

EXAMINATION OF THE ABSORPTION PROPERTIES OF VARIOUS FIBRES IN RELATION TO UV RADIATION

Joanna Alvarez, Barbara Lipp-Symonowicz

Technical University of Lodz, Department of Physics Fibre,
ul. Żeromskiego 116, 90-543 Łódź, Poland
E-mail: jalvarez@poczta.fm

Abstract

The barrier properties of model fabrics as a protection against UV radiation have been examined by measuring the UV absorbing capacity of polymers of selected fibres containing dulling agents and optical brightening agents.

Keywords

Cellulose fibres, polyamide fibres, polyester fibres, model fabrics, UV radiation, absorption properties of fibres, barrier characteristic of fibres

Introduction

The requirements imposed on clothing fabrics include a wide range of properties which in recent decades have become specified both more often and more closely, especially those concerning hygienic and physiological properties. More and more frequently, textile fabrics are manufactured so as to provide their users not only with comfort of use but also with safety and health protection. Such objectives are accomplished by means of modern textile technologies including fibre formation, spinning, weaving, knitting and finishing processes [1].

Recently, considerable attention has been paid to the barrier properties of textiles designed for clothing as a protection against UV radiation, while also taking into account the trends of current fashion. The findings reported in the literature concerning the barrier properties of fabrics in relation to UV radiation show that attention has been focused on the physical aspect of barrier properties of fabrics or yarns used for fabric production. A relatively weak emphasis has been put on the effect of fibre-forming polymers on the UV absorbing capacity, molecular structure specificity, morphological structure and macroscopic properties of fibres. The effects of additives such as dulling agents and optical brighteners have also been analysed to an insufficient extent. Thus, the resultant conclusions cannot be considered on a broad basis, as they do not reveal all factors which are requisites of barrier properties; they systematise fabrics of various textile raw materials with given constructions only from the point of view of UV transmission.

In order to fill the gap in treating the barrier properties of textiles broadly, the present study is aimed at the analysis of the barrier properties of model fabrics in respect of their UV absorbing capacity revealed by selected types of fibres, as well as after containing optical brightening agents.

Test items

The test items used included:

- man-made cellulose fibres of various generations, with both dull and glossy surfaces, manufactured by Lenzing (Austria);
- dull and bright polyamide and polyester fibres manufactured by Stilon S.A. and Elana S.A (Poland), respectively;
- model fabrics with plain weave made of the above fibres by Lenzing, Dolvis S.A. Ortal S.A, as well as those treated by optical brightening process.

The lists of fibres, fabrics, their characteristics and metrological parameters are given in Tables 1, 2 and 3.

Table 1. Characteristics and metrological parameters of from man-made fibres cellulose fabrics manufactured

Staple man-made cellulose fibres (100%)		Fabric made of man-made cellulose fibres of various generations (100%)				
Type of fibre	Metrolog. parameter	Type of fabric	Character of yarn	Weave density/10cm (warp/weft)	Fabric thickness, mm	Finishing
Viscose standard 'bright'	(1,3dtex/3 9mm)	Viscose standard 'bright'	Identical for all fibres investigated	320/270	0.23	without
Viscose standard 'dull'	(1,3dtex/3 9mm)	Viscose modal 'bright'		320/270	0.22	without
Viscose modal 'bright'	(1,3dtex/3 9mm)	Viscose modal 'dull'		320/270	0.25	without
Viscose modal 'dull'	(1,3dtex/3 9mm)	Lyocell 'bright'		320/270	0.22	without
Lyocell 'bright'	(1,3dtex/3 8mm)	Viscose rayon 'bright' (2)	dtex110/110	350/280	0.12	without
-	-	Viscose rayon 'bright' (1)	dtex167/167	425/230	0.22	without

Table 2. Characteristics and metrological parameters of from fibres polyester fabrics manufactured

Fabric made of PES filaments (100%)				
Type of fibres	Characteristic of yarn	Weave density/10cm (warp/weft)	Fabric thickness, mm	Finishing
(7) 'round semi-dull'	warp 165dtex/48·2; weft 330dtex/72	180/210	0.25	without
(6) 'round semi-dull'	warp 110dtex/36·1weft 165dtex/144	300/295	0.18	without

Table 3. Characteristics and metrological parameters of from fibres polyamide fabrics manufactured

Fabric made of PA filaments (100%)				
Type of fibres	Characteristic of yarn	Weave density/10cm (warp/weft)	Fabric thickness, mm	Finishing
(5) 'round semi-dull'	warp dtex72/17; weft dtex184/136 (micro rayon)	390/280	0.19	without
(4) 'round semi-dull'	warp dtex72/17; weft dtex78/24	455/350	0.11	without
(3) 'round semi-dull'	warp dtex72/17; weft dtex100/24	440/330	0.12	without

Measurement methods

The absorption properties of fibres were analysed in terms of the barrier characteristics of fabrics during exposure to UV radiation.

