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# What level of protection can be obtained using sun protective clothing? Determining effectiveness using an *in vitro* method

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ABSTRACT

It has been clearly demonstrated that ultraviolet radiation is harmful to the skin and can cause helioderma and cancers. There are different methods of combating ultraviolet radiation: sunscreens formulated with filters and/or screens as well as clothing. For this work, the authors studied different fabrics to evaluate what effect the type, color and thickness of an article of clothing might have in terms of providing UVB (UPF) and UVA (UPF–UVA) protection. This study was conducted using a spectrophotometer equipped with an integrating sphere and allowed the authors to discover that certain fabrics have UPF values which exceed 500, making them vastly superior to sunscreen creams. Synthetic fabrics appear to provide the highest level of sun protection.

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## 1. Introduction

Humans have always lived their lives according to the sun. Yet, no matter how vital the sun is for life on earth, it also carries risks of toxicity. Although the fact that the sun is harmful to the skin has been known for many years, raising awareness of sun protection methods is a long and difficult process (Shpall, 2007). The history of sunscreen products is a short one since this type of product only became the object of industrial manufacture in the 1930s (with products like Jean Patou's Huile de Chaldée® or Ambre solaire®) by Eugène Schueller, the founder of L'Oréal. The first products to appear on the market did not include any markers of their sun protection effectiveness. Nowadays, different methods of sun protection can be used: topically-applied protection using sunscreen products formulated with organic and/or inorganic filters, oral sun protection based on food supplements, foods and medicines containing free radical fighting substances, vitamins and provitamins or even filters like PABA, and finally, sun protective clothing (Béani, 1999). Although this last type of sun protection is, in fact, the oldest and considered intuitively to be the most effective, there are few studies which quantify the level of protection achieved in terms of the characteristics of the fabric involved. A certain number of factors influencing UPF (thickness, type of fabric, color, treatment with UV filter, . . .) have been identified (Lautenschlager et al., 2007). We decided to quantify the protection level achieved as a function of the characteristics of the clothing which was tested (type of fabric, thickness, color). While the notion of UPF (the equivalent of SPF – Sun Protection Factor – for a sunscreen product), a translation of the fabric's effectiveness against UVB rays is well established (Meunier, 2009; Van den Keybus et al., 2006), the protection factor against UVA rays has never been appropriately determined. Unfortunately, as yet there is no PF-UVA equivalent for protective clothing for sunscreen products. For this study, we followed the same strict rules with respect to effectiveness which oversee the manufacture of sunscreen products: a SPF/PF-UVA ratio $\leq$3 and a critical wave length ($\lambda_c$) (wave length below which 90% of a product's effectiveness manifests) greater than or equal to 370 nm. Any product which respects these two criteria will guarantee an effective protection against UVA and UVB radiation. Our project transposed these cosmetic-industry-based rules to clothing-based protection methods.

## 2. Experimental

### 2.1. Material tested

We tested standard retail clothing in a variety of types, colors and thicknesses.

### 2.2. Thickness measurement

The thickness of the various fabrics was determined using a thickness measuring machine (digital model MOD-497D, Erichsen,

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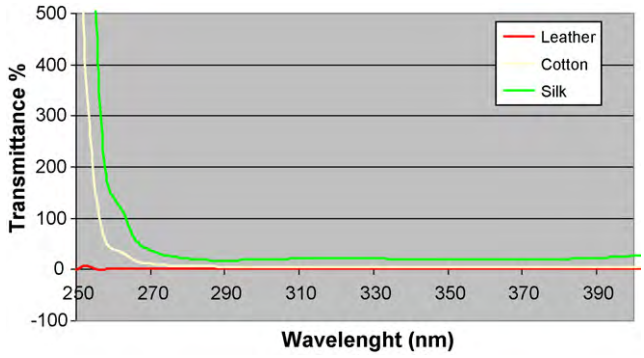


**Fig. 1.** Transmittance curves for natural fibers.

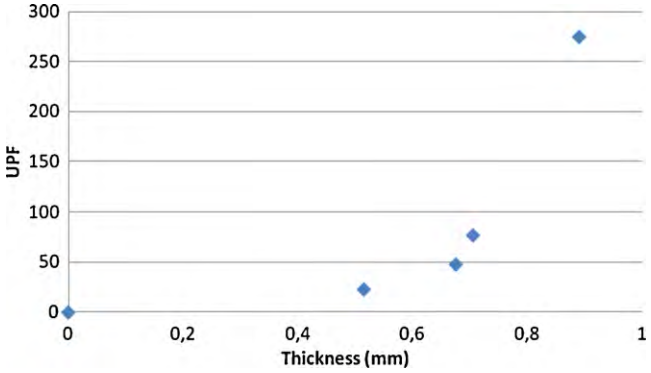


**Fig. 2.** Influence of thickness on effectiveness.

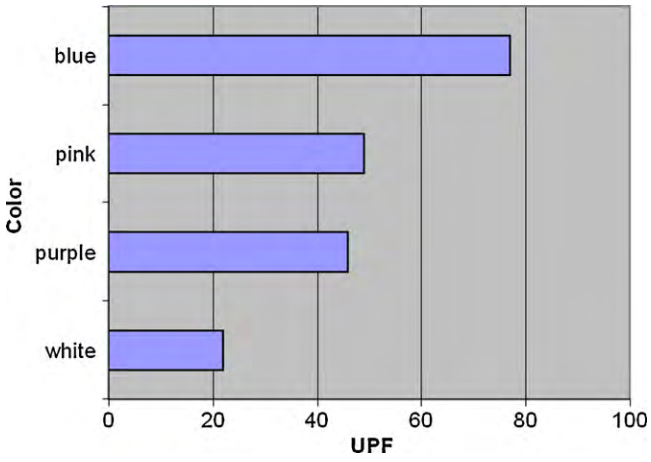


**Fig. 3.** Influence of color.

Rueil-Malmaison, France). The length and the force of the measurements were 12.5 mm and 0.80 N, respectively.

