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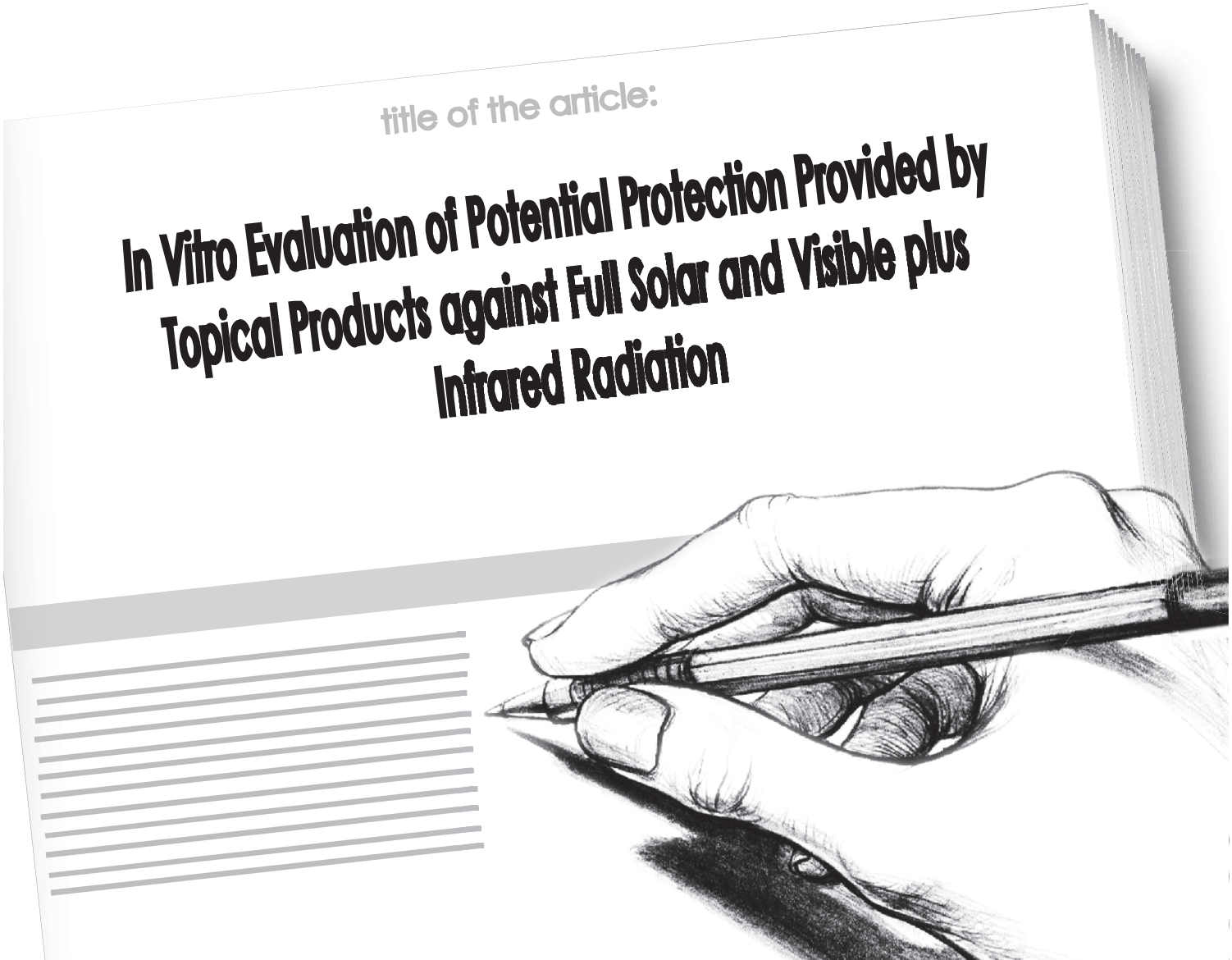

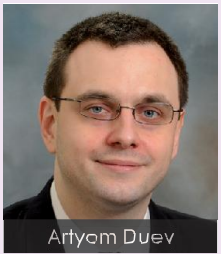

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In Vitro Evaluation of Potential Protection Provided by Topical Products against Full Solar and Visible plus Infrared Radiation

KEYWORDS: sun, VIS, IR, IR-A, protection; *in vitro*, evaluation, expanded protection wavelength (EPW)

Abstract Visible (VIS) and infrared (IR) portions of the solar spectrum are increasingly recognized as contributors to skin damage from sun exposure. In vitro testing methodologies were developed to qualitatively and semi-quantitatively rank protective properties of finished goods products against full solar, or VIS plus IR radiation. These methodologies utilize HD6 polymethylmethacrylate plates; simulated sunlight source with mirrors and cut-off filters to produce full solar or VIS plus IR irradiation - in conjunction with pyranometer; and monochromator-based spectrophotometer with wavelength range extending to 1100 nm. An expanded protection wavelength (EPW) definition and metric are proposed to measure the breadth of the protection of topical products against UV, VIS and partial IR-A irradiation range of the solar spectrum. EPW metric could be enhanced when the action spectra of photodamage, oxidative damage and photoageing caused by VIS and IR irradiation in the skin are more researched and become available.