Assessment of the barrier properties of woven fabrics during UV irradiation

Two measurement methods were used:

- a method proposed by Vassileva [2], modified in the Department of Fibre Physics
- a UV-spectrophotometric method of measuring the index of UV penetration through a fabric

Vassileva's method modified in the Department of Fibre Physics

This method, as described by the Bulgarian Patent Application [2], is an original measuring procedure based on the assessment of the fading degree of fabrics dyed with light sensitive dyes after exposure to UV radiation. The degree of dye photo-destruction is determined on the basis of changes in the values of Kubelka-Munk's function (K/S) of dyed reference fabrics. The relative colour intensity (RCI) can be found experimentally from the following equation:

$$RCI = \frac{(K/S)_t}{(K/S)_0} 100 \quad [\%] \quad (1)$$

This method of measurement allows one to assess and compare the barrier properties of various types of woven fabrics. However, the method proposed by Vassileva has been modified for the purpose of our studies on the barrier properties of textiles carried out at the Department of Fibre Physics. A polyamide woven fabric with a plain weave, dyed with methylene blue, was used as a reference standard fabric. The barrier properties of the woven fabrics used were assessed during irradiation with an UV-rich light source for 15, 30, 45 and 75 min. The degree of fading of the standard fabric was assessed under comparative conditions using a grey scale.

UV spectrophotometric method of measuring the UV penetration index

According to the literature [3], in order to objectively assess barrier properties, a so-called solar protection factor (SPF) was introduced that allows one to compare the protective capacity of various materials. This factor was being used in Europe and the USA as far back as the 1950s. It is defined as Maximum Exposure Dose (MED) ratio for unprotected skin exposed under the same conditions. It indicates how much longer a covered skin can be exposed to the sun's rays as compared to an uncovered skin. The literature data [4] reports an extended term of SPF, the so-called UPF index, which is an index of protection against UV radiation.

Various publications show different division of fabrics in respect of barrier properties. For instance, the Australian and New Zealand standard [5] assume the following division of barrier properties of woven fabrics:

UPF < 20	the fabric fails to meet protective properties
UPF : 21 – 30	protective properties at a low level
UPF: 32 – 40	medium protective properties
UPF: 41 – 50	good protective properties
UPF > 50	very good protective properties

In Poland these values are slightly adjusted [6]; UPF = 26 is the lower limit.

UPF can be calculated from the formula:

$$UPF = \frac{\sum E\lambda \cdot S\lambda \cdot \Delta\lambda}{\sum E\lambda \cdot S\lambda \cdot T\lambda \cdot \Delta\lambda} \quad (2)$$

where:

$E\lambda$	- spectral intensity of radiation ($W/m^2 \cdot nm$),
$S\lambda$	- spectral relative biological efficiency,
$T\lambda$	- spectral permeability of the protective item – textile fabric,
$\Delta\lambda$	- ranges of wavelength.

The summations play the part of integration of the spectral spheres of influence on UPF. According to standard [7], a xenon tube provides the best imitation of sunlight.

The spectral distributions of biological efficiency are available in a tabular form. The calculations of various daylight phases indicate that the spectral range 305-315 nm is of the greatest importance.

Measuring apparatus in various countries makes it possible to use different measurement techniques which do not always provide completely convergent results. The most objective measuring technique is that one which uses the so-called integrating Ulbricht's Globe (a photometric globe). This measuring system was used in the present study. Measurements were carried out in accordance with the draft standard EN 13758-1: 2001 [8].

Figure 1 illustrates the simplified effects of radiation on the protective layer-fabric.

Radiation I falling on the fabric (incident radiation) is reflected by this fabric in either a directional way I_{ok} (according to the laws of geometric optics) or in a scattered way I_{or} (the beam of radiation is deflected in many directions). Taking into account the third dimension of the item, i.e. its thickness, a part of the radiation is reflected from the surface and another part can be scattered inside the item. The remaining part of the incident radiation can penetrate the fabric.

