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Improve UV Protection Property of Single Jersey for Summer Protective Clothes

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ABSTRACT

This paper aims to improve the UV protection property for single jersey fabrics. Three different machine gauges with two different materials, two different yarn counts, and three yarn tension levels were studied. An ANOVA analysis was used to identify the significant effect of the machine gauges & yarn tensions in different materials. The correlation between UPF and different properties was determined. The results indicate that samples that are manufactured with the biggest machine gauge (28) and high yarn tension result in the highest UV protection. In addition, polyester microfiber is preferable for summer clothing over cotton. Finally, thicker yarns improve UPF for cotton samples.

Keywords: Single jersey, UV protection, Protective clothes, Machine gauge

1. Introduction

All energy required to sustain life comes from the sun [11], but it also carries risks of toxicity [6]. Ultraviolet radiation (UV) is a radiant energy coming from the sun [9]. UV radiation is about 7% of total solar emission, the spectrum extends from 290 nm to 400 nm, and it has dangerous effects on human skin [7]. There are three levels of UV, they are; UV-A (320-400 nm), UV-B (280-320 nm) and UV-C (200-280 nm) [13].

Health risks associated with exposure to UV include acute and chronic effects. These effects vary according to the nature of the exposure. Factors important in assessing these risks include: the levels of UV impinging on the person exposed, the duration and frequency of occurrence of exposures, and the individual sensitivity to UV. UV risks to skin can result in short-term effects (sunburn, tanning, and photosensitivity) or long-term effects (dryness, blemishes, aging, and skin cancer) [4].

Clothing can protect a person from UV radiation, as well as other environmental factors (cold, wind). People select their clothing based on their needs and desires. Although, people’s preferences change with the season, climate, age, type of work/activity, etc., comfort is the main requirement for clothing selection in all conditions [2]. Summer clothing must protect the skin from ultraviolet radiation which is emitted from the sun. In this case, summer clothing must serve as protective clothing. The definition of a sun protective fabric is a fabric that achieves a minimum UV Protection Factor (UPF) rating of at least UPF15 [5].

Table 1. UPF Rating [3]

UPF	% UV Radiation absorbed	Protection category
10	90.0	Moderate
15	93.3	Good
20	95.0	Good
30	96.7	Very good
40	97.5	Excellent
50	98.0	Excellent

The total UV transmission through the textile is measured by a radiometer [8]. Knit fabrics provide outstanding comfort qualities and have long been preferred in many types of clothing [12,14,1]. The single jersey structure is mostly used in summer clothes, so this study aims to study its properties and improve its UV protection.

2. Experimental

2.1 Materials and Methods

The objective of this research was to improve the UV protection property of single jersey knits. To achieve this, 21 samples were produced with single jersey structure based on three steps:

(A) First step: Two different materials, cotton and polyester microfiber, were selected because they are the most used fabric in summer clothing. Cotton yarn is characterized by its high comfort properties, while polyester yarn is characterized by its low cost, especially microfiber yarns, and its high protection from UV radiation.

(B) Second step: Three machines with three different gauges (20, 24 and 28) were used to produce the knits.

(C) Third step: Three different yarn tension levels were used. Table 2 presents the specifications of the cotton/polyester microfiber samples.

Table 2. Cotton / Polyester microfiber samples

Sample No.	Material	Yarn count	Structure	Machine gauge	Yarn tension level
1	Cotton	30/1 s Combed / Giza 86	Single Jersey	20	High
2					Medium
3					Low
7	Cotton	30/1 s Combed / Giza 86	Single Jersey	24	High
8					Medium
9					Low
10	Cotton	30/1 s Combed / Giza 86	Single Jersey	28	High
11					Medium
12					Low

Sample No.	Material	Yarn count	Structure	Machine gauge	Yarn tension level
13	Polyester Microfiber	150/288 Denier	Single jersey	20	High
14					Medium
15					Low
16	Polyester Microfiber	150/288 Denier	Single jersey	24	High
17					Medium
18					Low
19	Polyester Microfiber	150/288 Denier	Single jersey	28	High
20					Medium
21					Low

Furthermore, the research aimed to study the influence of yarn count on improving UV protection property, by using two different yarn counts (24\1 s and 30\1 s) with three yarn tension levels as is shown in Table 3.

