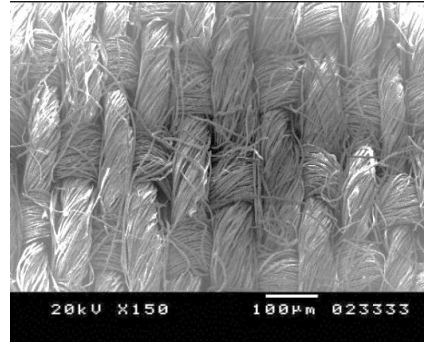
	<b>Len</b>	<b>Unif. %</b>	<b>Str.</b>	<b>Elong. %</b>	<b>MIC</b>	<b>Mat.%</b>	<b>Rd</b>	<b>+b</b>	<b>Neps/gm</b>
<b>Egyptian cotton Giza 86</b>	32.6	88.1	45.8	5.9	4.25	89	79.0	8.4	65

**Table 3. Design of experiments and samples specifications**

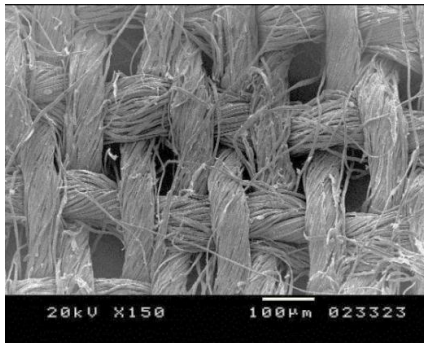
<b>Sample Number</b>	<b>Yarn Material</b>	<b>Single or Ply with PVA</b>	<b>e/cm</b>	<b>p/cm</b>	<b>g/m2</b>
<b>4</b>	<b>100% Tencel LF</b>	<b>Single</b>	<b>42</b>	<b>20</b>	<b>95</b>
<b>5</b>	<b>100% Cotton</b>	<b>Single</b>	<b>42</b>	<b>20</b>	<b>96</b>
<b>6</b>	<b>100% Tencel LF</b>	<b>Ply</b>	<b>42</b>	<b>20</b>	<b>99</b>
<b>7</b>	<b>100% Cotton</b>	<b>Ply</b>	<b>42</b>	<b>20</b>	<b>95</b>
<b>8</b>	<b>100% Cotton</b>	<b>Ply</b>	<b>42</b>	<b>27</b>	<b>111</b>
<b>9</b>	<b>100% Cotton</b>	<b>Single</b>	<b>42</b>	<b>28</b>	<b>112</b>
<b>10</b>	<b>100% Tencel LF</b>	<b>Single</b>	<b>42</b>	<b>28</b>	<b>115</b>
<b>11</b>	<b>100% Tencel LF</b>	<b>Ply</b>	<b>42</b>	<b>28</b>	<b>120</b>



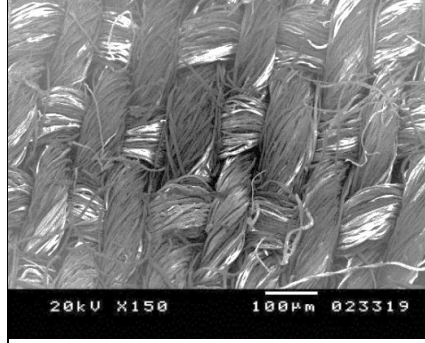
*Figure 1. Sample no 6 before dissolving PVA.*



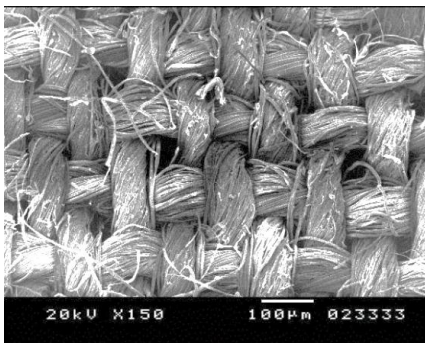
*Figure 2. Sample no 6 after dissolving PVA*



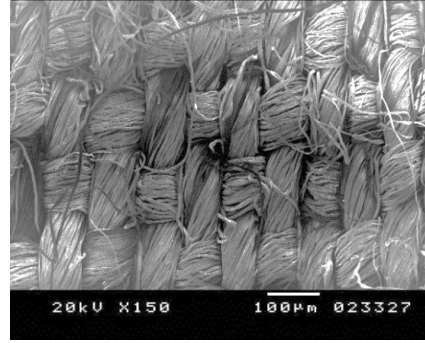
*Figure 3. Sample no 7 before dissolving PVA.*



