

Noninvasive *In-Vivo* Determination of Sunscreen-UVA Protection Factors**Introduction**

The development and evaluation of UVA (320–400 nm) sunscreens is important because UVA sunlight can penetrate deep into human skin and cause severe internal damage, besides erythema and photoaging. Human phototesting is usually used for determining the sunscreen protection factor (SPF), which is defined as the ability of a sunscreen to prevent a threshold erythema from solar radiation. The SPF definition is now considered as the tentative final FDA standard for measuring SPF. The SPF measured with this method, however, results primarily from UVB (280–320 nm) and not from UVA. Phototesting has proven unsuitable for the evaluation of UVA protection factors (PFA) because of the extremely long exposure time necessary to generate erythema from UVA radiation and the concerns of reciprocity. Recently, several *in vivo* and *in vitro* methods using animals have been proposed. However, none of the methods is capable of measuring the efficacy of UVA sunscreens *in vivo* on human skin.

The SPEX® SKINSCAN®, however, can be used for noninvasive *in-vivo* determination of sunscreen UVA protection factors (PFA) via diffuse-reflectance spectroscopy. This fiber-optic-based fluorometer is specifically designed for the measurement of cutaneous fluorescence and reflectance. The SKINSCAN® is composed of double grating monochromators for both excitation and emission. Because of the extremely low level of stray light that these monochromators allow, SKINSCAN® is capable of measuring highly scattering samples, such as human skin, with excellent sensitivity and precision. Diffuse-reflectance spectra of human skin both with sunscreen and without can be directly measured *in vivo* and differentiated within minutes using the SKINSCAN®. The ratio of spectra with and without sunscreen results in transmittance spectra of sunscreens, which allows the calculation of PFA values. This non-invasive method provides an alternative diagnostic tool for quick and accurate determination of PFA of sunscreen products.

Experimental

The diffuse-reflectance (DR) spectra with sunscreen and without sunscreen were measured by synchronously scanning both excitation and emission monochromators at the same wavelength. First, the light from a xenon lamp was passed through a double-grating monochromator and then was focused into one arm of a randomized, bifurcated fiber-optic bundle. This light then was transmitted to the common end of the fiber to irradiate the skin. The backscattered light was collected by the emission fiber, passed through another double-grating monochromator, and finally went to the photomultiplier-tube detector.

A 5-cm × 5-cm area on the arm was initially marked and checked under a Wood's lamp (UV light). DR spectra without the sunscreen product were measured on at least four different spots. The same area was then applied with 50 mg of product (2 mg cm⁻²) and viewed by a Wood's lamp for uniformity of the coverage. After air-drying for 20 minutes, the DR spectra were measured again at the same spots. The average of four spectra for each measurement was used to calculate the PFA values. The active ingredients in the sunscreens were oxybenzone and Parsol.

Results and Conclusions

The PFA value of a sunscreen product is defined in the following equation:¹

$$\text{PFA} = \frac{\sum_{320 \text{ nm}}^{400 \text{ nm}} S(\lambda) A(\lambda)}{\sum_{320 \text{ nm}}^{400 \text{ nm}} S(\lambda) A(\lambda) T(\lambda)}$$

where $S(\lambda)$ is the source spectrum,² $A(\lambda)$ is the reference action spectrum³ for ultraviolet-induced erythema in human skin, and $T(\lambda)$ is the calculated transmittance spectrum of the sunscreen product obtained on human *in vivo*. The function $T(\lambda)$ can be found using

$$T(\lambda) = \sqrt{\frac{I_{\text{with}}(\lambda)}{I_{\text{without}}(\lambda)}}$$

where the $I_{\text{with}}(\lambda)$ and $I_{\text{without}}(\lambda)$ are the re-emitted intensities at wavelength λ from the skin, with and without sunscreen product, respectively. A software program was specially developed to calculate the PFA values from these parameters.

The typical transmittance spectra of sunscreen products are shown in Figure 1.

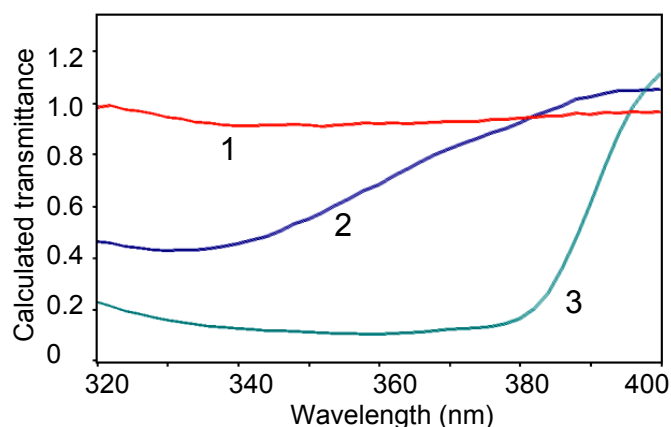


Figure 1. Sunscreen transmittance spectra for human skin: (1) with vehicle, but no active ingredient; (2) with 1% oxybenzone; (3) with 1% Parsol.

Table 1 summarizes the PFA values calculated for three sunscreen products.¹ The Table also lists the PFA values reported by the manufacturers via the phototesting method.³ The calculated PFA values through DR method show good agreement with the stated values for all three products. The discrepancies at the higher PFA arise from the inverse relation of the measured transmittance to the calculated SPF value. The accuracy of PFA values can be improved for high-PFA products by using thinner films and correcting for the standard film thickness.⁴

Sunscreen	PFA (by DR)	PFA (by manufacturer)
Shade 15	3.1	2.9
Shade 45	4.5	5.3
Photoplex	6.5	8.3

Table 1. PFAs for several sunscreens measured by DR compared to values reported by the manufacturers

¹ Kollias, N.; Gillies, R.; Anderson, R.R. In *Biological Responses to UVA Radiation*; Urbach, F., Ed.; Valdenmar Publishing: Overland Park, KS, 1992; p 371.

² Sayre, R.M.; Agin, P.P. *J. Am. Acad. Dermatol.* **1984**, *23*, 429.

³ McKinlay, A.F.; Diffey, B. L. *CIE Journal* **1987**, *6*, 17.

⁴ Gillies, R., Kollias, N. In *Sunscreens—Development, Evaluation, and Regulatory Aspects*; Marcel Dekker; Vol. 10; pp 601–610.

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