INTRODUCTION

Natural sun light at Earth surface has different amounts of Ultraviolet (UV, 290-400 nm) ~ 7%, Visible (VIS, 400~780 nm) ~ 55%, and Infrared (IR, >780 nm) ~40 %radiation (1). There are no precise limits for the spectral range of VIS since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer (2).
IR radiation is composed of the wavelengths that are longer than those for VIS, from about 780 nm to 1 mm. For IR, the range between about 780 nm and 1 mm is subdivided into: IR-A: 780 nm to 1400 nm, IR-B: 1400 nm to 3000 nm; and IR-C: 3000 nm to 1 mm (3).
For many years sun care research has focused primarily on the damaging effects of UV radiation on skin. However, more than 90% of total solar radiation to which individuals are exposed is in the VIS plus IR range, and it is plausible that it could contribute to various biological effects on human skin. While sunlight-induced skin erythema is an indication that UV damage with both acute and potentially long-term effects has occurred, the prevention of erythema does not guarantee the absence of long-term skin damage, for example photoaging. Our understanding of the impact of solar irradiation on the skin is constantly evolving. According to Shaath, a review of sun care innovations of the past half century reveals discoveries and developments that have changed our relationship to the sun (4).
Recently VIS and IR parts of the sun spectrum started to receive more attention concerning their potential contribution to skin damage. Bassel *et al.* and Schroeder *et al.* pointed out that the radiation in the VIS and IR ranges should be taken into account because it is absorbed by the human skin (5, 6). Cho *et al.* indicated that in addition to UV radiation, VIS, IR plus heat energy generated by sunlight exposure induce MMP-1 expression in human skin. In addition, IR plus VIS also increased MMP-9 expression and decreased type 1 procollagen synthesis after exposure to natural sunlight (7). Kamath and Ruetsch found that skin photodamage can be caused by full spectrum solar radiation in the VIS range and involves free-radical mechanisms; free radicals are generated by the interaction of radiation with the substrate and diffuse into the subsurface region causing damage (8). Zastrow *et al.* demonstrated that the free radical formation is occurring in epidermis and dermis at UV, VIS and near-IR wavelengths; and fifty percent of the total skin oxidative burden was generated by VIS light. The formation of excess free radicals induced by near-IR radiation was also evidenced (9,10). Cho *et al.* emphasized that in addition to sunscreens that block the effects of UV radiation, novel strategies to prevent VIS, IR- and heat induced skin aging need to be developed (11). It is well-known that certain particulate materials (for example iron oxides, titanium dioxide, zinc oxide, boron nitride, bismuth oxychloride, silica, nylon, composite powders, e.g. containing fine-grained zirconium oxide adhered to the surface of spherical nylon powder; spherical cross-linked polystyrene powder coated with boron nitride) absorb and/or scatter in various wavelength ranges. Recently silicon microspheres were also recommended as good candidates for developing filters effective against IR, VIS and UV radiation. These high refractive materials represent a new generation of solar filters that are chemically inert, able to absorb UV and VIS rays, and strongly scatter IR radiation (12). In order to better protect people from full spectrum solar

radiation, novel multifunctional sunscreen products capable to provide expanded protection against full solar spectrum, including UV, VIS and IR are needed. To achieve this goal product developers have to use sunscreen actives in conjunction with other functional ingredients and particulate materials, in parallel with establishment of relevant testing methodologies.

Presently there are no readily available *in vitro* test methods for determining the potential protection provided by topical products against full solar, VIS and IR radiation.

The authors report here the development of *in vitro* testing methodologies to qualitatively and semi-quantitatively rank protective properties of various finished goods products against full solar or VIS plus IR radiation. These methodologies utilize PMMA (polymethylmethacrylate). HD6 plates with controlled roughness; simulated sunlight source with mirrors and cut-off filters producing full solar or VIS plus IR irradiation in conjunction with pyranometer; and monochromator-based spectrophotometer with wavelength range extending to 1100 nm. In addition, an expanded protection wavelength (EPW) definition and metric are proposed to measure the breadth of the protection of topical products against UV, VIS and partial IR-A irradiation range of the solar spectrum (from 290 to1100 nm).

