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INFLUENCE OF COLOUR AND UV PROTECTING FINISHING ON SPECTRAL AND THERMOPHYSIOLOGICAL PROPERTIES OF SPORTS FABRICS

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ABSTRACT

When doing endurance sports in summer one has to protect from UV radiation by sun cream or long sleeved clothing. On one hand, long sleeves protect against the IR radiation of the sun. On the other hand, the fabrics can show a negative effect on the heat release of the human body and wear comfort. The correlation between textile construction, their wear comfort and their UV and IR protective properties is still unknown. Four fabrics were chosen as basis of the investigation. Two of them built a pair of similar fibre chemistry, but varied knit. Finishing encompassed different UV protection finishes and colours (white, red, black). The textiles were characterised in regards to UV standard 801 (UPF) and the IR protection according EN 410 (g-value). Furthermore, thermophysiological comfort and the sweat management were characterised by means of a sweating guarded-hotplate. Different sweat rates from vaporous to heavy sweating were simulated and according values were measured – water vapour resistance, buffering capacity of liquid and vaporous sweat, liquid sweat transport. Skin sensorial properties were characterised by means of five different indices - wet cling index, number of contact points, sorption index, surface index and stiffness.

KEYWORDS

UV protective properties; g-value; thermophysiological properties; sports textiles.

1. INTRODUCTION

In summer, clothing worn during endurance sports, like biking or running, needs to offer sun protective properties and good sweat management. In this manner, sun protection is related to shortwave ultraviolet radiation (UV) and long wave infrared radiation (IR). UV rays damage human skin, harm function of sweat glands and therefore decrease sportsmen's performance (Lambert et al., 2008). One long-term effect of UV light is skin cancer (Moehrle, 2008), wherefore this risk is higher for endurance sportsmen (Moehrle, 2008; Moehrle, 2001). Furthermore, human body is producing heat by metabolism, e.g. 140 W when walking slowly to more than 1000 W during sprints (de Marées, 2003). In summer, sun is causing an additional heat source due to IR radiation.

A study by Nielsen et al. showed a heat uptake of the body by sunlight of 120 W, what was 20% of overall heat production (Nielson et al., 1988). Of cause, this heat needs to be released to avoid overheating of the body, maintain wear comfort of clothing and performance of sportsmen (de Marées, 2003). At high temperatures during summer, "dry" heat loss by convection and conduction is relatively low, while sweat evaporation is more important.

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UV protection depends on the fibre composition of the textile. Textiles made of natural fibres (e.g. cotton, wool) provide lower UV protection than synthetic fibres (e.g. polyester) (Djam et al.,2001). Additional protection can be achieved by finishes like TiO_2 or ZnO (Haug, 2008; Mallik et al., 2003) and by dark colour (Achwal, 2000; Hunt, 2003). Furthermore, it is well known that fibres, textile construction and finishes influence sweat management as well as wear comfort of clothing, e.g. Harnisch et al. (Harnisch et al., 2014).

Nielsen compared different T-shirts (white vs. black, polyester vs. cotton) in subject trials simulating a sunny summer day (Nielsen, 1990). He found lower heart rate and sweat loss in trials with polyester in comparison to cotton and benefits of black shirts when compared to white ones. Kato et al. found no differences between black and white clothing subject trials in the field in regards to body core and skin temperature, but higher sweat rates when wearing white clothes, too (Kato et al., 1996). Therefore, Nielsen (Nielsen, 1990) and Kato et al. (Kato et al., 1996) summarised that white clothing allows higher transmission rates and leads to higher sweat rates. On the other hand, EMPA compared beige and black shirt by torso measurements and found lower sweat rates for the none-black shirt (Schoeller, 2012).

No papers were found on spectral/sun protective properties and thermophysiological properties in dependency of fibre chemistry, knit construction and finish.

2. MATERIALS AND METHODS

Four fabrics were chosen to represent sports shirts and as basis for finishing in the laboratory. Every two of them built a pair of similar fibre chemistry (PES/EL and CLY/PP/EL), but varied knit (single and piqué). PES fibres of samples 1 and 2 included an optical brightener and had been white. CLY/PP/EL fibres of samples 3 and 4 were not finished in any way and naturally grey. Table 1 shows the fibre characteristics of the used fabrics.

