



APPLICATION NOTE

Materials Characterization: UV/Vis/NIR Spectroscopy

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A Spectroscopic *In Vitro* Method for the Calculation of Sunscreen SPF Values

Introduction

The sun produces ultraviolet (UV) A and ultraviolet B rays that reach the Earth, which are part of an electromagnetic spectrum. UVA ray wavelengths range from 400 nanometers to 320 nanometers, while UVB rays range from 320 nanometers to 290 nanometers. UVA can penetrate both the upper layer of skin, the epidermis, as well as the lower layer of skin, the dermis. It is most often responsible for damaging keratinocytes in the epidermis, where skin cancer is typically

found. UVB, although it does not penetrate the dermis, is more intense because of its shorter wavelengths. However, both can be extremely harmful to humans, as they can cause sunburns, skin cancer, and other skin damage. In order to prevent these problems from happening, sunscreen use is recommended. Sunscreen protects skin by either absorbing or reflecting the harmful ultraviolet rays, preventing them from reaching the skin. Using sunscreen while exposed to the sun can greatly reduce the chances of damaging skin cells and developing cancer. For this study the PerkinElmer® LAMBDA™ 1050 equipped with a 150 mm integrating sphere will be used to collect scatter transmission data for sunscreen placed on a tape substrate. Testing sunscreen on a tape model of human skin to calculate the SPF value is more convenient and economical than testing on human skin.

Experimental

Different brands of surgical tape were measured (in transmission) to determine which brand was the best representation of human skin. Using surgical tape allows for sunscreen testing to be performed on a substitute for human skin, which is much safer than testing the product on actual skin. To measure the tape and pig skin in transmission, the samples had to be placed in the transmittance port, in front of the integrating sphere. Figure 1 displays the optical diagram of a 150 mm integrating sphere and shows where the samples were placed (transmittance port) for scatter transmission measurements.

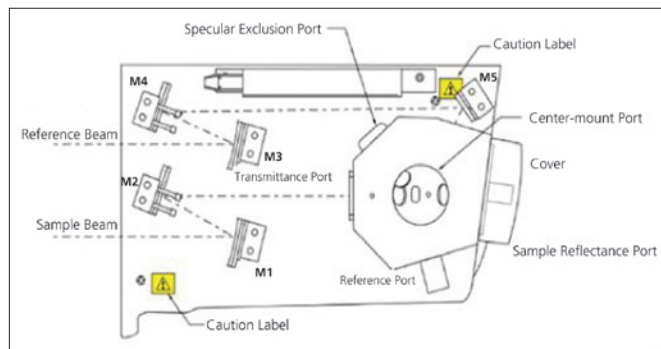


Figure 1. Optical diagram of the 150 mm integrating sphere.

Measuring a sample in transmission mode calculates how much light passes through the sample, and using that information, the amount of light absorbed in the sample can also be determined. Figure 2 demonstrates what happens to the beam of light after it passes through the sample as the sample is being scanned in the transmittance port.

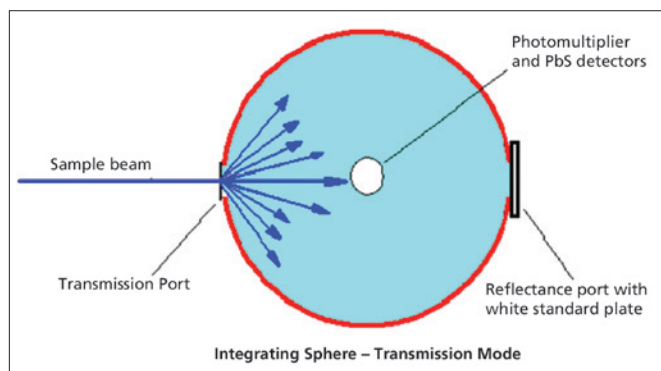


Figure 2. Sample lightpath for scatter transmission measurements with an integrating sphere.

Surgical tape, pig skin, and human skin are all hazy samples that scatter light. When the instrument beam passes through the sample, the integrating sphere collects the scattered light. In order to determine which brand of tape most accurately modeled human skin, the tape transmission spectra were compared against transmission measurements

of pig skin. Nexcare® Transpore Surgical tape matched the pig spectra the closest. Next, the tape was scanned again in transmission, with varying layers. The data showed that between two, three, and four layers of tape, two layers placed back to back represented the pig skin most closely. Figure 3 shows percent transmission spectra of the UVA and UVB regions of the spectrum.