TEST ARTICLES

Eight commercially available branded finished goods products (BB, CC and sunscreen creams and lotions) were randomly selected, purchased in US stores in 2013, and subsequently tested for their protective properties against full solar or VIS plus IR radiation using testing methodologies described below. All test articles have quoted SPF values in the range 15-30, and broad spectrum protection.

#1: Broad Spectrum SPF 30; Sunscreen Actives: Avobenzone 2.7%, Homosalate 8%, Octisalate 5%, Octocrylene 3.5%, Oxybenzone 4%; **Inactive Ingredients:** Water, Dimethicone, Potassium Cetyl Phosphate, Benzyl Alcohol, Diethylhexyl 2, 6-Napthalate, Caprylyl Glycol, Silica, Cetyl Dimenthicone, Beeswax, PPG-12/SMDI Copolymer, Ethyhexylglycerin, Dimethicone/PEG-10/15 Crosspolymer, Trisiloxane, Ethylhexyl Stearate, Behenyl Alcohol, Sodium Polyacrylate, Trideceth-6, Disodium EDTA, Glyceryl Stearate, Peg-100 Stearate, Xanthan Gum, Chlorphenesin, Fragrance.

 # 2: BB Cream Illuminator. Broad Spectrum SPF 15; **Sunscreen Actives:** Octinoxate 4%, Titanium Dioxide 3.6%; **Inactive Ingredients:** Water, Isononyl Isononanoate, Isohexadecane, Glycerin, Alcohol Denat.,PEG-20 Methyl Glucose Sesquistearate, Methyl Glucose Sesquistearate, Cetyl Palmitate,Nylon-12,Cyclohexasiloxane,Propylene Glycol, Hydrogenated Polyisobutene, Stearyl Alcohol, Magnesium Aluminum Silicate, Phenoxyethanol, Caprylyl Glycol, Lithium Magnesium Sodium Silicate, Ethylhexyl Hydroxystearate, Disodium EDTA, Linalool, Benzyl Salicylate,Limonene,Niacinamide,Triethanolamine,Caffeine,Tocopheryl Acetate, Ascorbyl Glucoside, Oxothiazolidinecarboxylic Acid, Benzyl Alcohol, Geraniol, Cellulose Acetate Butyrate, Polyphosphorylcholine Glycol Acrylate, Citral, Ammonium Polyacryloydimethyl Taurate, Castanea Sativa (Chestnut) Seed Extract, Polyvinyl Alcohol, Sodium Chloride, Butylene Glycol, Sodium Hyaluronate, Fragrance, Iron Oxides, Bismuth Oxychloride.

 # 3: BB Cream for Fair/Light, Broad Spectrum SPF 15; Sunscreen Actives: Octinoxate 4%, Titanium Dioxide 2.1%; **Inactive Ingredients:** Water, Isononyl Isononanoate, Isohexadecane, Glycerin, Alcohol Denat., PEG 20 Methyl Glucose Sesquistearate, Cetyl Palmitate, Nylon 12, Cyclohexasiloxane, Propylene Glycol, Hydrogenated Polyisobutene, Stearyl Alcohol, Magnesium Aluminum Silicate, Phenoxyethanol, Fragrance, Caprylyl Glycol, Lithium Magnesium Sodium Silicate, Disodium EDTA, Linalool, Benzyl Salicylate, Limonene, Caffeine, Ascorbyl Glucoside, Benzyl Alcohol, Geraniol, Cellulose Acetate Butyrate, Polyphosphorylcholine Glycol Acrylate, Citral, Ammonium Polyacryloyldiethyl Taurate, Polyvinyl Alcohol, Sodium Chloride, Butylene Glycol, Sodium Hyaluronate, Methyl Glucose Sesquistearate, Iron Oxides, Titanium Dioxide

 # 4: BB Cream for Light/Medium, Broad Spectrum SPF 20; **Sunscreen Actives:** Octinoxate 3%, Titanium Dioxide 4.7%; **Iactive Ingredients:** Water, Isononyl Isononanoate, Isohexadecane, Glycerin, Alcohol Denat., Peg-20 Methyl Glucose Sesquistearate, Methyl Glucose Sesquistearate, Cetyl Palmitate, Nylon-12, Cyclohexasiloxane, Propylene Glycol, Hydrogenated Polyisobutene, Stearyl Alcohol, Magnesium Aluminum Silicate, Phenoxyethanol, Caprylyl Glycol, Lithium Magnesium Sodium Silicate, Disodium EDTA, Linalool, Benzyl Salicylate, Limonene, Caffeine, Ascorbyl Glucoside, Benzyl Alcohol, Geraniol, Cellulose Acetate Butyrate, Polyphosphorylcholine Glycol Acrylate, Citral, Ammonium Polyacryloyldimethyl Taurate, Polyvinyl Alcohol, Sodium Chloride, Butylene Glycol, Sodium Hyaluronate, Fragrance; Titanium Dioxide, Iron Oxides.

