Application Note: 51463

Measuring the Sun Protection Factor (SPF) of Sunscreens

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Key Words

- DRA
- *in vitro* Measurements
- SPF
- Sunburn
- Sun Protection
- Sunscreen
- Transmission
- UV Protection
- UV-Visible

Introduction

Sun protection products, including sunscreen lotions, are designed to absorb or reflect the sun's UV radiation to protect the skin from damage. The rating system for sunscreens specifies a Sun Protection Factor (SPF) value, which can be thought of as a time factor for the protection of skin compared to exposure without any protection. For example, if a person would show visible erythema (sunburn) after five minutes of exposure, application of a sunscreen with SPF eight extends that time to five minutes times the protection factor of eight, or forty minutes. Scientific methods of evaluating the SPF of sunscreens have been developed and specified according to Australia/New Zealand (AS/NZ) standard 2604:1998. Other nations and regions have produced their own standards modeled after this original work, for example the COLIPA International Sun Protection Factor Test Method, most recently updated in 2006. These standards rely on diffuse transmittance measurements obtained using a UV-Visible spectrophotometer equipped with a diffuse reflectance accessory. This application note describes how sunscreen transmission measurements can be carried out using a Thermo Scientific Evolution™ 600 spectrophotometer, a Diffuse Reflectance Accessory (DRA-EV-600) with 0.008mm pathlength quartz demountable cell, and VISION*lite*™ (VL) MaterialsCalc software.

Background

Sunburn, skin cancers, premature skin aging and suppression of the immune system are all linked to exposure of skin to UV light. The UV spectrum lies between 200 nm and 400 nm and is commonly divided into three regions:

- UV-A: 320-400 nm
- UV-B: 280-320 nm
- UV-C: 200-280 nm

The highest energy region, UV-C, is absorbed completely by ozone in the stratosphere. Of the solar UV radiation reaching the earth's surface, 6% is in the UV-B region and 94% in the UV-A.

The potential of UV radiation to cause skin damage rises exponentially with decreasing wavelength. UV light at 280 nm is 1000 times more damaging than light at 340 nm, therefore, a sunscreen's ability to block UV-B is more important to prevent the negative effects of sun exposure. The international standard for quantifying the damaging effects of UV radiation on skin is the erythemal action spectrum, shown in Figure 1.[1]

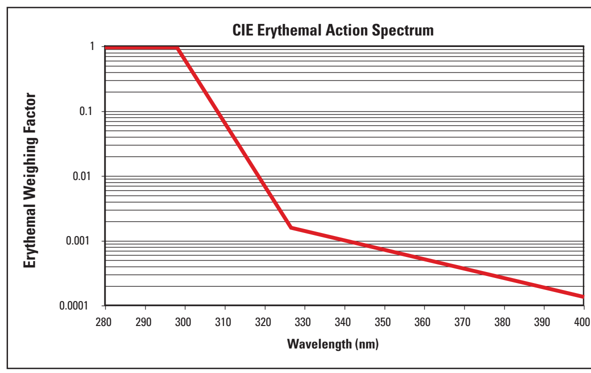

Figure 1

Calculations to determine UV protection factors as defined by the COLIPA standard and other regulatory agencies involve measurement of the percent transmission of a sunscreen lotion sample across the UV spectrum weighted by the erythemal weighting factors at different wavelengths. This particular method is convenient because the lotion can be measured directly in a short pathlength demountable cell without dilution or sample preparation. The tedious calculations for sunscreen ratings are automated in the VL MaterialsCalc software package. This software enables the user to acquire the transmission data and perform calculations automatically after data acquisition. Calculations can also be performed after the data has been acquired.