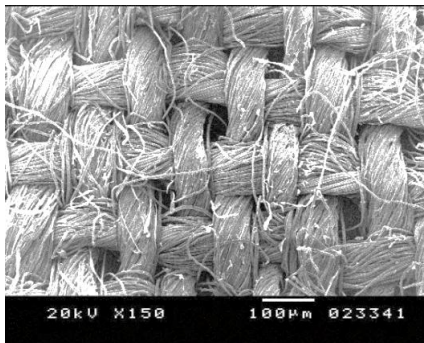
*Figure 4. Sample no 7 after dissolving PVA*



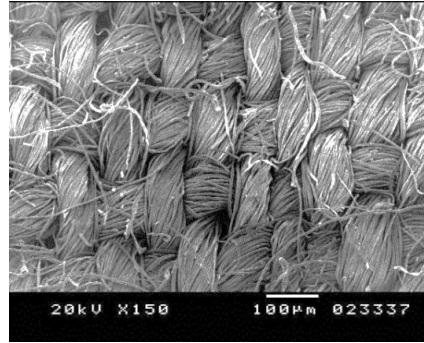
*Figure 5. Sample no 8 before dissolving PVA.*



*Figure 6. Sample no 8 after dissolving PVA*



*Figure 7. Sample no 11 before dissolving PVA.*



*Figure 8. Sample no 11 after dissolving PVA*

**Figures(1-8) Microscopic inspection SEM analysis was for all twissless Samples before and after dissolving PVA**

## 4- Results and Discussion:

Table 4 illustrates the results of the thermal, wetting and mechanical properties of the woven samples. These results show the performance of the woven fabrics with changing yarn type “single or ply with PVA yarn – twistless technique”, yarn material and fabric picks density.

SEM (Scanning Electronic Microscope) analysis was conducted for all twistless samples before and after dissolving PVA.

This microscopic inspection was accomplished in order to examine the surface characteristics of the fabrics. SEM microscopic studies seen in figures 1 to 8 showed that the best appearance and bulkiness are cleared after removal PVA material. It was also observed that woven samples contained twistless Tencel weft yarns seemed to be more brilliant, bulky and uniform than other samples contained Egyptian cotton weft yarn samples

**Table 4. Results of Fabric Properties**

Sample Number	Yarn Material	Single or Ply with PVA	Air Permeability (cm <sup>3</sup> /cm <sup>2</sup> /s)	Thermal Conductivity "W.m <sup>-1</sup> .k <sup>-1</sup> "	Thermal Absorptivity (W S <sup>1/2</sup> /m <sup>2</sup> k)	Immersion Time "Second"	Gain %	Tear Strength "Kg <sub>r</sub> "	Max. Tensile Load "Kg <sub>r</sub> "	Elongation %
4	100% Tencel LF	Single	83	40.4	163	35	149	1	9.99	20.3
5	100% Cotton	Single	154.6	35.7	99.5	44	140.8	0.8	8.5	19.35
6	100% Tencel LF	Ply	133	39.9	146	24	155.1	1	8.96	24.94
7	100% Cotton	Ply	136.2	35.2	93.5	36	143.8	0.9	8	22.37
8	100% Cotton	Ply	87.25	38.8	97.9	5	118.8	0.9	13.9	26.98
9	100% Cotton	Single	46.64	40.7	130	14	109.1	0.7	17.01	24.5
10	100% Tencel LF	Single	45.98	42.6	174	10	115.1	0.9	19.01	25.23
11	100% Tencel LF	Ply	54.44	41.3	154	4	127.8	1.1	16.12	30.92

Sample Number	Yarn Material	Single or Ply with PVA	Thermal Resistivity "Tog"	Water Vapor Permeability (g/m <sup>2</sup> /hr)	Comfort Index
4	100% Tencel LF	Single	0.87	23.29	4.02
5	100% Cotton	Single	1.22	22.32	1.47
6	100% Tencel LF	Ply	0.90	32.10	3.34
7	100% Cotton	Ply	1.31	25.39	1.77
8	100% Cotton	Ply	1.18	22.41	2.71
9	100% Cotton	Single	1.13	18.04	4.09
10	100% Tencel LF	Single	0.85	20.54	6.55
11	100% Tencel LF	Ply	0.87	26.78	7.04