The total transmitted index was measured in the present study by means of a DK-2A spectrophotometer from Beckman at RM 33%, placing the test item within the radiation beam between the radiation source and Ulbricht's Globe, just in the immediate proximity of the Globe to eliminate the losses of transmitted scattered radiation (Figure 2).

In order to measure the total transmittance of the optically brightened fabrics, a non-fluorescence filter was used which transmits UV radiation below 400 nm and no visible radiation within the range from 400 nm to 700 nm.

The values of transmittance within the wavelength range from 300 to 360 nm were measured for all the fabrics under investigation, and then UPF indices were calculated.

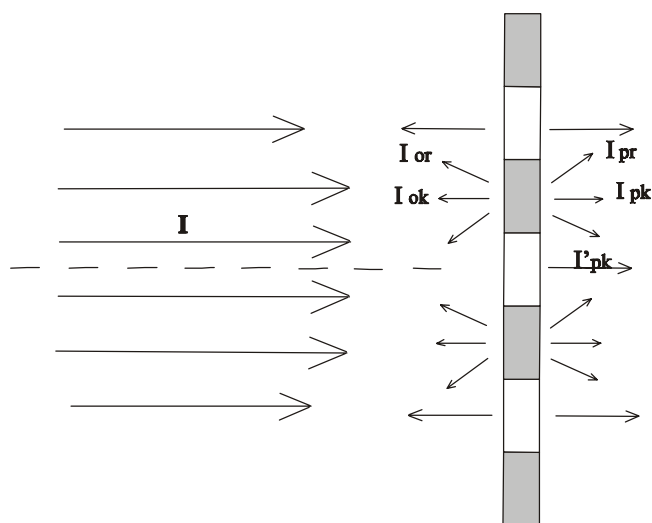


Figure 1. Effects of radiation on the protective layer-fabric [3]

where:

I – radiation

I_{ok} – scattered radiation I_{or} – reflected radiation

$(I_{pk} + I'_{pk})$ – partly directional transmitted radiation of the total transmitted beam

I_{pr} – partly scattered transmitted radiation

$(I_{pk} + I'_{pk})/I$ – index of directional transmitted radiation

I_{pr}/I – index of scattered transmitted radiation

The sum of the last two indexes gives the total transmitted index

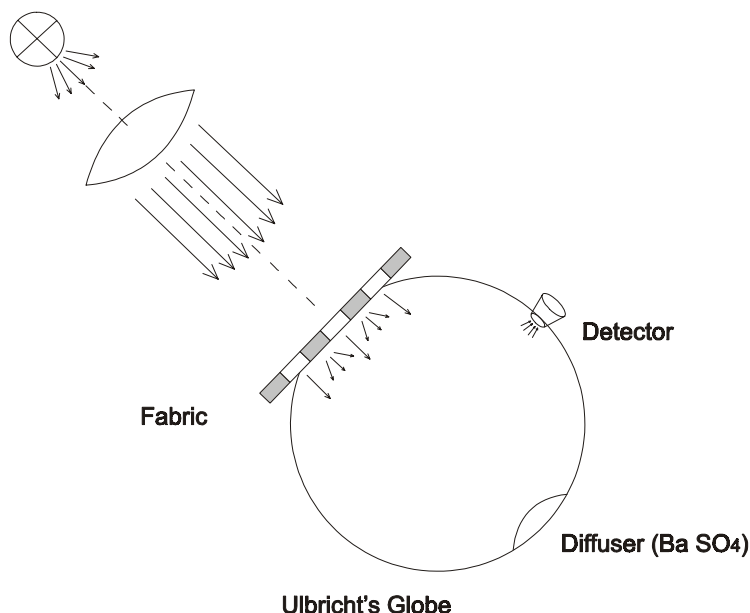


Figure 2. Schema of the DK-2A Beckman spectrophotometer [3]

Results

The results of the assessment of the barrier properties of model fabrics with the use of the measurement methods described are listed in Table 4.