 # 5: CC Cream, Broad Spectrum SPF 15; Sunscreen Actives: Avobenzone 2%, Octisalate 3%, Octocrylene 3%, **Inactive Ingredients:** Water, Glycerin, Titanium Dioxide, Niacinamide, Acetyl Glucosamine, Isopropyl Lauroyl Sarcosinate, Panthenol, Tocopheryl Acetate, Dimethicone, Dimethiconol, Triethanolamine, Benzyl Alcohol, Carbomer, Behenyl Alcohol, C13-14 Isoparaffin, Cetearyl Glucoside, Stearyl Alcohol, Laureth-7, Cetyl Alcohol, PEG-100 Stearate, Methylparaben, Cetearyl Alcohol, Propylparaben, Ethylparaben, PEG-4 Laurate, PEG-4 Dilaurate, Iodopropynyl Butylcarbamate, PEG-4, Ammonium Polyacrylate, Polyacrylamide, Iron Oxides.

 # 6: CC Cream, Broad Spectrum SPF 20. Sunscreen Actives: Titanium Dioxide 7.5%, Zinc Oxide 2%; **Inactive Ingredients:** Aqua, Dimethicone, Isodecane, Trisiloxane, Butylene Glycol, PEG/PPG-19/19 Dimethicone, Nylon 12, C16-13 Isoparafin, Cetyl PEG/PPG-10/1 Dimethicone, HDI/Trinethylol Hexyllactone Crosspolymer, Phenyl Trimethicone, Sodium Chloride, Glycerin, Isodecyl Neopentanoate, Prunus Amygdalus Dulcis (Sweet Almond) Seed Extract, Hydrolyzed Rice Protein, Macrocystis Pyrifera Extract, Nerrocystis Leukeana Extract, Laminaria Japonica Extract, Tocopheryl Acetate, Tocopherol, Maltodexrin, Saccharomyces Magnesium Ferment, Saccharomyces Potassium Ferment, Cucumis Sativus (Cucumber) Fruit Extract, Aloe Barbadensis Leaf Extract, Camellia Sinensis (Green Tea) Leaf Extract, Pisum Sativum (Pea) Extract, Oligopeptide-24, Palmitoyl Tripeptide-5, Hydrogenated Lecithin, Sodium Hyaluronate, Trimethylsiloxysilicate, Alumina, Tribehenin, Disteardimonium Hectorite, Polyisobutene, C10-13 Isoparaffin, Boron Nitride, Dimethicone/Bis-Isobutyl PPG-20 Crosspolymer, Methicone, Triethoxycaprylylsilane, Propylene Carbonate, Silica, Sorbitan Sesquioleate, Galactoarabinan Sucrose Dilaurate, Pentylene Glycol, Sodium Cocyl Glutamate,

Acrylonitrile/Methacrylonitrile/Methyl Methacrylate Copolymer, Palmitoyl Hydroxypropyltrimonium Amylopectin/Glycerin Crosspolymer, Tetrasodium EDTA, Phenoxyethanol, Caprylyl Gylcol, 1, 2-Hexandiol, Titanium Dioxide, Iron Oxides, Zinc Oxide.

 # 7: Broad Spectrum SPF 15 sunscreen; Sunscreen Actives: Avobenzone 3%, Octisalate 5%, Octocrylene 3%; **Inactive Ingredients:** Water, Glycerin, Dimethicone, PTFE, Alcohol Denat., Isopropyl Isostearate, Ammonium Acryloyldimethyltaurate/ Steareth-25 Methacrylate Crosspolymer, Arachidyl Alcohol, Argania Spinosa Kernel Extract, Behenyl Alcohol, Benzyl Alcohol, C13-14 Isoparaffin, Capryloylsalicylic Acid, Carbomer, Cetearyl Alcohol, Cetearyl Glucoside, Cetyl Alcohol, Citral, Dimethicone/ Vinyl Dimethicone Crosspolymer, Dimethiconol, Disodium EDTA, Disodium Stearoyl Glutamate, Hydrolyzed Rice Protein, Laureth-7, Linalool, Methylisothiazolinone, Methylparaben, Panthenol, PEG-100 Stearate, Phenoxyethanol, Polyacrylamide, Retinyl Linoleate, Sodium Cocoyl Glutamate, Tocopheryl Acetate, Zingiber Officale (Ginger) Root Extract, Fragrance.