### 4-1 Air Permeability:

It can be seen that from the following figure that the woven fabric with twistless weft Tencel ply yarn has more air permeability than other with single Tencel yarn. After removing of

PVA, the yarn will try to achieve a state of minimum energy level i.e. twistless structure. This leads to the bulkiness of twistless yarn while achieving of minimum energy level and this accompanied with the decrease in the

intensity and packing of fibers in the yarn cross section and increase the availability of more air space in the yarn structure, resulting in increase the fabric air permeability(11,18). This could be referred to the more open spaces created between the fibers inside yarn cross section after twistless stage and removing of PVA. Also, it can be seen from figure 9 that the cotton samples behave in a different manner for the increasing of its air permeability than the Tencel fabrics.

These phenomena may be explained by the ribbon cross section shape of the cotton fibers against the round shape of the Tencel fibers. This cotton ribbon shape helps in increasing open spaces inside the fabric. Moreover, this figure shows the results of changing fabric picks density. It could be noticed that the fabric with more pick density has less air permeability than the other samples. The higher picks density makes the yarns to be more adjacent to each others.

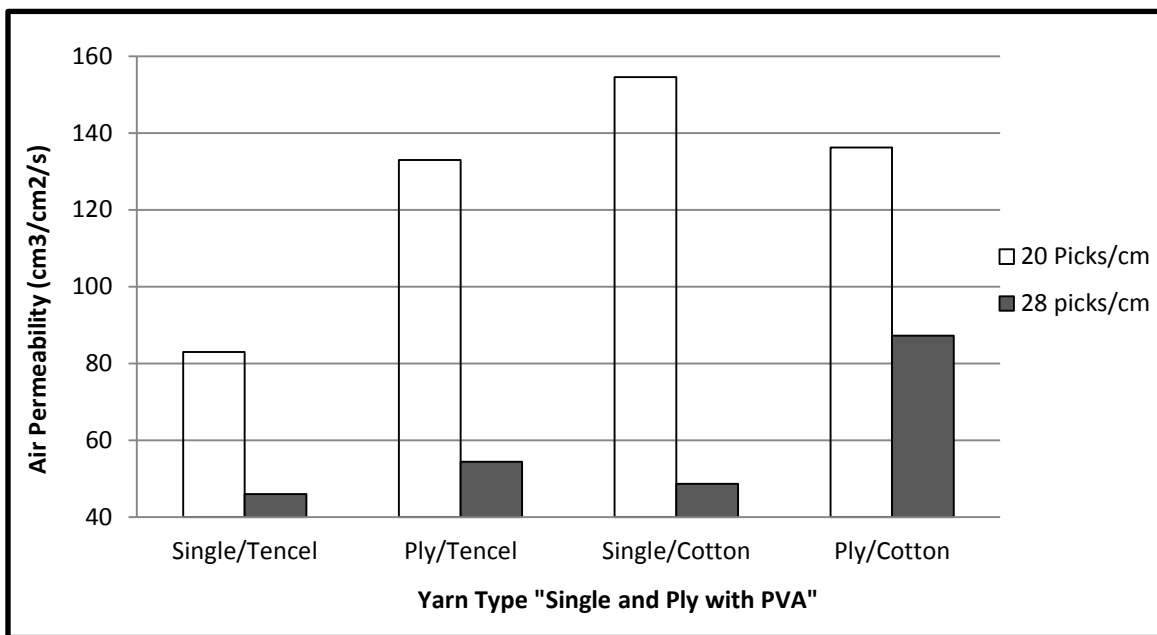


Figure (9) Relation between yarn type and fabric permeability

**4-2 Thermal Conductivity:**

As it can be seen from figure (10) that twistlessweft ply yarn has less thermal conductivity than other with single yarn; this is due to the more contained air inside the yarn which represents as a good insulator in spite of the high fabric thickness accompanied with twistless fabric samples. Also Tencel fabric gives higher thermal conductivity which is referred to the high degree of crystallinity and molecular orientation of Tencel fibers Tencel has a unique fibril structure. Fibrils

are the tiniest components which form the fiber. The channels between the individual fibrils control absorption and release of moisture. Therefore, these small fibrils guarantee the best transportation of moisture(19).