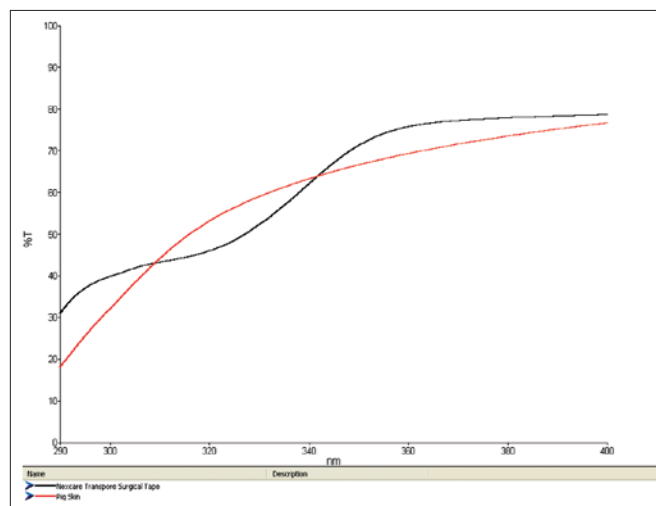


Figure 3. Scatter transmission spectral comparison of epidermis (porcine) with tape substrate (UVA + UVB).

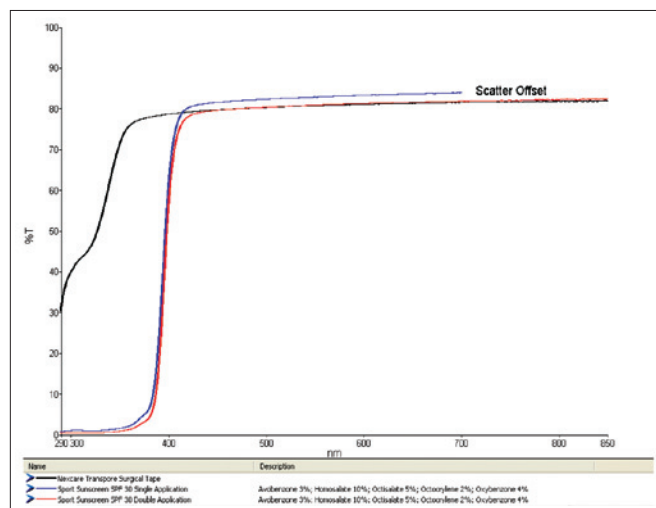


Figure 4. Scatter transmission spectra of tape substrate and tape with sunscreen applied.

Using the information of what kind of tape and how many layers of it most accurately modeled pig skin, various methods of applying sunscreen could be tested on the tape, rather than actual human skin. The methods tested were: coating sunscreen on the two layers of surgical tape using one's finger, and spraying the tape twice with the sunscreen. The sunblock used on the tape was Sport® Sunscreen SPF 30.

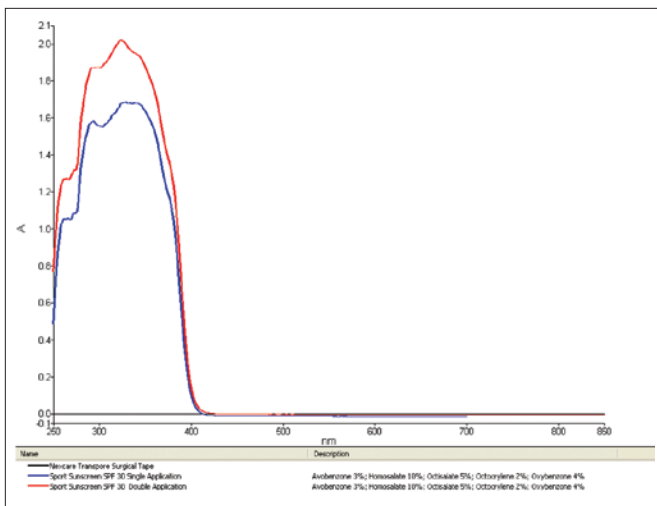


Figure 5. Absorbance conversion of scatter transmission spectra.

Figure 4 is the raw %T (percent transmission) measurement of two layers of Nexcare® Surgical Tape, the two layers of tape with a single application of sunscreen by smearing, and the two layers of tape sprayed twice with the same sunscreen. The spectra from 250 nm to 80 nm were measured to observe the scattering properties of the samples. The S shaped curve on the graph is due to the sunscreen on the samples. From there, several steps must be followed in order to calculate the SPF value of the sunscreen. Initially, the graph of the transmission measurements (see Figure 4) must be converted to absorbance (see Figure 5 for converted graph).