 # 8: BB Cream, Broad Spectrum SPF 30, Sunscreen Actives: Homosalate 5%, Octinoxate 7.5%, Octisalate 5%, Oxybenzone 2%; **Inactive Ingredients:** Water, PPG-3 Myristyl Ether Neopentanoate, Phenyl Trimethicone, Glycine Soja (Soybean) Seed Extract, Butylene Glycol, Hydrogenated Palm Kernel Glycerides, Silica, PEG-100 Stearate, Glyceryl Stearate, Cetearyl Alcohol, Glycerin, Hydroxyethyl Acrylate/ Sodium Acryloyldimethyl Taurate Copolymer, Caprylyl Glycol, Isohexadecane, Bisabolol, Triethoxycaprylylsilane, Fragrance, Citric Acid, Magnesium Aluminum Silicate, Cetearyl Glucoside, Polysorbate 20, p-Anisic Acid, Sodium C14-16 Olefin Sulfonate, Hydrogenated Palm Glycerides, Urea, Sodium PCA, Cetyl Hydroxyethylcellulose, Polysorbate 60, Xanthan Gum, Tetrasodium EDTA, Hexylene Glycol, Trehalose, Polyquaternium-51, Triacetin, Methylisothiazolinone, Sodium Hyaluronate, Titanium Dioxide, Mica, Iron Oxides.

IN VITRO TESTING METHODOLOGY TO QUALITATIVELY ASSESS POTENTIAL PROTECTIVE PROPERTIES OF VARIOUS FINISHED GOODS PRODUCTS AGAINST SIMULATED FULL SOLAR AND VIS PLUS IR RADIATION

The *in vitro* tests were conducted under controlled irradiation conditions to qualitatively assess potential protective properties of various finished goods against simulated full spectrum sunlight and its VIS+IR portion. The experimental set-up included: Solar Simulator LS 1000-6R-002 Rev.3 with Xenon Arc Lamp and XPS 1000 precision current source; PMA2144 Pyranometer providing uniform spectral response - with PMA2101 Detector to measure the total radiant power of incident radiation from 310 nm to 2800 nm (all from Solar Light Company, Glenside, PA, USA). Simulated full spectrum sun irradiance at Earth surface was achieved with the use of plain mirror, AM0 (SL04486) and AM1.5 (SL04204) filters; the VIS+IR portion of sun irradiance at Earth surface was achieved with plain mirror, AM0 (SL04486), AM1.5 (SL04204) and UV cut-off (SL07876) filters (all from SolarLight Company, Glenside, PA, USA). The *in vitro* test is based on the measurements of simulated full spectrum sunlight or its VIS+IR portion transmitted through the test article applied to the substrate with controlled roughness. The test articles were uniformly applied to PMMA (polymethylmethacrylate). HD6 plates, lot 38 (from HelioScreen Labs, Creil, France); the application density was exactly 1.3 mg/ cm^2 dispensed onto each plate using an analytical balance. PMA2144 Pyranometer with PMA2101 Detector were used to measure the total radiant power of incident radiation. An opaque housing was made for the PMA2144 Pyranometer to ensure accurate positioning of the HD6 plates over the detector. Distance from the bottom lip of solar simulator aperture to the top of HD6 plates was about 252 mm, with a distance of about 5 mm from the bottom of HD6 plates to the top of the Pyranometer protective dome. This experimental set-up is illustrated in Figure 1.

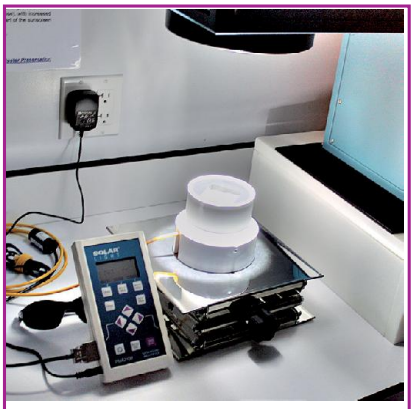

Figure 1. The experimental set-up to qualitatively assess potential protective properties of finished goods products against full solar radiation and its VIS plus IR portion.