Table 3. Cotton single jersey samples

Sample No.	Material	Yarn count	Structure	Machine gauge	Yarn tension level
1	Cotton	$30/1^{s}$ Combed / Giza 86	Single Jersey	20	High
2					Medium
3					Low
4	Cotton	$24/1^{s}$ Combed / Giza 86	Single Jersey	20	High
5					Medium
6					Low

2.2 Analyzing and Testing

Samples were analyzed and tested to find stitch length (BS5441), stitch density(ASTM, D3887), tightness factor [10], mass per unit area (ASTM, D3776), thickness (ASTM, D1777), burst strength (ASTM-3786-01), fabrics' surface roughness using Surface Roughness Measuring Instrument (Surfcoder) SE1700; manufactured by Kosaka Laboratory Ltd.(Japan), air permeability (ASTM D737–96) and the transmission of ultraviolet radiation (UV-R) through a specimen(AATCC 183-2004,ASTM-D6603-00).

3. Results and discussion

3.1 Effect of machine gauges & yarn tensions on UPF

The findings in Tables 4 and 5 present the effects of machine gauges and yarn tensions on UPF for cotton and polyester microfiber samples. The results indicate that samples with high yarn tensions achieved the highest UPF, while samples with lower yarn tensions achieved the lowest UPF. The explanation of these results is that high tension decreases the stitch length, which raises the tightness and subsequently the reflection ability of the samples. The findings for the effect of the machine gauges were that samples manufactured with the largest machine gauge

(28) resulted in the highest UPF with different yarn tension levels compared with other machines gauges (20, 24). The justification results suggest that the machine gauge increases the courses and wales per cm, which increases the stitch density and consequently the reflection area for the samples.

Table 4. The effect of machine gauges and yarn tensions on UPF for cotton samples.

Machine gauge	Yarn tension	Sample No.	Stitches Density			Stitch length (mm)	[k] Tightness Factor	Weight (gm/m2)	Thickness (mm)	Burst (kpa)	Roughness (µm)	Air permeability ($cm^3/cm^2.sec$)	UPF
			[W] Wales W/cm	[C] Courses cm	[S] Stitches density Stitches/cm^2								
20	High	1	10.83	22.44	242.96	2.85	15.57	132.7	0.62	1000	15.85	241	6.8
	Medium	2	11.55	19.75	228.04	2.9	15.305	130	0.62	880	14.85	241	6.76
	Low	3	12.24	17.05	208.82	3.033	14.63	128	0.63	760	13.84	250	6.38
24	High	7	12	23.23	278.92	2.7	16.44	147.1	0.6	900	21.94	197.7	7.05
	Medium	8	11.55	21.26	245.49	2.8	15.85	137	0.62	900	16.5	209.3	6.9
	Low	9	11.61	19.69	228.63	3.1	14.32	130.3	0.623	900	15.8	236	6.81
28	High	10	13.18	23.42	308.86	2.6	17.07	163.4	0.56	820	22.99	194.8	7.93
	Medium	11	13.12	21.65	284.05	2.74	16.2	155.2	0.58	780	21.61	197.7	7.68
	Low	12	13.05	20.47	267.27	2.88	15.41	147	0.6	720	20.32	203.5	7.07

Table 5. The effect of machine gauges and yarn tensions on UPF for polyester microfiber samples.

