Development of a Universal Sun Protection Factor

ABSTRACT
The sun protection factor, which is correlated to the short wavelength part of the UV radiation, is used to characterise the protective efficacy of sunscreens. But results of the last decades have shown that the long wavelength part of the sun radiation also represents a high health risk. The combination of tape stripping and optical spectroscopy was used to quantify the influence of sunscreens on the intensity of the radiation in the complete ultraviolet range. On the basis of the obtained ex vivo data, a Universal Sun Protection factor was calculated, which describes the amount of time for which it is possible to stay in the sun without any danger, taking into account the complete ultraviolet radiation, UVA and UVB.

INTRODUCTION
Sun radiation is the prerequisite for human life on earth with special importance for sufficient vitamin D maintenance. However, specific damages arise for the health if the intensity or length of the irradiation is exceeded (1). In correlation to different wavelength dependences of UV induced biological interactions, two parts of the ultraviolet (UV) sun radiation are distinguished, the UVA range (280-320 nm) and the UVB range (320 - 400 nm). The UVB radiation initiates the most evident effect arising after sun exposure, the sunburn (2). While other effects may not be as obvious, they can essentially be more dangerous. These include skin cancer (3, 4), immunosuppression (5), radical formation (6) as a source of critical DNA damage, as well as the aesthetic effect of skin ageing (7). Historically, sunscreens were mainly developed to protect against the UVB-correlated sunburn. The radiation-reducing UV filters as well as the determination of the sun protection factor (SPF) are concentrated on this range of the UV radiation (8). In agreement with the increasing knowledge about the UVA-induced risks of the sun, UVA filter substances are now often added to sunscreens, enhancing the protective efficacy in this wavelength range. To date, however, internationally accepted values quantifying the efficacy of sunscreens in the UVA and the UVB range do not exist, although different proposals have been made (9-11).

In this paper, the developed method defines a protection factor, which covers the complete UV range. The basis of this method is the combination of two well-established technologies of measurement: tape stripping and optical spectroscopy.

BASICS OF THE DEVELOPED METHOD
Tape stripping
Tape stripping transfers the stratum corneum layer by layer from one definite skin area to adhesive tapes, translocating not only the horny layer but also topically applied substances. These applied substances, such as sunscreens, are transferred without disturbing the distribution determined by the skin profile (12). This procedure results in a stack of strips, which contain all the information characterising the applied sunscreens used, e.g. the optical behaviour measured by UV / VIS spectra.

Optical spectroscopy
The efficacy of sunscreens depends directly on the absorption capacity of the included UV filters. Absorption / transmission spectra measured by optical spectroscopy principally reflect this behaviour. However, the direct measurement of the original products results in misleading data because the specific skin profile, determined by furrows and follicles, alters the optical behaviour in a characteristic manner. The UV spectra of the removed tape strips measured immediately after removal (13) reflect this specific distribution and are therefore best suited to quantify the absorption behaviour of sunscreens in close correlation to the in vivo situation (12).

Determination of the sum transmission
The determination of the spectra of all removed tape strips with a detectable filter content results in the sum transmission spectra after the cumulative addition illustrated in Figure 1. The upper curve belongs to the first tape strip removed from the skin. The curves beneath were obtained by adding the spectra of each of the following tape strips, until a constant value was reached. These calculated sum transmission spectra represent the absorption capacity of the applied sunscreens. The detailed protocol has been described previously (14).

Determination of the average sum transmission
The shaded areas under the lowest spectra (Figure 1) are the basis to characterise the efficacy of the
It is obvious that the UVA protection of sample A is very small corresponding to a high average UVA sum transmission = 43%. In contrast, the UVB protection is high with an average sum transmission value of 0.43. The corresponding values in sample C are found to be 6.7 % (UVA) and 2.3 (UVB), respectively. This sunscreen reduces the incident radiation in both wavelength ranges to a comparable degree.

At this stage of the methodical development, the quantitative data of the spectral behaviour of sunscreens in the different parts of the UV range are available but without any practical relevance for the consumers applying these products, necessitating the following advancement.

**THE UNIVERSAL SUN PROTECTION FACTOR**

**Calculation of the Universal Sun Protection Factor**

The average sum transmission values describe to what extent the incident radiation is lowered in the UVB, the UVA, but of special importance in the complete UV range as a result of sunscreen application. The values obtained for the UV range can be used to calculate a Universal Sun Protection Factor (USPF), which is determined by correlating the average transmission to the transmission value of the unprotected skin, set at 100 % (15).

The factor 100 % transmission divided by the spectroscopic average sum transmission value describes the reduced radiation intensity after sunscreen application, and thus the increased length of time that it is possible to stay in the sun without danger. This for example means that if the measured average sum transmission is reduced to 10 %, the time is enhanced by a factor of 10.

This calculation results in the proposed Universal Sun Protection Factor (Table 1), which provides information relevant to consumers, which is principally identical to the classical SPF, describing the length of time it is possible to stay in the sun without danger after sunscreen application. But this new factor is not restricted to the UVB-induced damages in contrast to the SPF, but rather valid for the complete UV range, including the UVA range.

**Comparison of the Universal Sun Protection Factor with the classical SPF**

In order to check the USPF data, a comparison with the classical SPF was done. The methods for determining both values are completely different: the SPF is correlated to the sunscreen behaviour in the different sunscreens describing the remaining intensity after sunscreen application. The numerical values of these areas divided by the length of the corresponding wavelength range (UVB = 80 nm, UVA = 40 nm and UV =120 nm) result in average sum transmission values. The obtained values numerically reflect the size of the remaining intensity averaged over the corresponding wavelength ranges. The calculated values are given in Table 1. With this transmission, a measured value is available that quantifies the differences in the protection in the UVA, the UVB, as well as in the complete UV range.