It is noticed that the higher fabric picks density gives more thermal conductivity than other samples. This difference is related to the more material accompanied with higher fabric density which makes it to be a good conductor of the heat.



### 4-3 Thermal Absorptivity:

Figure (11) shows the relation between yarn type “single or ply with PVA” and the thermal absorptivity for different fabric picks density. It could be seen from figure (11) that the both the twistless effect and the fiber material affect the thermal absorptivity. It is clear from the figure that the twistless fabrics gave less absorptivity than the samples woven with single yarn. The thermal absorptivity of yarn depend on its

available specific surface, the lower no of fibers in yarn cross section for the twistless weft yarn results in decreasing specific surface which is proportional to the thermal absorptivity due to availability of air spaces which reduces fabric thermal absorptivity. Also the Tencelfibers heighten thermal absorptivity and this agrees with the previous thermal conductivity trend. This means that the Tencel gives cool feeling when touch.

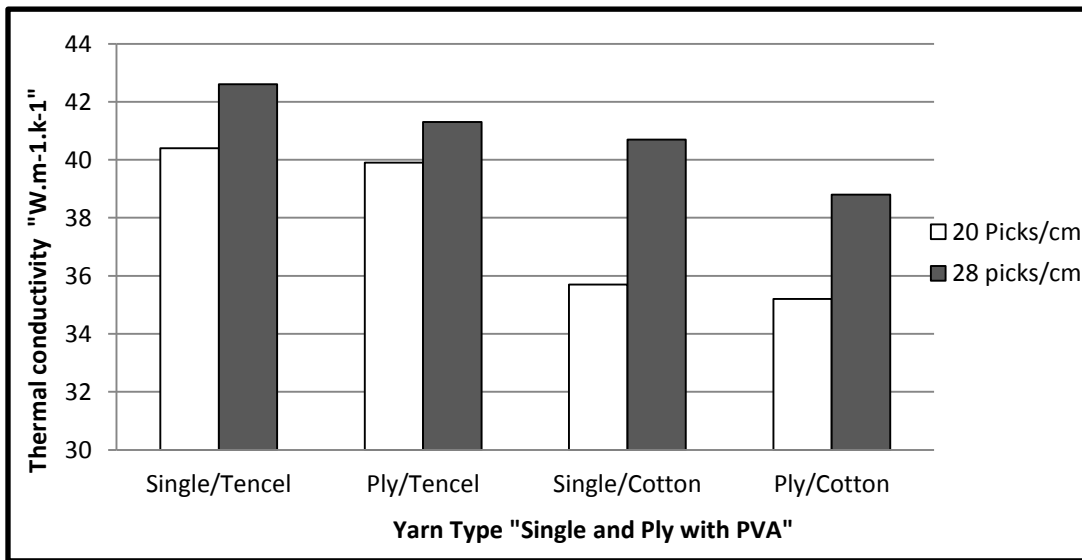


Figure (10) Relation between yarn type and thermal conductivity

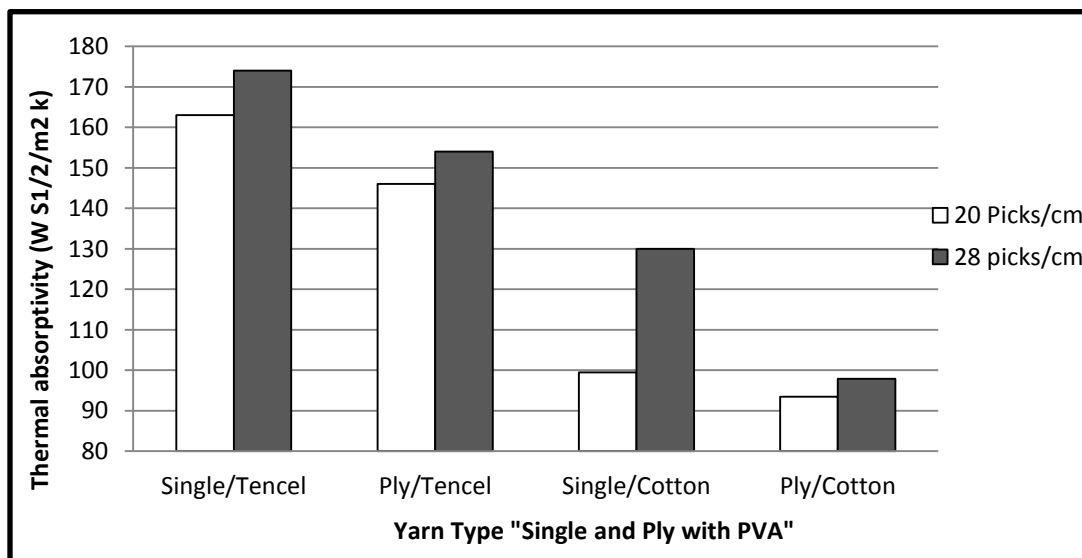


Figure (11) Relation between yarn type and thermal absorptivity