Table 4. • Result of study barrier properties of model fabrics after exposure to UV radiation
 • Value index UPF characterises the barrier properties of fabrics

Type of fibres	Estimate of barrier properties after irradiation UV (grey scale) various time t, min				Value index UPF $UPF = \frac{\sum E\lambda \cdot S\lambda \cdot \Delta\lambda}{\sum E\lambda \cdot S\lambda \cdot T\lambda \cdot \Delta\lambda}$ (range: 300-360nm)	Fabric thickness, mm
	15'	30'	45'	75'	-	
Time of irradiation	15'	30'	45'	75'	-	-
(1) Viscose rayon 'bright'	3	3	2/3	2	10	0.24
Ⓡ Viscose rayon 'bright'	4	3/4	3	2/3	28	0.29
(2) Viscose rayon 'bright'	3	2	1/2	1	5	0.12
Ⓡ Viscose rayon 'bright'	4	3	2/3	1/2	14	0.18
Viscose modal 'bright'	3	3	2/3	1/2	4	0.22
Ⓡ Viscose modal bright'	4	3/4	3	3	above 200	0.27
Viscose modal 'dull'	4	3	2/3	2	29	0.25
Ⓡ Viscose modal 'dull'	4	3/4	3	3	above 200	0.29
Viscose standard 'bright'	3/4	3	2	2	4	0.23
Ⓡ Viscose standard bright'	4	3/4	3	3	above 200	0.28
Lyocell - 'bright'	3/4	3	2	2	3	0.22
Ⓡ Lyocell - 'bright'	4	3/4	3	3	above 200	0.26
(3) PA - round fibres, 'semi dull'	3	2/3	2	1/2	2	0.12
Ⓡ PA - round fibres, 'semi dull'	4	3	3	2	9	0.13
(4) PA - round fibres, 'semi dull'	2/3	2/3	2	1	2	0.11
Ⓡ PA - round fibres, 'semi dull'	4	3/4	3	2	9	0.13
(5) PA - round fibres, 'semi dull'	3/4	2/3	2	1	6	0.19
Ⓡ PA - round fibres, 'semi dull'	4	3	3	2	79	0.20
(6) PES - round fibres, 'semi dull'	3	2	2	2	17	0.20
Ⓡ PES - round fibres, 'semi dull'	3/4	3	3	2	above 200	0.21
(7) PES - round fibres, 'semi dull'	3	2/3	2	1/2	27	0.25
Ⓡ PES - round fibres, 'semi dull'	4	3	3	2/3	above 200	0.31

Ⓡ – fabric including optical brighteners

Discussion of results

The barrier properties assessed of the model items used in relation to UV radiation provide a basis for drawing conclusions in respect to the absorption properties of particular types of fibre-forming polymers, the dulling agent in the form of titanium dioxide and the optical brighteners added to the fibres. It is also possible to draw conclusions about the effect of fabric thickness and weave density on the barrier properties of woven fabrics.

Of the measurement methods used, only the UV-spectrophotometric method allows us to draw unmistakable conclusions about the barrier properties of the woven fabrics examined.

The method proposed by Vassileva, with the accepted assumption that simplifies the assessments and with the use of the grey scale, allows only a qualitative evaluation of the effect in question, or to state that that the barrier properties can be improved by incorporating optical brighteners, and also that such an effect shows a prolonged stability.

Based on the results obtained with the UV-spectrophotometric method in respect to the effect of fibre-forming polymer on the barrier properties of fabrics, one can conclude that this effect is rather inconsiderable.

In the case of fabrics with comparable thickness and weave densities made of different types of fibres, the UPF factors range from 4 to 17.

The incorporation of a dulling agent into fibres causes the UPF index to increase, as confirmed by the results obtained for fabrics with comparable thickness and the same weave density made of glossy and dulling modal fibres (UPF 4 and 29).

The barrier properties of the fabrics under investigation are considerably improved by incorporating optical brightener molecules into fibres. The best barrier effects were obtained for all fabrics made of staple cellulose fibres and for fabrics of polyester fibres (UPF over 200). However, the fabric of standard polyamide fibres containing optical brighteners fails to meet the barrier requirements, but when the fabric is made of polyamide micro-fibres with optical brighteners (5), its UPF value is at the level corresponding to the highest value required from the point of view of protective properties (UPF = 79).

Based on the values of UPF obtained for polyester fabrics with different weave densities and thickness, one can conclude that of these two parameters of fabric structure, thickness exerts a greater influence on the barrier properties of the fabrics, but the differences are relatively inconsiderable.

Conclusion

Based on the results obtained with the UV-spectrophotometric method, we may conclude:

- the barrier properties of model fabrics made of various fibres are affected to some extent by:
 - the type of fibre-forming polymer,
 - the dulling agent,
 - the fabric's structural parameters.

However, the effect is not high enough to provide any substantial improvement in the barrier characteristics of fabrics.

- An essential improvement in the barrier properties of the majority of the examined fabrics is obtained by incorporating optical brightener molecules into fibres.

In this case, the value of UPF exceeds the level corresponding to fabrics with very good protective properties.

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