Evaluation of the ultraviolet protection factor (UPF) offered by various knit fabric structures

E Louris[1], E Sfiroera[1], G Priniotakis[1], R Makris[1], H Siemos[1], C Efthymiou[2] and M N Assimakopoulos[2]

[1] University of West Attica, Faculty of Engineering, Department of Industrial Design and Production, University Campus 2, 250 Thivon & P. Ralli Str., 12244, Egaleo, Greece

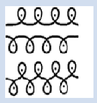
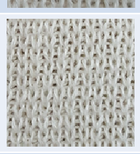
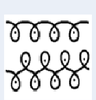
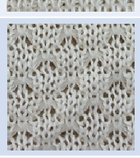
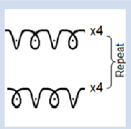
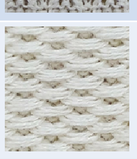
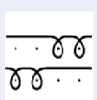
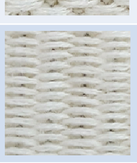
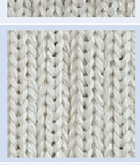
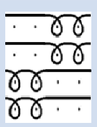
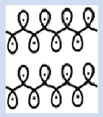
[2] National and Kapodistrian University of Athens, Faculty of Physics, Division of Environmental Physics and Meteorology, University Campus Zografou, 15784, Athens, Greece

Abstract. Public awareness regarding the risks of prolonged skin exposure to the sun light and more specifically to the UV spectrum part is increased during the last decades. Clothing is the most natural and suitable way of protecting the human body, thus the market interest in clothes that can offer adequate UV protection is growing continuously. Previous research works have revealed the main factors that influence the ability of fabrics to block harmful UV radiation. However, the variability of these factors and the versatility of their combined effect make UV protection factor prediction difficult and hence the design of fabrics with high performance against UV radiation becomes a complicated task. Hopefully, the most critical and predictable among all the various factors is the fabric structure itself. Expectedly, closer and tighter structures offer higher UV protection. Due to this fact, the majority of previous research concern woven structures which generally are less porous and offer a higher UV protection. However, the possibility to obtain knitted fabrics with adequate UV protection factor is of great interest, since knitted fabrics are more appropriate for sports as well as for casual summer fashion garments. Current literature regarding the UV protection factor of knitted fabrics is very limited and concerns mostly fabrics produced in machines of relative large gauges. In the present work the UV protection factor of various typical weft-knitted structures, produced in a flat knitting machine with 7 gauge and by using grey 100% Organic Cotton yarns, Ne 30/2, 330 TPM is studied. The yarn has been selected due to the increasing market interest for Organic Cotton products and has been offered for the purposes of this research by the Greek cotton industry VARVARESSOS S.A.

Factors influencing the UPF of fabrics

- Fabric structure (construction)
- Material (fiber type)
- Color (shade)
- Bleaching (whitening)
- Stretch (fabric deformation)
- Wetness (water absorption)
- Washing
- UVR absorbing additives (agents)
- Yarn morphology

Materials and methods. For each one of 14 typical weft-knitted structures we constructed two samples, one by using a 2-ply yarn and another one by using a 3-ply yarn, except the Interlock structure for which we constructed only one sample with a 2-ply yarn. Samples have been constructed in a flat knitting machine STOLL CMS 411.6 - 7 Gauge. As material we have selected grey yarns made of 100% Organic Cotton, Ne 30/2, 330 TPM which have been offered by the Greek cotton industry VARVARESSOS S.A. UV transmittance measurements realized in a Varian Cary 5000 UV-Vis-NIR spectrophotometer, equipped with integrating sphere. Measurements made in the range from λ_{min}= 290 nm to λ_{max}= 400 nm with a step of Δ_λ = 5 nm. Samples measurement and evaluation made according to the "European Standard EN 13758-1:2001 Textiles - Solar UV protective properties - Part 1: Method of test for apparel fabrics". Measurements made with the fabric in a non- stretch state. Specimens' storage and measurements have been realized in a laboratory environment with controlled conditions of temperature 25 +/- 2ºC and relative humidity 55 +/-5 % RH. Because any side of a knitted fabric may be used in the external face of a garment, measurements have been made in both sides of the samples. For each knitted structure eight measurements have been made, four in the technical front and four in the technical back. Since in most knitted structures, each technical side has a different appearance and texture, we followed the more strict evaluation method for "Non-uniform samples" as described in the European Standard EN 13758-1:2001. In this case which is applied "for materials with areas of various shades and/or construction, the lowest positive UPF value measured shall be reported as the sample UPF".