### 4-4 Fabric Moisture Properties:

For the wicking behavior of the sample, the following figure (12) shows the factors affecting the immersion time (sec). It can be seen that the fabric produced from twistless weft yarn gave less immersion time. The impact of removal of PVA on the improving of wicking characteristics of woven fabric is due to the increase of the openness of fabric and yarn bulkiness resulting in availability of more air spaces in yarn structure. Furthermore, parallel arrangement of fibers creates proper channeling within the yarn, leading to increase in wicking (20, 21). It is clear from the same figure that the fabric wettability was improved with using Tencel fibers than cotton fibers. Furthermore, figure (13) shows that gains % for the woven fabric produced with twistless weft ply yarn has more air permeability than other with single yarn. It

is clear from this figure that the gain % for the fabrics woven from Tencel fibers is more than the other samples. The fabric can keep more water inside its fabric. Furthermore, Raj (22) defined the Comfort Index for summer clothing as follows:

$$\text{Comfort Index (CI)} = (\text{MTR} * \text{AR}) / \text{TR}$$

Where:

MTR= Water Vapor Permeability (g/m<sup>2</sup>.hr)

AR= Air Resistance Value (kpa.s/m)

TR= Thermal Resistance Value (Tog)

Summer fabrics should possess high permeable characteristics to both air and moisture and also should have low thermal resistance. Consequently, table 4 shows the value of the comfort index for every sample. It can be noticed that sample number 11 which produced from twistless weft Tencel yarn at picks density 28 has the highest thermo-physiological comfort index for summer clothing.