The importance of the values becomes clear by comparing the samples given in Figure 1.

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**Table 1. UVA, UVB, and UV behaviour; comparison of USPF and SPF for all investigated sunscreens**

<table>
<thead>
<tr>
<th>Sunscreen</th>
<th>Average sum-transmission UVA [%]</th>
<th>Average sum-transmission UVB [%]</th>
<th>Average sum-transmission UV [%]</th>
<th>SPF</th>
<th>USPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLIPA P2 (Figure A, Figure 1)</td>
<td>0.43</td>
<td>42</td>
<td>26</td>
<td>12.7</td>
<td>3.4</td>
</tr>
<tr>
<td>NIVEA sun Feuchtigkeits-Sonnenmilch® (Beiersdorf AG, Hamburg, Germany), SPF 20, earlier product, not any more produced</td>
<td>0.40</td>
<td>26</td>
<td>17</td>
<td>30</td>
<td>9.5</td>
</tr>
<tr>
<td>COLIPA P4</td>
<td>4.2</td>
<td>74</td>
<td>16</td>
<td>42</td>
<td>2.9</td>
</tr>
<tr>
<td>NIVEA sun Feuchtigkeits-Sonnenmilch® (Beiersdorf AG, Hamburg, Germany), SPF 20, actual product</td>
<td>2.5</td>
<td>18</td>
<td>26</td>
<td>15.5</td>
<td>7.9</td>
</tr>
<tr>
<td>NIVEA sun Feuchtigkeits-Sonnenmilch® (Beiersdorf AG, Hamburg, Germany), SPF 20, actual product</td>
<td>1.0</td>
<td>16</td>
<td>14</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>Table 1. UVA, UVB, and UV behaviour; comparison of USPF and SPF for all investigated sunscreens</td>
<td>3.1</td>
<td>26</td>
<td>16</td>
<td>12</td>
<td>5.9</td>
</tr>
</tbody>
</table>

**Figure 1. Ex vivo sum transmission spectra of three sunscreen samples**

(A) COLIPA P2 High SPF Standard (CTFA/JCIA Standard), SPF 12.7.
(B) NIVEA sun Feuchtigkeits-Sonnenmilch® (Beiersdorf AG, Hamburg, Germany), SPF 20, earlier product, not any more produced.
(C) NIVEA sun Pflegende Sonnenmilch® (Beiersdorf AG, Hamburg, Germany), SPF 20, actual product.

Data obtained by addition of the spectra measured for the individual tape strips taken from one skin area, with UVA and UVB ranges marked.

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UVB, determined by help of a biological response, the formation of an erythema, while the USPF describes the behaviour in the complete UV range objectively, and independently of any specific UV induced injury. In Table 1, the USPF and the SPF are shown together with the average sum transmission values for the investigated sunscreens, beginning with the lowest relative protection in the UVA, and leading up to the highest one. As expected, the largest differences between both factors occur if a low UVB transmission, corresponding to a large SPF value, is linked with a high transmission in the UVA. This is illustrated by the sunscreens at the top of the table. In the most obvious case, the SPF value related to the UVB range is found to be 60. Taking into account the protective ability of this sunscreen in the complete UV range as realized by the USPF the corresponding value is lowered to 6 (second line in Table 1). At the end of the table, the sunscreens with a relatively high UVA protection as typical examples for modern products are listed possessing a comparable degree of protection in the UVB and the UVA ranges. In this case, the SPF and the USPF are nearly identical, demonstrating that the described method for calculating USPF values is reasonable.

**EXPERIMENTAL SECTION**

The investigated sunscreens were commercial products or model emulsions described previously (15). Specific protocols must be taken into account during tape stripping and UV / VIS spectroscopic measurements in order to obtain correct data (for details see (14) and (15)). The tape strips (tesa film No.5529, Beiersdorf, Hamburg, Germany) were measured immediately after removal in order to avoid disturbances by diffusion processes to and inside the adhesive layer (13). The spectrometer (Lambda 5 (PerkinElmer, Frankfurt/Main, Germany) worked with an integrating sphere and an enlarged measuring area of 1 cm² in order to cover a larger area of the strips (14, 15).

**CONCLUSION**

A Universal Sun Protection Factor has been developed to quantify the efficacy of sunscreens for the sun radiation in the complete UV range, on the basis of tape stripping and optical spectroscopy. This USPF can be determined non-invasively and describes the protective ability of sunscreens in terms known to consumers, namely by giving the increased length of time that it is possible to stay in the sun subsequent to sunscreen application. Further investigations must be conducted to ensure a broad application.

**AKNOWLEDGEMENTS**

We would like to thank BASF AG, 67056 Ludwigshafen, Germany for financial support realizing parts of the investigations. Dr. Thomas Wünsch, Dr. Valerie André (BASF AG, 67056 Ludwigshafen, Germany) as well as Josepha Herrling, Maude Suisse de Sainte Claire, Virginie Bahaban, Fabienne Durat (Charité) who have contributed to the results by experimental support and discussions. We would like to thank the Foundation "Skin Physiology" of the Donor Association for German Science and Humanities for financial support.

**REFERENCES AND NOTES**