Machine gauge	Yarn tension	Sample No.	Stitches Density			Stitch length (mm)	[k] Tightness Factor	Weight (gm/m2)	Thickness (mm)	Burst (kpa)	Roughness (µm)	Air permeability ($cm^3/cm^2.sec$)	UPF
			[W] Wales W/cm	[C] Courses cm	[S] Stitches density Stitches/cm^2								
20	High	13	14.76	20.87	308.06	2.75	14.84	127.57	0.54	1180	26.63	355	12.94
	Medium	14	14.5	19.03	275.9	2.92	13.98	127.4	0.59	960	20.32	356.8	11.16
	Low	15	14.57	16.14	235.14	3.11	12.67	116.9	0.65	1200	16.39	394.8	10.15
24	High	16	13.62	23.29	317.28	2.57	15.87	141.86	0.53	1180	34.7	247	13.34
	Medium	17	16.53	19.42	321.07	2.68	14.7	132.56	0.56	1140	24.3	308.5	11.51
	Low	18	15.94	17.72	279	3.04	13.43	119.17	0.6	880	17.75	362.2	10.28
28	High	19	16.53	21.39	353.69	2.55	16.04	142.53	0.5	1110	36.41	197.7	17.59
	Medium	20	16.93	20.47	346.58	2.6	15.67	135.83	0.55	1020	26.49	296.4	11.29
	Low	21	16.26	18.90	307.27	2.79	14.64	125.23	0.57	1080	23.42	303.4	10.33

3.2 Correlation Coefficient UPF VS Properties

To study the relationship between UPF and other properties, the correlation coefficient was used (as it showed in table 6.). The results refer to the high positive correlations between UPF and Weight (gm./cm^2), and the high negative correlation between UPF and Thickness (mm).

Table 6. Correlation Coefficient UPF VS properties

	Factors	Correlation Coefficient
UPF	Wales (W/cm)	0.68
	Courses (C/cm)	0.70
	Stitch Density (stitches/cm^2)	0.93
	Stitch Length (mm)	-0.79
	Tightness Factor	0.81
	Weight (gm./ cm^2)	0.95
	Thickness (mm)	-0.97
	Burst (kpa)	-0.23
	Roughness (µm)	0.87
	Air permeability (cm^3/ cm^2.sec)	-0.81

3.4 ANOVA Analysis

The objective of our research was to study the influence of machine gauges and yarn tensions in improving UPF in cotton and polyester microfiber single jersey. An ANOVA analysis (Alpha 0.05) was used to identify the significant effect of machine gauges and yarn tensions in UPF. The results in Tables 7 & 8 indicate that machine gauge has a significant effect on cotton samples, while yarn tension has a significant effect on polyester microfiber samples (where $F > F$ crit, $P < 0.05$). The explanation is related to the nature of the yarns. Despite cotton yarn's many advantages, it results in lower UV protection. The cotton knit requires an increase in stitch density (stitches/cm^2) to improve its ability in UPF, which is correlated to machine gauges rather than yarn tensions. On the other hand, the nature of Polyester microfibers (more protective toward UV radiation as it showed in different machine gauges) requires stitch tightness to increase the reflection surface area, which is obtained by yarn tensions rather than machine gauges.

ANOVA Analysis of Yarn tensions VS UPF

ANOVA analysis	*UPF*		
	F	*P-value*	*F crit*
Cotton samples	0.850259	0.473036	5.143253
Polyester microfiber samples	6.993214	0.027055	5.143253

ANOVA Analysis of Machines Gauges VS UPF

ANOVA analysis	*UPF*		
	F	*P-value*	*F crit*
Cotton samples	7.487633	0.023406	5.143253
Polyester microfiber samples	0.351601	0.717145	5.143253

3.5 Radar charts

To identify the best cotton and polyester microfiber sample in different properties, radar charts were used to evaluate the results in all properties.

3.5.1 Samples Rating

Figure 1 shows radar charts for cotton & polyester microfiber samples successively. Calculating radar charts' area for rating cotton & polyester microfiber samples is presented in Figure 2. The findings of the effect of machine gauges & yarn tensions on characterizing cotton & polyester microfiber single jersey properties, where that sample number (1) with machine gauge (20) & high yarn tension results in the highest rating in cotton samples, while the sample number (15) using machine gauge (20) with low yarn tension achieved the highest rating in polyester microfiber samples.

Figure 3 shows radar charts for the highest sample in cotton and polyester microfiber. The rating for the best sample is presented in Figure 4. The results show that the polyester microfiber sample attained a higher rating than the cotton sample. The polyester microfiber single jersey fabric is provides more protection for summer clothing than cotton single jersey fabric.