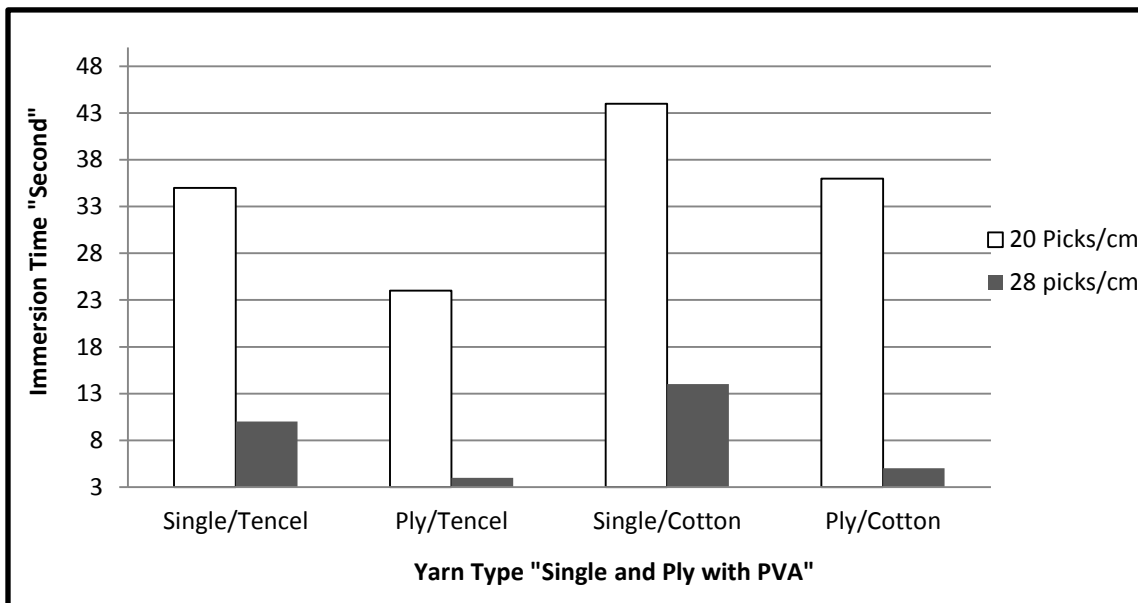
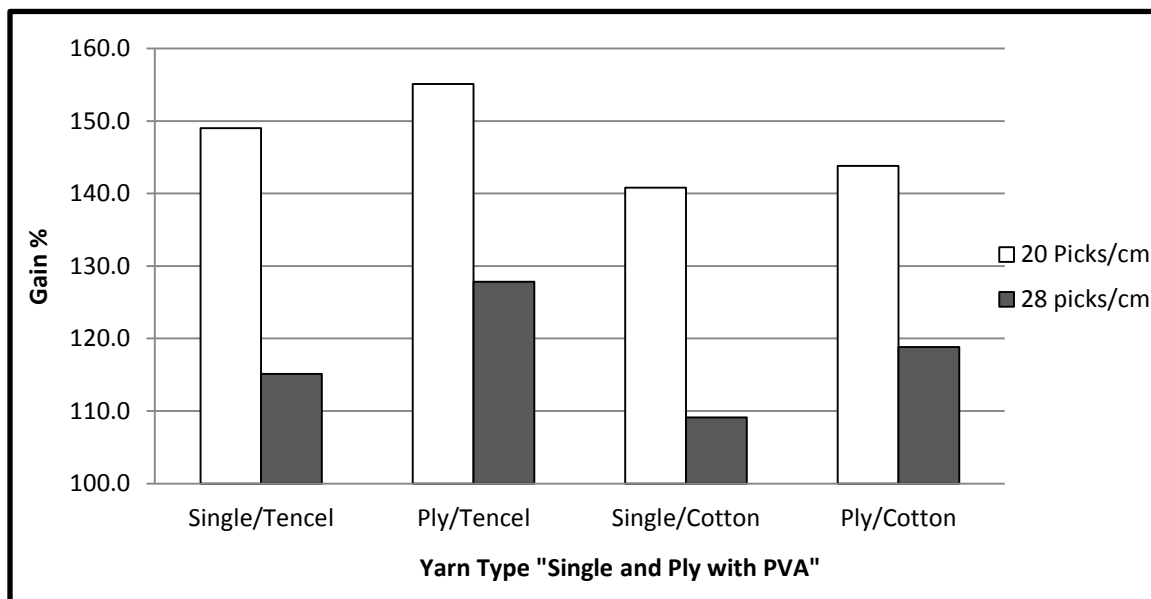


Figure (12) Relation between yarn type and fabric immersion time



**Figure (13) Relation between yarn type and fabric gain %**

#### 4-5 Tear Resistance

Figure (14) shows that the twistless weft yarn, fiber type and fabric picks density affect the woven fabric tear strength. It can be seen that the fabric tear strength in the weft direction for the ply yarn with PVA is higher than the single yarn. The tear strength is primarily depends on the yarn strength, yarn surface characteristics and fabric structure. From a different point of view, the alignment of fibers in yarn as well plays an essential role. The tightness of the fabric structure controls how many yarns carry the load. A tight fabric permits only one yarn to break at a time as the tear propagates. A loose fabric allows more yarns to carry the load at any one time (23). In this study, we have compared the fabrics of same structure with different kinds of weft yarns. The higher tear strength of fabric woven with twistless weft yarn is mostly due to two causes: (i) the smooth surface of twistless yarn which permits to slide within delta zone and consequently more than one yarn carry the load at one time, and (ii) the orientation of fibers along the axis of yarn

results in maximum sharing of load. Moreover, it is clear that Tencel fabrics improves tear strength in weft direction. This might be due to the higher strength and breaking elongation percentage of Tencel yarns against the cotton yarns.