The irradiance received by the Pyranometer was recorded 1 minute after opening the lamp shutter - to ensure stable readings. The irradiance data for empty light path and untreated HD6 substrate is presented in Table 1. The attenuation of simulated full spectrum

Test Conditions	Full Solar Simulated Sun*		VIS+IR	
	Irradiance, W/ m^2	% Attenuation	Irradiance, W/ m^2	% Attenuation
Empty Light Path (without Test Article)	1149	0	1038	0
Untreated Plate PMMA HD6	1060	7.7	952	8.3

Note. * Full solar simulated sun irradiance is close to typical solar radiation at clear sky - 1100 W/ m^2

Table 1. The irradiance data for empty light path and untreated substrate.

Test Article	Full Solar Simulated Sun Irradiation		VIS+IR portion of Simulated Sun Irradiation	
	Irradiance, W/ m^2	% Attenuation*	Irradiance, W/ m^2	% Attenuation**
#1: Broad Spectrum SPF 30	1029	2.9	942	1.1
# 2: BB Cream Illuminator Broad Spectrum SPF 15	689	35.0	633	33.5
# 3: BB Cream for Fair/Light Broad Spectrum SPF 15	687	35.2	636	33.2
# 4: BB Cream for Light/Medium Broad Spectrum SPF 20	624	41.1	589	38.1
# 5: CC Cream Broad Spectrum SPF 15	587	44.6	551	42.1
# 6: CC Cream Broad Spectrum SPF 20	632	40.4	590	38.0
# 7: Broad Spectrum SPF 15	1005	5.2	930	2.3
# 8: BB Cream Broad Spectrum SPF 30	659	37.8	640	32.8

Note. Irradiance transmitted through untreated HD6 considered as 100% transmittance and 0% attenuation: * 1060 W/ m^2; ** 952 W/ m^2

Table 2. Test results.

sunlight and its VIS-IR portion by each test article was calculated as a percentage of irradiance blocked assuming that the transmittance of the untreated HD6 is 100%. Test results are presented in Table 2.

Based on their respective attenuations (%), the test articles # 2, 3, 4, 5, 6 and 8 (BB and CC products with SPF 15-30) demonstrated about 35% - 45% potential protection against simulated full solar sun Irradiation (in the 310 nm - 2800 nm range) and about 32% - 42% protection against its VIS plus IR portion (from about 400 nm to 2800 nm). The test articles # 1 and 7 are sunscreen products with SPF 15-30 that provided only about 3% - 5% protection against full solar simulated sun Irradiation (in the 310 nm to 2800 nm range) and about 1% - 2% protection against its VIS plus IR portion (from about 400 nm to 2800 nm). Our findings indicate that in the formulation composition, both sunscreen actives and inactive ingredients could significantly contribute to a product's protection potential against simulated full solar sun and its VIS plus IR portion.

All tested multifunctional BB and CC products are complex formulations containing sunscreen actives and various inactive ingredients (iron oxides, titanium dioxide, zinc oxide, boron nitride, bismuth oxychloride, nylon-12, lithium magnesium sodium silicate, magnesium aluminum silicate, polyacrylamide, silica, boron nitride) which are capable of absorbing and/or scattering VIS and/or IR radiation.

The proposed test method described above is based on absolute radiation absorbance measurements and could be used as a supporting tool to qualitatively assess potential protective properties of various finished goods products against full solar and VIS plus IR radiation.

It should be noted that the standardization of the spreading (application) step will further improve the accuracy of this methodology.

THE *IN VITRO* TESTING METHODOLOGY TO SEMI-QUANTITATIVELY ASSESS POTENTIAL PROTECTIVE PROPERTIES OF FINISHED GOODS PRODUCTS AGAINST SOLAR RADIATION FROM 290 NM TO 1100 NM

Attenuation of irradiation of specific wavelengths by the test articles in the 290-1100 nm range covering UV, VIS and part of IR-A was determined using a dual-beam UV-Visible Spectrophotometer (Ultrospec 9000 manufactured by General Electric Healthcare Pittsburg, PA, USA) and HD6 substrates (from HelioScreen Labs, Creil, France). Test articles were uniformly applied to PMMA HD6 plates, lot 38; with application density - exactly 0.75 mg/cm^2. HD6 plates with no materials applied were used as blanks for reference measurements. Blank HD6 plates were placed into reference light path and HD6 plates with applied samples were placed in sample light path, both at an equal distance of ~2mm from the lamp apertures. Absorbance readings of the test articles were taken at wavelengths from 290nm to 1100nm, with 1nm bandwidth.

These absorbance values combine absorption of light by the test article as well as the scattering of light at angles sufficient to miss the detector and are believed to be a practical measure of attenuation.

In order to semi-quantitatively assess and compare potential protective properties of finished goods products against solar radiation from 290 to 1100 nm, authors proposed the expanded protection wavelength (EPW) term and metric.