Table 1: Characteristics of used textiles

fabric	fibre composition	construction	fabric weight [g/m²]	thickness [mm]
1	PES/EL (82/18)	single	181.5	0.671
2	PES/EL (81/19)	piqué	186.6	0.919
3	CLY/PP/EL (53/45/2)	single	159.4	1.159
4	CLY/PP/EL (53/45/2)	piqué	177.9	1.398

The Fabrics were finished and dyed in the laboratory (red and black, BEMECRON for PES, BEZAKTIV for CLY/PP, all dying agents from BEZEMA AG). Two commercially available UV protection finishes were used, an inorganic one based on TiO_2 (finish 1 – f1, CHT BREITLICH GmbH) and an organic one based on heterocyclic compounds and benzophenone derivate (finish 2 – f2). In combination with those finished fabrics were tested in non-dyed state, red and black.

UV protective properties were characterised according to UV standard 801 in dry and wet state (UPF-value). Sun protection in regards to heat transfer through the fabrics was characterised according to EN 410 (g-value).

Sweat management was characterised by means of a sweating guarded hot plate. Based on human thermoregulation and resulting wear situations different sweat rates from vaporous to heavy liquid sweating were simulated and according values were measured. Water vapour resistance R_{et} was measured according to ISO 11092. Higher sweat rates were characterised by buffering capacity of vaporous sweat F_d and the liquid sweat transport F_1 (CEN/TR 16422, 2013).

Skin sensorial properties – the perception of a textile on the skin– were characterised by means of five different indices (Mecheels, 1982; Bartels, Umbach, 2001). The wet cling index i_K simulated the clinging of a textile on wet skin, measuring the force to pull the specimen across a wetted plate. The number of contact points between skin and textile n_K was measured by means of a topographer and gives information how fast a textile will be perceived as clammy. The absorption time i_B of a single water droplet defined the sorption index. The surface index i_O expresses the hairiness or roughness/smoothness of a textile and was characterised by the number and height of fibres coming out of the textile body. Stiffness s was measured to characterise adaption of fabrics onto body shape. In addition, skin sensorial wear comfort $TK^{(S)}$ was calculated using measured skin sensorial indices (Bartels, Umbach, 2001).

3. RESULTS AND DISSCUSSION

3.1. Spectral properties

The UPF-values according to UV standard 801 of the base samples 1 to 4 as well as the finished ones show that the PES ones have a higher UV protection, caused by the additional brightener within the fibre. The UPF of PES samples 1 and 2 increases by UV protective finish. On the other hand, the UV protection of CLY/PP/EL sample 3 and 4 could not be improved by the use of an UV protection-finishing (table 2).

Table 2: UPF-value of basic, finished and coloured textiles

		UPF [-]								
fabric	finish	-	f1	f2	-	-	f1	f1	f2	f2
	colour	white	white	white	red	black	red	black	red	black
1		40	30	50+	-	-	-	-	-	-
2		20	20	25	15	15	15	15	15	20
3		5	5	5	10	10	5	10	10	10
4		5	10	10	-	-	-	-	-	-

The base samples 3 and 4 out of CLY/PP show a lower, better g-value than the PES ones. By applying an UV protection finishing the g-value is significantly decreased. Therefore, less IR radiation transmits the sample and the space between wearer and sample is warmed up less (table 3).

Table 3: g-value of basic, finished and coloured textiles

		g-value [-]				
fabric	finish	non	non	non	f1	f2
	colour	non	red	black	black	black
1		0.3515	-	-	-	-
2		0.4364	0.3687	0.3538	0.3401	0.3384
3		0.2892	0.2221	0.2274	0.2259	0.2295
4		0.2936	-	-	-	-

Further investigation deals with the influence of the colour on the UPF- and g-value. The results show that the UPF- as well as the g-value of the black samples show better results than the red and non-coloured ones.

3.2. Thermophysiological properties

Water vapour resistance (R_{et}) of the PES fabric is better than CLY/PP fabric and the single jersey is better compared to piqué (table 4). Looking at UV protective finishing, the finish leads to slightly higher R_{et} values in comparison to non-finished state. Overall vapour resistance R_{et} of all fabrics (new state, dyed or finished) is very good for this kind of fabric.