#### 4-6 Fabric Tensile Strength:

The woven fabric produced from twistless weft yarn has a higher tensile strength in the weft direction than the normal single yarn as cleared in figure (15). Once the twistless yarn has been established inside the fabric structure, the compacting forces created by the fabric structure itself hold the system together. Also, this may be due to the fact that the compacting forces created in fabric structure itself result in higher inter-fiber friction force. In addition, the parallel orientation of fibers in weft yarn along the load direction lead to uniform and maximum load sharing by all the component fibers in weft direction of the fabric. The structural characteristics of Tencel fibers are responsible for their superior mechanical properties. Tencel

fibers have high degree of crystallinity and orientation, as well as high molecular mass and degree of polymerization as obvious in same figure. This enables Tencel fibers to reach high tensile strength and modulus. The higher breaking elongation of twistless yarn in comparison with typical single yarn could be attributed to the empty

space at the twistless yarn central zone and looser structure which gives the chance for lateral contraction. Higher compaction and contraction of twistless yarn under tensile load, is accompanied by higher fiber entangling and hence higher breaking elongation as shown in figure (16).

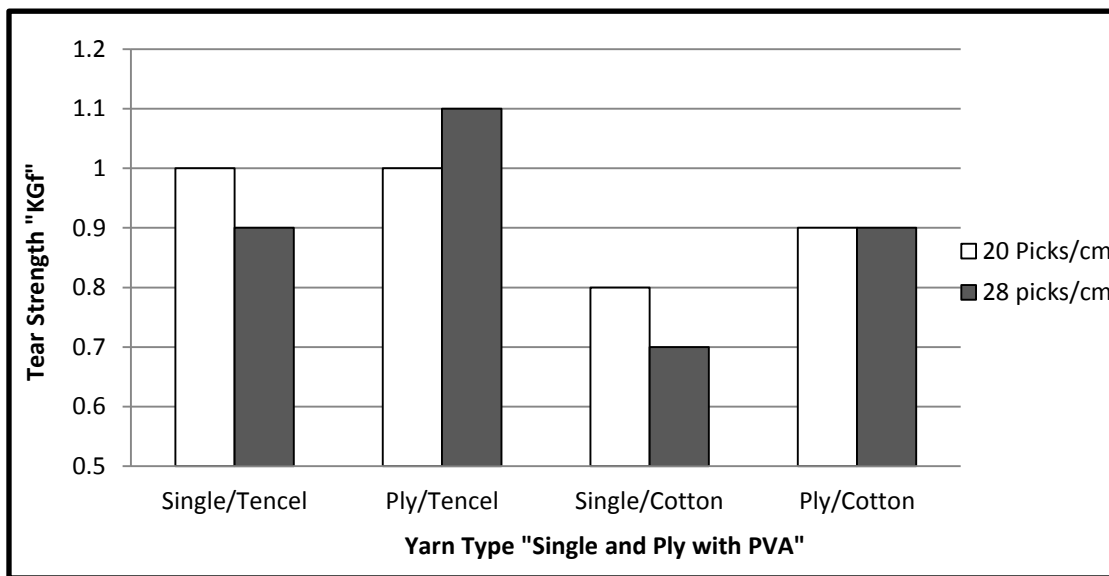