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Experimental Methods

To measure the sunscreen sample directly, an 8 µm quartz demountable cell is required. This short pathlength cell consists of two rectangular quartz pieces (Figure 2), one of which has an eight micron indentation etched into its surface. To load the demountable cell, a disposable plastic pipette was dipped into a well-mixed sample of the sunscreen and used to spread a thin layer of sunscreen along the center of the etched side. The cell was placed on a laboratory tissue on a solid surface. The other half of the cell was then placed on top of the loaded sample and pressed downward to fill the indentation completely with sunscreen. Excess sunscreen leaking out of the sides of the cell was wiped away, the tissues were replaced with fresh ones, and the squeeze and cleaning procedure was repeated until a uniform, bubble-free film was present in the center of the cell. When the film is correctly formed, no significant opacity due to sunscreen is present adjacent to the recessed area.

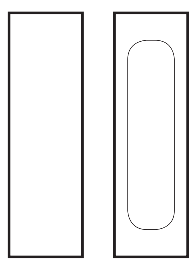

Figure 2: 8 µm quartz demountable cell for the direct analysis of sunscreen creams and lotions by transmission

The cuvette holder accessory and the spring-loaded demountable cell holder were placed at the transmission port of the DRA-EV-600 and a baseline scan recorded against the Spectralon® reference material placed at the reflectance port. Next, the demountable cell was carefully placed into the spring-loaded demountable cell holder and inserted into the cuvette holder accessory mounted at the transmission port of the DRA-EV-600 accessory. The *alignment mode* feature of the VL MaterialsCalc software was used to set the spectrophotometer to *white light* and visually verify the position of the sample by looking down into the reflectance port to view the beam coming up through the sample at the transmission port. Spectra of sunscreen samples were collected from 280 - 400 nm with the VL MaterialsCalc software. The software automates the determination of the following:

- COLIPA – Sun Protection Factor
- COLIPA – UVA Protection Factor
- AS/NZS 2604 – Maximum transmittance 320-360 nm
- AS/NZS 2604 – Near-UV Transmittance

Results

To demonstrate the analysis of sunscreen lotions, two different types of sunscreens samples were selected. Sample 1 is a physical sunscreen containing zinc oxide (10.0%) and titanium dioxide (5.0%). Physical sunscreens contain no organic chemicals as active ingredients and have been proven to have equal or better UVA and UVB protection properties in comparison to chemical sunscreens.[2, 3] Sample 2 is a chemical sunscreen containing zinc oxide (6.0%), octinoxate (7.5%), oxybenzone (3.0%) and octocrylene (2.0%). Both samples 1 and 2 have an SPF rating of 30+ and advertise broad-spectrum protection covering the UVA and UVB.

Absorption spectra of samples 1 and 2 are shown in Figure 3. Clearly, the chemical sunscreen (sample 2) offers better protection in both the UVA and UVB. Calculated SPF values are shown in table 1. *In vitro* methods of analysis often produce very high SPF values on chemical sunscreens compared to *in vivo* measurements.[4] Physical sunscreens generally have *in vitro* SPF measurements closer to their advertised values.

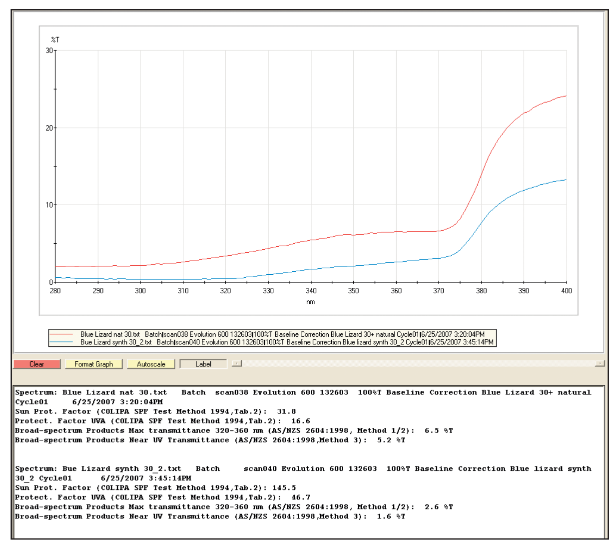

Figure 3: VISION*lite* MaterialsCalc data of test sunscreens

The AS/NZ standard specifies a standard test for broad-spectrum protection. To be classified as a broad spectrum protection product, the sunscreen "shall have a tested protection factor of not less than 4" and "the product shall not transmit more than 10% of radiation at any wavelength from 320 nm to 360 nm inclusive."[5] According to the AS/NZ standard, the tested protection factor is determined using human subjects and cannot be determined using a UV-Visible spectrophotometer.