Table 4: Thermophysiological properties of new state and finished textiles

sample	finish	R_{et} [m^2 Pa/W]	F_d [-]	F_1 [g/m^2 h hPa]
1	-	2.30	0.76	20.9
1	f1	2.59	0.65	19.8
1	f2	2.61	0.65	20.9
2	-	2.83	0.65	20.3
2	f1	3.24	0.64	18.5
2	f2	3.12	0.67	19.8
3	-	3.36	0.64	17.7
3	f1	3.90	0.61	17.5
3	f2	3.63	0.64	19.1
4	-	3.78	0.60	16.0
4	f1	4.25	0.59	17.6
4	f2	4.00	0.62	18.2

In regards to buffering capacity of vaporous sweat, all fabrics show similar values (table 4). Transport of liquid sweat F_1 is higher for PES fabrics compared to CLY/PP fabrics. F_1 values of piqué samples are lower in comparison to single jerseys. For PES fabrics, the inorganic finish has a negative effect, while comparison of non-finished to UV protective organic finish shows approximately same values. In CLY/PP, organic finish has a benefit for both knits in regards to F_1, while inorganic one just shows a benefit in piqué (table 4).

Sorption index i_B should be lower than 270. This requirement is reached by all samples (table 5). On the other hand, inorganic finish leads to slower absorption. PES piqué shows highest wet cling index i_K in every state. Other fabrics just exceed the limit with inorganic finish. CLY/PP knits are on the same level for all finishes, the PES single jersey shows lowest i_K values. Already in non-finished state all fabrics had just very few fibres coming out of the textile body and consequently low surface index i_O. With regard to sensorial comfort, a fabric has to be judged the better, the smaller the number of contact points n_K. Particularly n_K should be below 1500. Just the PES jersey exceeds 1500 contact points n_K. CLY/PP fabrics show lower n_K values compared to PES fabrics, piqué does so in comparison to single jersey. It was assumed, that finishes do not have an effect on n_K. In regards to stiffness s, CLY/PP fabrics and piqué are more comfortable when compared to PES or single jersey, respectively. UV protecting finishes on PES single hardens the fabric, while they do not influence stiffness of the PES piqué and smoothen both CLY/PP knits. Skin sensorial properties of fabrics can be summarised by a comfort vote. This shows higher comfort for knits of CLY/PP when compared to PES. Piqué samples are more comfortable than single jerseys. The inorganic finish lowers skin sensorial comfort while organic finish shows similar values like non-finished fabrics.

Table 5: Skin sensorial properties of basic and finished textiles

fabric	finish	i_B [-]	i_K [-]	i_O [-]	n_K [-]	s [-]	$TK^{(S)}$ [1 best-6 worst]
1	non	0.4	4.8	0.7	1759	9.0	3.45
1	f1	11.5	52.1	-	-	11.6	4.31
1	f2	0.1	8.3	-	-	16.6	3.32
2	non	0.9	15.4	0.9	1315	12.5	2.63
2	f1	15.7	125.0	-	-	13.5	4.76
2	f2	0.1	16.2	-	-	12.4	2.70
3	non	0.8	10.1	4.2	1159	20.3	1.88
3	f1	10.1	16.7	-	-	14.8	2.03
3	f2	0.8	11.0	-	-	13.6	1.89
4	non	0.8	10.1	3.6	954	22.5	1.58
4	f1	9.0	15.4	-	-	18.1	1.64
4	f2	0.4	8.9	-	-	14.3	1.43
target		<270	<15	$3<i_O<15$	<1500	$5<s<25$	low

4. CONCLUSION

PES samples show less UV protection, a higher g-value and an inferior thermophysiological comfort in comparison to CLY/PP. By colouring the samples, UV protection and g-value were improved. The better g-value was ascribable to higher light absorption, which could lead to warming of the skin when tightly fitting clothes are worn. Furthermore, no influence of dying on the thermophysiological properties has been observed.

In comparison to dying the finishing has less effect on the UV protection and g-value. A clear statement on the influence of the UV finishing on thermophysiological comfort is not possible.

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