Assessment of homogeneity and UV filter skin retention

Vincenzo Nobile – Complife Italia, Italy

ABSRACT

Sunscreens have been used for more than a century to protect the skin against the harmful effects of ultraviolet radiation. Although the beneficial role of sunscreens in protecting the skin, there is increasing evidence of UV filters' systemic absorption and environmental repercussions. Sunscreen formulators are now facing the challenge of increasing sunscreen performance while decreasing the UV filter concentration.

In a collaborative study with a customer we evaluated the ability of a raw material in increasing the homogeneity of application and the retention on skin of UV filters. In order to reach this goal, a preliminary study on 6 subjects was carried out using two simple and reliable techniques: UV fluorescence emission and the skin stripping technique.

The test product demonstrated a better homogeneity of application (≈50%) and a better retention on skin than the base formula containing only the UV filters. These results were confirmed by the SPF measurement (5.2 points higher than the base cream plus UV filters).

UV fluorescence and skin stripping are a valuable tool to preliminarily assess sunscreen homogeneity of application and retention on skin. Further testing is in progress to standardise the study design.

Sunscreens are the most popular products used, for more than a century, to protect the skin against the harmful effects of ultraviolet radiation.[1] Although the UV filters used in sunscreen formulation are highly regulated and undergo rigorous toxicological testing, there are an increasing number of manuscripts reporting their systemic absorption.[2–5] Sunscreen products also have environmental repercussions. In recent years, benzophenone-3 (oxybenzone) and ethylhexyl methoxycinnamate (octinoxate) have been restricted in Palau, Thailand, Philippines and Hawaii due to their harmful effect on the coral reefs.[6] Sunscreens represent then both a valid protection against dangerous effects derived from UV radiation and a concern for humans and the environment. Sunscreen formulators are then facing the challenge of increasing sunscreen performance while decreasing the UV filters' concentration.

The idea of increasing the performance of sunscreens products and "decreasing" the UV filters is very attractive. Early studies from Sohn and colleagues reported an influence of solvents on the absorbing properties of UV-filters which was shown to be connected to the solvent polarity.[7] Antioxidants have been also demonstrated to be effective in improving the SPF and the UVA-PF.[8–9] The sunscreen industry should have, in the near future, the mission to research and develop new molecules with booster effect or increase the protecting effectiveness of UV filters via synergic mechanisms.

From a methodological point of view, the assessment of UV filter retention on skin, addresses the need of fast and reliable techniques. Conventional techniques include absorption studies both *in vitro* and *in vivo*[10] using reconstructed epidermis, skin stripping (ST) and HPLC.[10] Fourier transform infrared (FTIR) spectroscopy[11] or laser scanning microscopy (LSM)[12] to detect the UV filters. Despite their reliability, the timing and/or the cost of these techniques could limit the effective routinary screening of sunscreen products. This is the reason why in a collaborative project with a customer we developed a fast and reliable method to evaluate the retention and the homogeneity of application of the UV filters.

Materials and methods

Test products

The test product was a raw material named Celus-Bi® Feel (ROELMI HPC srl, Origgio, Italy). Celus-Bi Feel (zea mays starch, polyvinyl alcohol, glycerin) has a medium granulometry spheroidal physical structure. For test purposes the raw material was added to 3.5% concentration to a base formula (aqua, stearic acid, cetearyl alcohol, isononyl isononanoate, chlorophenesin, disodium EDTA, o-cymen-