Knit Structure	Technical Front	Technical Back	Knitting Notation
Single Jersey			
Lacoste			
Full Cardigan			
Half Cardigan			
Full Milano			
Half Milano			
Pineapple			
KM22C			
KM22W			
KM11			
KT22C			
KT22W			
RIB 1x1			
Interlock			

Measurements and Results.

Knit Structure	Course / cm	Wales / cm	Weight /sqm	Thickness (mm)	UVA	UVB	UPF
SINGLE JERSEY x2	6	5	178,5	0,85	16,447	12,705	7,342
SINGLE JERSEY x3	5,9	4,5	254,9	1,1	9,809	7,487	12,429
LACOSTE x2	6	3,5	162,8	1,76	23,947	20,526	4,640
LACOSTE x3	5	3,5	299,6	1,85	10,629	8,838	10,657
CARDIGAN x2	5	5	228,3	0,96	11,028	7,917	11,603
CARDIGAN x3	5	4	329,4	1,66	6,828	4,519	19,899
HALF CARDIGAN x2	4,2	4,5	236,1	1,15	14,650	10,861	8,557
HALF CARDIGAN x3	4,2	4,5	344	1,95	3,836	2,143	**41,002**
FULL MILANO x2	5	8	304,8	1,45	7,693	5,690	16,167
FULL MILANO x3	6	8	442,6	1,96	2,296	1,277	**68,807**
HALF MILANO x2	7	8	265,9	1,45	10,942	8,098	11,435
HALF MILANO x3	7	8	419,5	2,17	5,044	3,685	24,941
PINEAPPLE x2	5	4	165,8	0,91	22,437	18,718	5,061
PINEAPPLE x3	5	4	314	1,65	9,718	7,874	11,946
KM22C x2	5,5	5	240	1,08	7,525	5,216	17,457
KM22C x3	7	4,7	412,2	1,51	2,768	1,944	**48,595**
KM22W x2	5,5	5,9	204	1,02	11,404	8,507	10,866
KM22W x3	7	5	423,7	1,54	1,761	0,927	**93,448**
KM11 x2	5	5,3	207,8	1,02	11,142	8,534	10,904
KM11 x3	6	5,5	370,5	1,42	3,132	1,844	**47,902**
KT22C x2	5,8	3,6	222,1	1,5	11,268	8,015	11,404
KT22C x3	6,5	3,5	367,2	1,89	6,572	5,070	18,335
KT22W x2	4,2	4	140,2	0,77	23,755	19,914	4,759
KT22W x3	4	4	243	1,45	11,411	8,847	10,525
RIB x2	5	8	178,5	0,82	7,376	4,601	19,499
RIB x3	5	7	383,7	1,89	3,510	2,059	**42,729**
INTERLOCK x2	5,3	6	361,4	1,69	3,140	1,667	**51,359**

Conclusions. As expected, the use of thicker yarns (3-ply instead of 2-ply) with higher loop densities lead to increased UV protection performance. However, the comparison between different samples indicates that fabric structure has the greatest influence in the UPF. For instance, a lighter structure of Rib 1x1 with a 2-ply yarn has higher UPF than a heavier Lacoste structure with a 3-ply yarn. Seven knit structures have been found with a UPF > 40, namely Half Cardigan. Full Milano, Rib 1x1, KM11, KM22C, KM22W with 3-ply yarn and Interlock with 2-ply yarn, while three of found with a UPF > 50 (Full Milano, KM22W and Interlock). By using any of these structures we can be pretty sure that the final knitwear will have a high UPF, considering also that later wet-treatments, like dyeing or washing, will further increase their UPF. The above structures is expected to have high UPF also in higher gauges, which is in accordance with the results of other research works. Finally, it is worth to mention that in all knit structures a transmittance increase is observed as the wavelength increases, resulting lower protection levels in the UVA region, especially above 350 nm.

Acknowledgments. We thank the Greek company VARVARESSOS S.A. and Mr.George Kostopoulos for their support

ΠΑΝΕΠΙΣΤΗΜΙΟ ΔΥΤΙΚΗΣ ΑΤΤΙΚΗΣ UNIVERSITY OF WEST ATTICA

HELLENIC REPUBLIC
National and Kapodistrian University of Athens

VARVARESSOS