Both sunscreens are labeled as having a 30+ protection factor, satisfying the first requirement for broad spectrum protection. As shown in Table 1, the maximum transmission between 320 and 360 nm for both samples is less than 10%, verifying that both products offer broad spectrum protection.

	Sample 1	Sample 2
COLIPA SPF	31.8	145.5
COLIPA UVA Protection Factor	16.6	46.7
Maximum Transmittance 320-360 nm (AS/NZS 2604:1998)	6.5%	2.6%
Near-UV Transmittance (AS/NZS 2604:1998)	5.2%	1.6%

Table 1: Calculated parameters for sunscreen samples from VISION*lite* MaterialsCalc software

Another characteristic for sunscreens defined in the AS/NZS 2064 standard is the near-UV transmission. The standard requires a transmission less than 1.0% in the near-UV to advertise the product as having near-UV protection. As indicated in Table 1, both sunscreens do not offer near-UV protection as they have transmission above 1.0%.

Conclusion

Data for determining sun protection factors and broad spectrum protection classification of sunscreens can be obtained using an Evolution 600 spectrophotometer equipped with a Diffuse Reflectance Accessory (DRA-EV-600) accessory. VISION*lite* MaterialsCalc software automatically performs calculations using pre-programmed methods for international standards (COLIPA and AS/NZS 2604) and determines the values of SPF, broad spectrum compliance and near UV compliance. Of the two sunscreens tested, both are labeled as having a SPF value of 30+, the highest claim allowed under AS/NZS 2604. Both were in compliance with the claims on the label but, in this *in vitro* test, the chemical-based sunscreen was far more effective at absorbing UV radiation than the physical-based product.

References

1. CIE (International Commission on Illumination) Research Note 1987, A reference action spectrum for ultraviolet induced erythema in human skin, *CIE J.* 6, pp. 1722. Also contained in Joint ISO/CIE Standard ISO 17166:1999/CIE S007-1998.
2. Van Der Molen, RG; Hurks, HMH; Out-Luiting, C; Spies, F; Van't Noordende, JM; Koerten, HK; Mommaas, AM. Efficacy of micronized titanium dioxide-containing compounds in protection against UVB-induced immunosuppression in humans in vivo. *J. Photochem. Photobiol. B* **1998** *44*, 2, 143-150.
3. Wolf, P; Donawho, CK; Kripke, ML. Effect of sunscreens on UV radiation-induced enhancement of melanoma growth in mice. *J. Natl. Cancer Inst.* **1994**, *86*, 2, 99-105.
4. Sheu, MT; Lin, CW; Huang, MC; Shen, CH; Ho, HO. Correlation of In Vivo and In Vitro Measurements of Sun Protection Factor. *Journal of Food and Drug Analysis* **2003**, *11(2)*, p128–132.
5. AS/NZ standard 2604:1998, *Sunscreen Products Evaluation and Classification*, available from SAI Global.

Ordering Information

The following is the recommended Thermo Scientific UV-Visible system for sunscreen analysis:

Description	Part Number
Evolution 600 PC Controlled Spectrophotometer	10600501
DRA-EV-600 Diffuse Reflectance Accessory	222-219000
VISION*lite* MaterialsCalc Software	869-124500
8 mm Quartz Demountable Cell	268-813400
Cuvette Holder for DRA-EV-600	222-222900
Cell Holder for Short Path Length Cells and Demountable Cell	268-823500

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