### 2.3. Study of effectiveness

The material under study was placed directly below the UV radiation emitter. The UPF and UPF–UVA values were determined using an *in vitro* method. Each test resulted in five measurements. Transmission measurements between 290 nm and 400 nm were taken using a spectrophotometer equipped with an integrating sphere (UV Transmittance Analyzer UV1000S, Labsphere, North Sutton, US). The calculations used the following Eq. (1) for UPF:

$$\mathrm{UPF} = \frac{\sum_{290}^{400} E_\lambda B_\lambda}{\sum_{290}^{400} E_\lambda B_\lambda / \mathrm{MPF}_\lambda} \quad (1)$$

where $E_\lambda$ is the spectral irradiance of terrestrial sun light, $B_\lambda$ is the erythemal effectiveness and $\mathrm{MPF}_\lambda$ is the mean monochromatic protection factor (Robson and Diffey, 1990; Hoffmann et al., 2001; Couteau et al., 2007). This is the CEN-EN 137-58-1 method.

In the same way, we determined UPF–UVA according to the following equation:

$$UPF - UVA = \frac{\sum_{320}^{400} E_\lambda B_\lambda}{\sum_{320}^{400} E_\lambda B_\lambda / \mathrm{MPF}_\lambda} \quad (2)$$

## 3. Results and discussion

We determined that natural fibers provide broad protection against the entire UV spectrum since the critical wavelength remains near 390 nm (Fig. 1). Also, the thickness of the fabric plays an important role (Fig. 2). Extreme UPF and UPF–UVA values were obtained, respectively, for a silk scarf (UPF = 5.28 ± 0.34; UPF–UVA = 5.21 ± 0.30) and a leather vest as well as for a pair of denim jeans (UPF > 500; UPF–UVA > 500). Denim is considered highly sun protective and our results agree with the literature (Kullavanijaya and Lim, 2005). Color is also an important factor (Fig. 3). For the same article of clothing, the darker the color, the higher the level of sun protection. For the same color and the same material, it is important to consider the weave of the fabric. This type of difference explained the variations between a T-shirt and a shirt (Table 1). This explains why tests on cotton, for example,

**Table 1**
Influence of weave on sun protection factor.

| Type of clothing | Brand | Fabric | Color | Thickness (mm) | UPF ± SD | UPF-UVA ± SD | $\lambda_c$ (nm) |
|---|---|---|---|---|---|---|---|
| Shirt | Pierre Cardin | Cotton (100%) | White | 0.450 | 79.55 ± 7.01 | 103.59 ± 11.14 | 389 |
| T-shirt | Tex | Cotton (100%) | White | 0.515 | 22.52 ± 1.08 | 25.86 ± 1.34 | 390 |

**Table 2**
Results obtained with synthetic fabrics.

| Type of clothing | Brand | Type of fabric | Color | Thickness (mm) | UPF ± SD | PF-UVA ± SD | $\lambda_c$ (nm) |
|---|---|---|---|---|---|---|---|
| Tights | Dim | 100% polyamide | Pepper | 0.205 | 2.39 ± 0.11 | 2.08 ± 0.08 | 389 |
| Tights | Dim | 100% polyamide | Black | 0.250 | 8.25 ± 1.20 | 8.09 ± 1.15 | 389 |
| Tights | Dim | 100% polyamide | Squirrel | 0.300 | 3.69 ± 0.14 | 2.92 ± 0.11 | 389 |
| Tights | DIM | 100% polyamide | Amber | 0.280 | 2.88 ± 0.13 | 2.54 ± 0.11 | 390 |
| T-shirt | Aigle | 100% polyamide | Gray | 0.270 | 131.22 ± 6.58 | 104.03 ± 5.28 | 389 |
| Trousers | C and A | 100% polyamide | Gray | 0.360 | 485.80 ± 28.40 | 463.19 ± 72.33 | 389 |
| Skirt | Patrice Bréal | 100% viscose | Red | 0.445 | 26.81 ± 2.44 | 25.84 ± 2.24 | 389 |
| Scarf | Bella mar | 100% polyester | Beige | 0.191 | 9.02 ± 0.36 | 5.39 ± 0.16 | 386 |
| Scarf | Asgold as 519 | 100% polyester | Black | 0.266 | 205.94 ± 26.50 | 194.02 ± 26.66 | 390 |

result in a wide variety of values that can range between 4 (Davis et al., 1997) and 20 (Gamblicher et al., 2000).

The efficacy provided by synthetic fabrics is also broad, but overall higher, with the same differences in terms of material, type of weave and color (Table 2). A dark polyamide fabric has a high sun protection factor.

Regardless of blended fabrics (cotton–elastane, polyester–spandex, elastane–viscose, viscose–polyamide–elastane, spandex–rayon–nylon) had high values (UPF > 500; UPF–UVA > 500), even more remarkable because the thickness is of the order of a millimeter.

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