The expanded protection wavelength (EPW) is calculated using the modified equation that was developed by Diffey in 1994 to calculate the Critical Wavelength (CW) of sunscreen products (13).

Diffey's CW *in vitro* test requires substrate spectroscopy measurements; CW is defined as the wavelength at which the area under the absorbance curve represents 90 percent of the total area under the curve in the UV (290-400 nm) region (13).

Presently, the CW 370 nm criterion is used to extend the *in vitro* measurement of sunscreen effectiveness against the UVA portion of sunlight - in order to substantiate the broad spectrum protection claims for sunscreen products (14). However, there is an ongoing debate in the industry whether the current CW threshold should be revised (15, 16).

Thus, in order to maintain consumer confidence in the category, sunscreen finished goods manufacturers have to continue developing more effective products based on the on-going research, new scientific discoveries, and the novel strategies to prevent VIS plus IR induced skin aging (15, 16, 11).

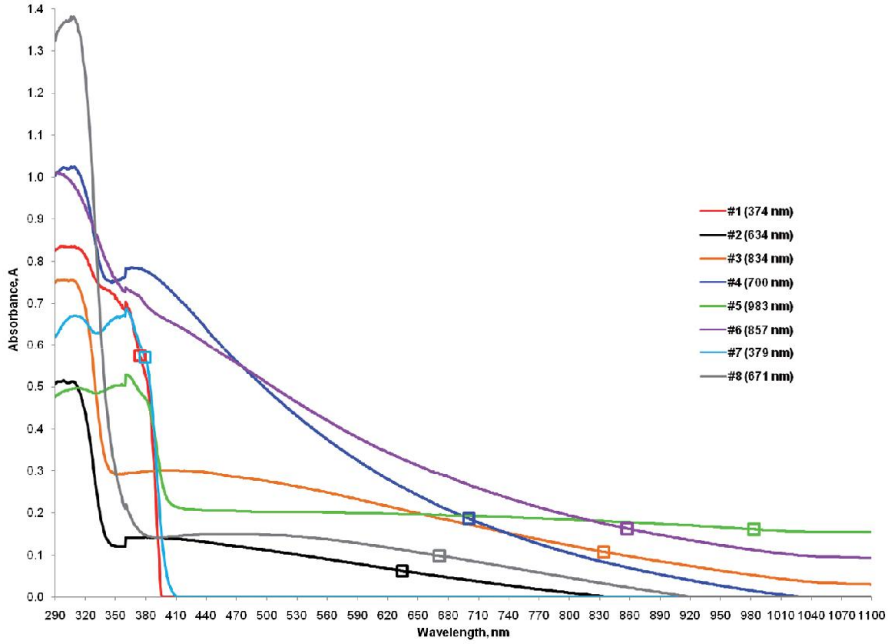

Figure 2. The Absorbance Spectra and EPW values (marked as squares) of the Test Articles.

Proposed expanded protection wavelength (EPW) is calculated according to the following expression:

$$\int_{290}^{\lambda EPW} A(\lambda)d\lambda = 0{,}9 \cdot \int_{290}^{1100} A(\lambda)d\lambda$$

In this expression, A(λ) is the mean absorbance at each wavelength, and dλ is the bandwidth (wavelength interval between measurements).
The expanded protection wavelengths (EPW) values were calculated for the test articles based on their absorbance data.
The absorbance spectra of the test articles with their respective EPW values (indicated in the legend and marked as squares on each spectrum) are presented in Figure 2.

The EPW values shown in Figure 2 indicate that multifunctional BB and CC lotions and creams (test articles # 2, 3, 4, 5, 6 and 8) possess protection potential against irradiation from the 290 nm to 1100 nm representing the UV, VIS, and partial IR-A irradiation range of solar spectrum. Our findings are especially encouraging because according to Mintel the key trend in 2014 will be that of "mixologiste" which is fast becoming the stand-out trend that spans all beauty and personal care categories; it is based on the success of hybrids such as BB creams that has inspired manufacturers to explore different ways through which they can bring categories together to create something exciting for consumers (17). The use of the proposed EPW metric could be considered to measure the breadth of the protection of topical products against the 290 nm to 1100 nm representing UV, VIS, and partial IR-A irradiation range of the solar spectrum. The proposed EPW is presently based on purely physical spectrophotometric measurements and would have greater biological relevance when the action spectra for mechanisms behind skin damage caused by VIS and IR irradiation are more researched, developed and published.
EPW metric could be enhanced, such as by better tuned integration limits, when relevant action spectra for skin damage caused or induced by VIS plus IR radiation, including photodamage, oxidative damage and photoageing become available.