Next, the tape spectra must be subtracted from the tape plus sunscreen spectra. This subtraction will provide the sunscreen measurement by itself. The subtraction of the tape sample is why the black line on Figure 5 is flat and at zero. After the tape spectrum has been subtracted, the sunscreen spectrum must be converted back to %T. Dividing the %T spectrum by 100 will provide the transmittance of the spectra. %T is a number between zero and 100, and transmittance is a number between zero and 1.

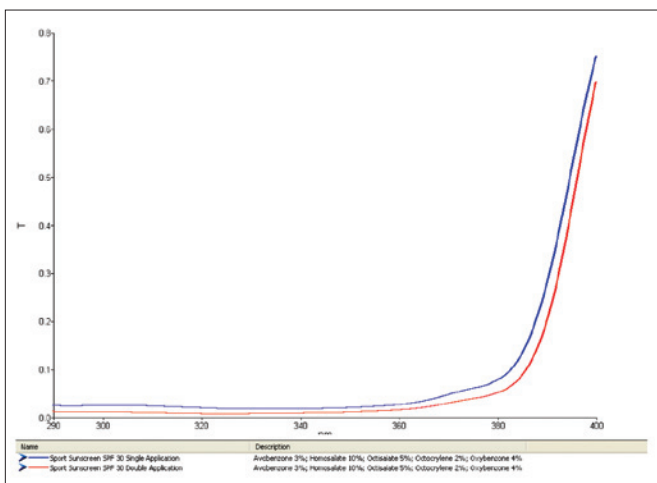


Figure 6. Tape/sunscreen spectra converted to transmittance for SPF calculation in spreadsheet.

Figure 6 displays the graph of the data in transmittance that are ready to be calculated for SPF value. Figure 7 shows the data values copied to an Excel® spreadsheet and the calculated SPF value. Only data between 400 and 290 nanometers, the UVA and UVB regions, are used for the SPF calculation.

Wavelength nm	T (from spectra)	SPF	Erythema action spectrum	UVA radiation source Wam Jem 1	E ₀	E ₀ /T ²
300	0.021894	45.6764265	8.55E-03	8.84E-02	4.54E-04	9.07E-05
314	0.021668	46.1110689	8.39E-03	8.47E-02	5.89E-04	1.26E-05
328	0.021375	46.79162373	8.25E-03	1.36E-01	7.52E-04	1.61E-05
342	0.020796	48.1219318	4.47E-03	2.07E-01	2.27E-04	3.19E-05
356	0.020397	49.02681767	3.90E-03	3.03E-01	1.09E-03	2.22E-05
370	0.020375	48.6797546	2.90E-03	4.29E-01	1.34E-03	2.58E-05
384	0.020297	49.51220961	2.32E-03	7.00E-01	1.77E-03	3.20E-05
398	0.020296	49.44880861	1.88E-03	8.85E-01	1.85E-03	3.76E-05
412	0.020269	49.31642508	1.51E-03	1.22E+00	1.84E-03	3.77E-05
426	0.020269	49.77648376	1.41E-03	1.67E+00	2.18E-03	4.27E-05
440	0.020266	49.77648376	1.36E-03	1.87E+00	2.47E-03	4.97E-05
454	0.020304	49.21179604	1.32E-03	2.13E+00	2.81E-03	5.73E-05
468	0.02021	49.2102915	1.27E-03	2.44E+00	3.11E-03	6.32E-05
482	0.020319	49.2102912	1.22E-03	2.82E+00	3.46E-03	7.02E-05
496	0.02021	49.46714682	1.18E-03	3.19E+00	3.76E-03	7.65E-05
510	0.02043	48.94762604	9.66E-04	3.61E+00	4.42E-03	1.16E-04
524	0.02036	4.756279406	1.84E-04	2.07E+00	3.70E-04	7.78E-05
538	0.240637	4.11659585	1.78E-04	1.64E+00	1.52E-04	7.00E-05
552	0.280132	3.68704891	1.72E-04	1.31E+00	1.28E-04	6.31E-05
566	0.321493	3.111098248	1.68E-04	1.02E+00	1.71E-04	3.48E-05
580	0.368656	2.726202629	1.65E-04	7.90E-01	1.27E-04	4.54E-05
594	0.41539	2.407976261	1.65E-04	6.99E-01	8.28E-05	8.88E-05
608	0.468129	2.145420921	1.60E-04	4.48E-01	6.68E-05	1.18E-05
622	0.518395	1.920309911	1.58E-04	3.20E-01	4.71E-05	2.44E-05
636	0.569993	1.756107511	1.60E-04	2.38E-01	3.21E-05	1.81E-05
650	0.620487	1.611873611	1.59E-04	1.80E-01	2.18E-05	1.32E-05
664	0.668268	1.496405884	1.60E-04	1.04E-01	1.38E-05	9.10E-06
678	0.712403	1.407918482	1.59E-04	4.88E-02	8.05E-06	4.58E-06
692	0.752828	1.327373723	1.62E-04	8.47E-02	4.63E-06	2.74E-06
SUM					2.49E-01	8.07E-03
SPF Value						30.84

Figure 7. Example spreadsheet of SPF calculation.