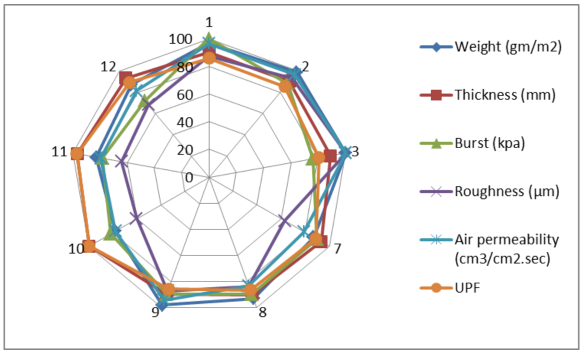

Figure 1a. Radar charts for Cotton Samples

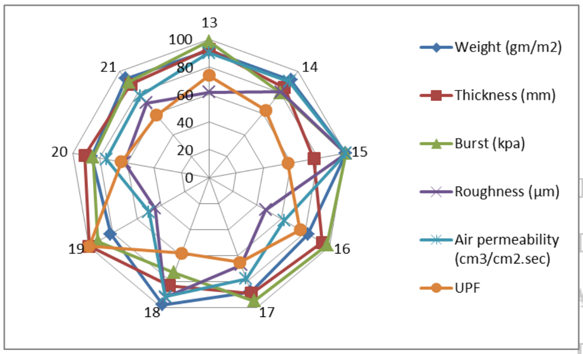

Figure 1b. Radar charts for Polyester Microfiber Samples

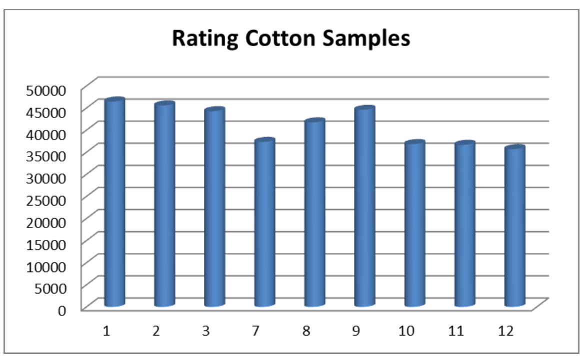

Figure 2a. Radar charts' area for Cotton Samples

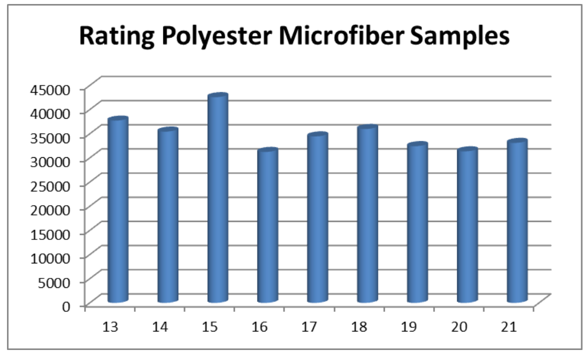

Figure 2b. Radar charts' area for Polyester Microfiber Samples

3.6 Effectiveness of yarn count in improving UPF

Cotton yarns are the yarns most often used in producing Egyptian summer clothes, and according to the previous results, the cotton samples with the highest rating are manufactured with machine gauge (20). This research aims to study how to improve UPF in cotton single jersey by using two yarn counts with the same machine gauge (20) and different yarn tension as it is presented in Table (7).

The results show that effectiveness of yarn count in improving UV property for cotton single jersey knits. Samples manufactured by yarn count 24/1 s Combed / Giza 86 with different yarn tensions achieved a higher UPF than samples manufactured by yarn count 30/1 s Combed / Giza 86. The thickness of the yarn increases. The thickness of the yarn increases stitch density (stitches/cm^2), tightness factor [K], and subsequently the reflection ability of the fabric.