Figure (14) Relation between yarn type and fabric tear strength

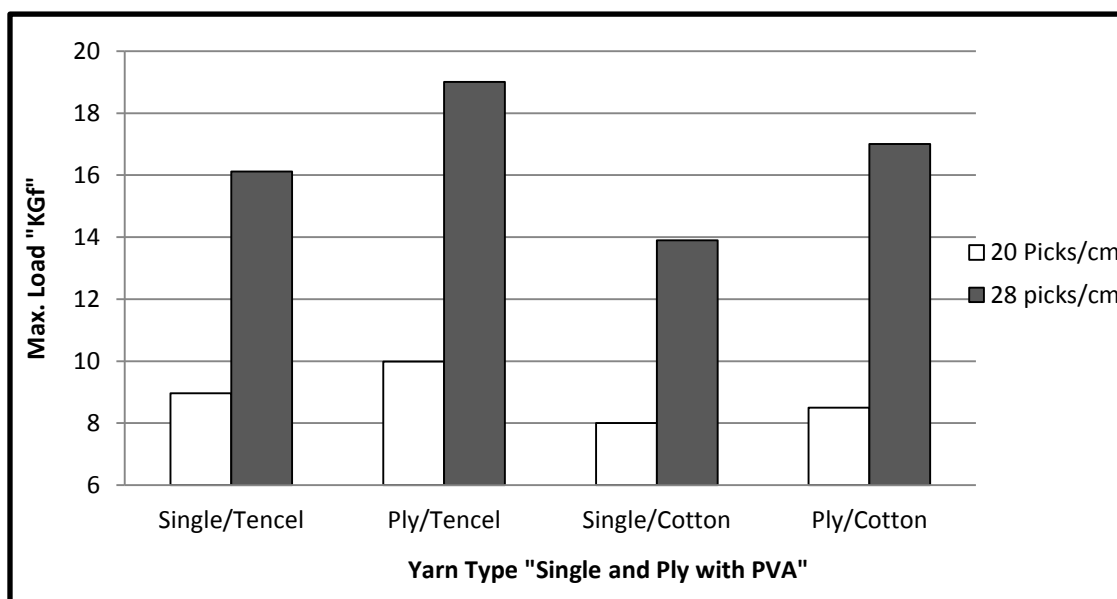


Figure (15) Relation between yarn type and fabric tensile strength

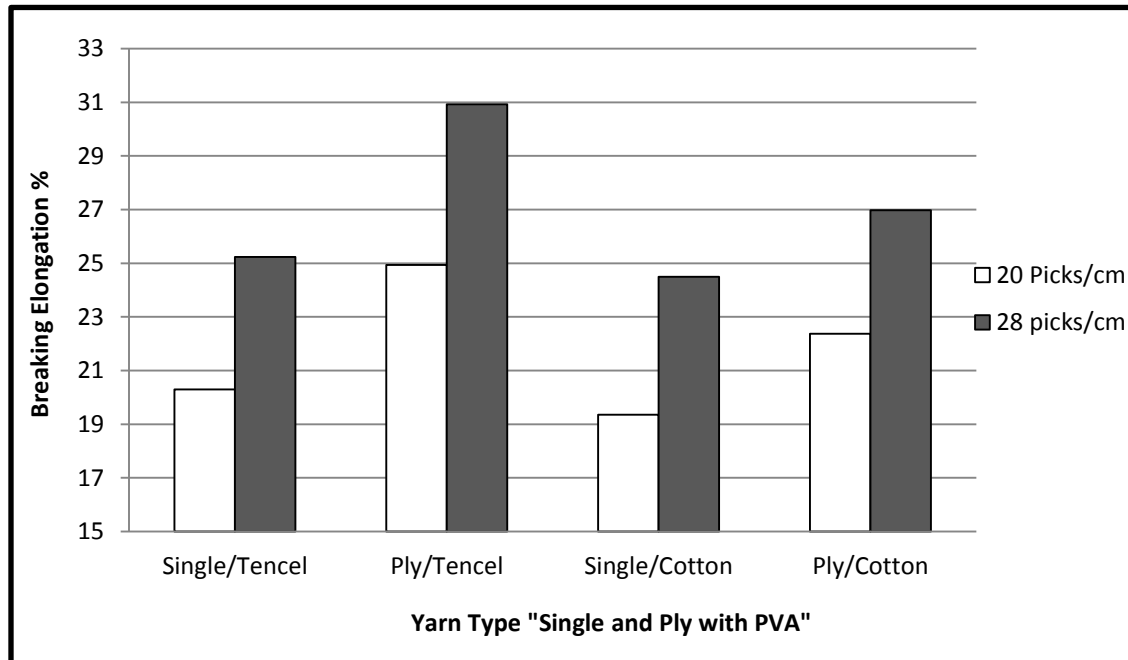


Figure (16) Relation between yarn type and fabric elongation

## 5-Conclusion:

In this research, thermal, wetting and mechanical properties of woven fabrics produced from twistless weft yarn using PVA and different yarn material have been studied. Comfort characteristics of plain-woven fabrics has been improved after using PVA twistless weft yarn. Within this research work, fabric woven with twistless weft ply yarn has more air permeability, wickability, gain %, tear strength, elongation % than other with single yarn. Furthermore, fabric thermal conductivity and thermal absorptivity are decreasing for fabrics produced from twistless weft yarn.

Results show that for the fabric have Tencel yarn, the air permeability, thermal conductivity, thermal absorptivity, wickability, gain %, thermo-physiological comfort index, tear strength, tensile strength and elongation % are increased than other woven fabrics contained cotton weft yarns.

The unique structure and the smooth surface of twistless weft Tencel yarn result in enhanced physiological and mechanical functions that make it stand out amongst the family of cellulosic fibers.

## Acknowledgement

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