Mathematically, the SPF is calculated from measured data as:

Equation 1

$$SPF = \frac{\int A(\lambda)E(\lambda)d\lambda}{\int A(\lambda)E(\lambda)/MPF(\lambda)d\lambda}$$

In this equation, $d(\lambda) = 1 \text{ nm}$, $A(\lambda)$ stands for the Erythema Action Spectrum, $E(\lambda)$ represents the sun's radiation power, and $MPF(\lambda)$ stands for how much light is absorbed and the ability of skin cells to be damaged. MPF is the inverse of the transmission ($1/T$) at a given wavelength.

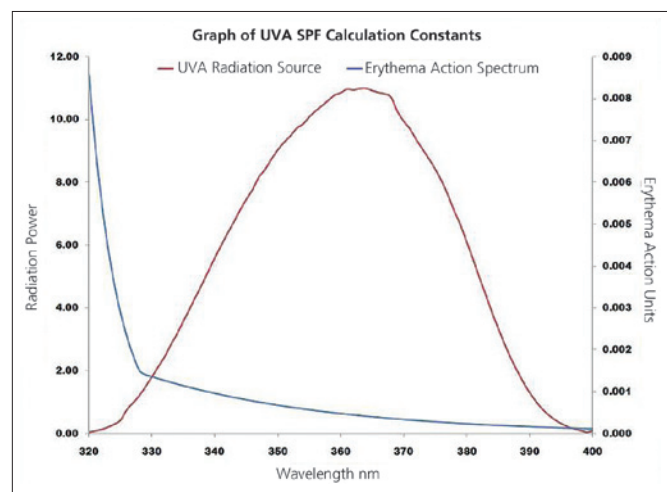


Figure 8. Wavelength dependent constants for the calculation of SPF values.

Figure 8 shows a wavelength dependent function for the SPF constants: radiation power and action units ($E \times A$). The dotted green line represents the radiation power of the sun at different wavelengths of light. As one can see from the graph, the radiation power from the sun is most intense between 350 and 370 nanometers. In the equation E multiplied by A , E stands for the sun's radiation power. A stands for the Erythema Action Spectrum, and the units for that are on the right hand side of the graph. The black line shows E and A multiplied together, and it represents how much light is absorbed in the skin and the ability of skin cells to be damaged by radiation from the sun.

Results

The Transpore tape substrate was very successful in representing human skin, as the calculation for the SPF value was the same as what was published on the Sport® Sunscreen container. Figure 3 demonstrates how the Transpore tape is similar to pig skin, and pig skin has similar properties to human skin.

Table 1. Calculated values for 30 SPF spray Sport® Sunscreen.

	SPF UVA	SPF UVA + UVB
One Application	30.84	39.07
Two Applications	50.1	80.76

The Sport Sunscreen contained five different sunscreens and had a reported SPF value of 30. The sunscreen had 3% Avobenzone (blocks the UVA region), 10% Homosalate (blocks the UVB region), 5% Octisalate (blocks the UVB region), 2% Octocrylene (blocks the UVB region), and 4% Oxybenzone (blocks both the UVA and UVB regions). The mixture of UVA and UVB sunblocks covers the 400 nm – 290 nm region. Figure 5 shows the effect of sunscreens in that region, compared to the entire spectrum.

In this experiment, the single application on the tape substrate, when calculated, produced an SPF of 30.84 (only for UVA, which is the calculation approved by the FDA). The SPF value almost doubles for two applications of the sunscreen, because the concentration of sunscreen is doubled on the tape. The SPF for UVA+UVB also increases for both one and two applications, because the sunscreen is blocking more of the electromagnetic spectrum, and therefore, protecting skin from harmful UV rays.

Conclusion

The experiment to create a substrate for human skin using surgical tape was successful and different sunscreens could be tested on the substrate rather than actual human skin. The LAMBDA 1050/150 mm integrating sphere spectrophotometer combination provides an excellent platform for the transmission measurement of SPF values for sunscreen active ingredients for both research and quality control.