In addition, the calculated area of radar charts for the cotton samples are shown in Figure 4. The results indicate that sample number (5) which was manufactured by using a yarn count 24/1 s Combed / Giza 86 with a medium yarn tension resulted in the highest rating. As it demonstrated in Figure 5, and thus concluded, the thicker yarns with a medium yarn tension have the largest magnitude to implement improvements in UPF with different properties in cotton single jersey.

Table 7. Effectiveness of yarn count in improving UPF

Yarn count	Machine gauge	Yarn tension	Sample No.	Stitches Density			Stitch length (mm)	[k] Tightness Factor	Weight (gm/m2)	Thickness (mm)	Burst (kpa)	Roughness (µm)	Air permeability ($cm^3/cm^2.sec$)	UPF
				[W] Wales W/cm	[C] Courses cm	[S] Stitches density Stitches/cm2								
30/1 s Combed / Giza 86	20	High	1	10.83	22.44	242.96	2.85	15.57	132.7	0.62	1000	15.85	241	6.8
		Medium	2	11.55	19.75	228.04	2.9	15.305	130	0.62	880	14.85	241	6.76
		Low	3	12.24	17.05	208.82	3.033	14.63	128	0.63	760	13.84	250	6.38
24/1 s Combed / Giza 86	20	High	4	10.30	24.41	251.4	2.8	17.76	164.9	0.65	1300	15.92	162.5	8.51
		Medium	5	10.37	21.32	221.04	2.9	17.15	154.9	0.65	1280	15.9	189	7.87
		Low	6	10.43	18.24	190.26	3.16	15.74	144.9	0.66	1000	15.7	216	7.83

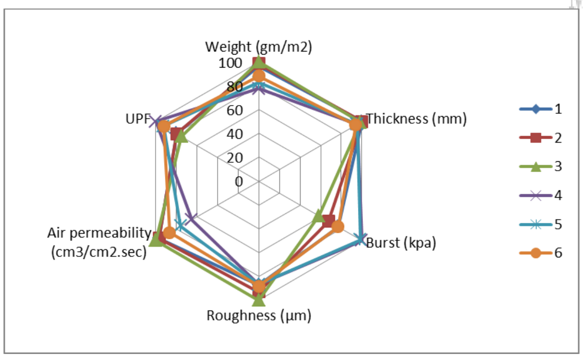

Figure 4. Radar charts for Cotton Samples with different yarn count

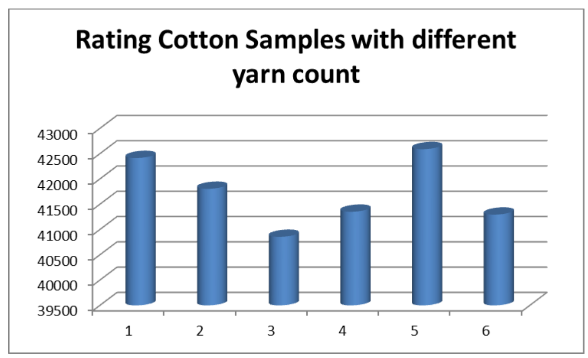

Figure 5. Radar charts' area for Cotton Samples with different yarn count

4. CONCLUSIONS

The results show the influence of yarn tensions & machine gauges on improving UPF for Cotton & Polyester Microfiber Single Jersey. Samples manufactured with the largest machine gauge (28) and high yarn tension, realized the highest UV protection. At the same time, the results show the high positive correlations between UPF and weight (gm./cm^2), while there is a high negative correlation between UPF and thickness (mm). The ANOVA analysis showed that machine gauges have a significant effect on cotton samples, while yarn tensions have a significant effect on polyester microfiber samples.

By calculating radar charts area for the samples, the results showed that the polyester microfiber sample attained a higher rating than cotton sample. This indicates that polyester microfiber single jersey fabric, provides more protection for summer clothing than cotton single jersey fabric.

Cotton yarn are most often used in producing Egyptian garments, especially summer clothing. This research aimed to study the impact of yarn count on improving UV protection. The findings indicate that thicker yarns improve UPF for cotton samples. By calculating radar charts' area, one can determine that thicker yarns with a medium yarn tension have the largest magnitude to improve UPF with different properties in cotton single jersey.

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