CONCLUSIONS

Visible (VIS) and infrared (IR) portions of the solar spectrum are increasingly recognized as contributors to skin damage from sun exposure. *In vitro* testing methodologies were developed and utilized to qualitatively and semi-quantitatively rank protective properties of finished goods products against full solar, or VIS plus IR radiation. These methodologies utilize HD6 polymethylmethacrylate plates; simulated sunlight source with mirrors and cut-off filters to produce full solar or VIS plus IR irradiation - in conjunction with pyranometer; and monochromator-based spectrophotometer with wavelength range extending to 1100 nm. An expanded protection wavelength (EPW) definition and metric are proposed to measure the breadth of the protection of topical products against UV, VIS and partial IR-A irradiation range of the solar spectrum.

Presently the proposed EPW is based on purely physical spectrophotometric measurements. EPW metric could be enhanced, such as by better tuned integration limits, when relevant action spectra for skin damage caused or induced by VIS plus IR radiation, including photodamage, oxidative damage and photoageing become available.

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REFERENCES AND NOTES

1. CIE (Commission Internationale de l'Eclairage): Solar spectral irradiance, CIE Tech Rep, 1989, Table 4. Global solar irradiance at sea level No 85.
2. CIE (Commission Internationale de l'Eclairage) at http://eilv.cie.co.at/term/1402 accessed 26 January, 2014.
3. CIE (Commission Internationale de l'Eclairage) at http://eilv.cie.co.at/term/580 accessed 26 January, 2014.
4. N Shaath, After 50 years of sun care. *HAPPI* Vol. 51, No.1, 42-43 (2014).
5. HM Bassel, CL Hexcel, IH Hamzavi and HW Lim, Effects of visible light on the skin. *Photochemistry and Photobiology* 84, 450-462 (2008).
6. P Schroeder, S Shieke and A Morita, Premature skin aging by infrared radiation, tobacco smoke and ozone. In Skin Aging, B. Glichrest and J Krutmann, eds. Springer: Berlin, 45-53 (2006).
7. Cho S, Lee MJ, Kim MS, Lee S, Kim YK, Lee DH *et al.* Infrared plus visible light and heat from natural sunlight participate in the expression of MMPs and type 1 procollagen as well as infiltration of inflammatory cell in human skin *in vivo*.*J Dermatol Sci* 50: 123-33 (2008).
8. Yash K. Kamath and Sigrid B. Ruetsch. Characterization of surface and subsurface photodegradation of skin. *IFSCCMagazine* – vol.6, no 3/2003: 200-204.
9. Zastrow L, Groth N, Klein N, Kockott D, Lademann J, Ferrero L. Detection and identification of free radicals generated by UV and visible light in *ex vivo* human skin. *IFSCC Magazine*- vol.11, no 3/2008: 207-215 .
10. Zastrow L, Groth N, Klein F, Kockott D, Lademann J, Renneberg R, Ferrero L.The missing link --light-induced (280-1,600 nm) free radical formation in human skin. *Skin Pharmacol Physiol*. 22(1):31-44 (2009).
11. S Cho, MH Shin, YK Kim, Y-E Seo, YM Lee, C-H Park and JH Chung. Effects of Infrared Radiation and Heat of Human Skin Aging *in vivo* Journal of Investigative Dermatology Symposium Proceedings Vol. 14, 15-19(2009).
12. I Rodriguez, R Fenollosa and F Meseguer, Silicon Microspheres as UV, Visible and Infrared Filters for Cosmetics. *Cosmetics and Toiletries* Vol. 125, No. 9, 42-50 (2010).
13. Diffey BL. A Method for broad-spectrum classification of sunscreens. *Int J Cosmet Sci*, 16, 47-52 (1994).
14. FDA 21 CFR Parts 201 and 310 (Docket No. FDA-1978-N-0018) (formerly Docket No. 1978N-0038) RIN 0910-AF43).
15. Diffey BL. The FDA final rule on labeling and effectiveness testing of sunscreens: Too little, too late? J Am Acad Dermatol, Vol. 66, No.1, 162-163 (2012).
16. A Duev, G Kelm, R Wickett and O Dueva-Koganov. Are SPF and Critical Wavelength sufficient to measure the efficacy of sunscreen products against sun induced skin damage? Monographic Supplement Series: Sun Care – *H&PC Today* – Vol. 8 (4), IX-XII, July/August 2013.
17. Multifunctional make-up to boom in U.S as 2014 sees the Mixologiste trend arrive. By A McDougall at http://www.cosmeticsdesign.com/Market-Trends/Multifunctional-make-up-to-boom-in-U.S.-as-2014-sees-the-Mixologiste-trend-arrive accessed 27 January, 2014.