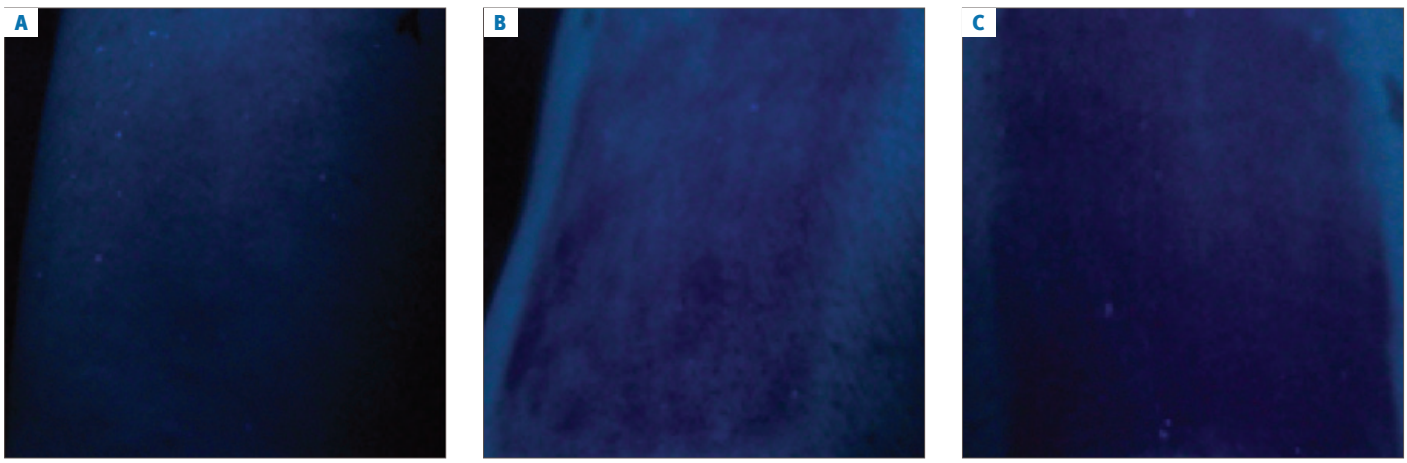

Figure 1: Homogeneity of the distribution of the sunscreen. a) Base cream: no fluorescence emission under Wood Lamp. b) Base cream + UV filters: non-homogeneity of fluorescence emission under UV lamp. c) Base cream + UV filters + test product: fluorescence emission under Wood Lamp is very homogenous.

5-ol, sodium hydroxide). The UV filters octocrylene and ethylhexyl methoxycinnamate were added at 5% concentration. The tested products were then: base cream (BC, negative control), base cream + UV filters (BC_UV positive control), and base cream + UV filters + Celus-Bi Feel (BC_UV_TP, test product).

Homogeneity and retention of sunscreen on skin
The homogeneity of the distribution and the retention of the test products were investigated by Wood lamp and tape stripping. To reach this goal, a preliminary study was carried out on six (n=6) male and female subjects. The test products were applied at 2 mg/cm^2 rate on the volar surface of the forearm. Digital pictures under UV light (Wood lamp, GIMA, Italy) and sequential tape stripping, using Corneofix® (Courage + Khazaka electronic GmbH), were performed to assess the retention of the UV filters on skin. Both evaluations were taken 30 minutes and 4 hours after products application.

Sun Protection Factor (SPF)
The SPF was determined according to the ISO 24444:2010 standard after 30 minutes from the application of the test products on the back of 6 volunteers using a multiport solar ultraviolet simulator (Model 601, Solar Light Corp., Philadelphia, Pa., USA). All the procedures were carried out in accordance with the ISO standard without any deviation.

Results

Homogeneity and retention of sunscreen on skin
The evaluation of the homogeneity of the distribution of the sunscreen on skin was carried out qualitatively taking advantage of the property of sunscreens to glow (fluorescence emission) under UV light (Fig 1). The qualitative results, 30 minutes after products application, were as follows: the base cream did not emit any fluorescence (as expected), the base cream plus the UV filters emitted non-homogenous fluorescence, and the base cream plus the UV filters and the test product emitted homogenous fluorescence under Wood lamp. To make the visual examination more objective the histogram of colour distribution was analysed (Fig 2). The histogram of colour distribution highlighted: a deeper intensity of the emitted fluorescence and a lower standard deviation (≈50%) in the test product treated area. The number of skin strippings to completely remove the emitted UV fluorescence, 30 minutes after products application, is lower for the base cream plus the UV filters (n=6) when compared to the base cream plus the UV filters and the test product (n=10). Similar results were obtained 4 hours after product application (data not reported). These results demonstrate the efficacy of the test product in improving the skin substantivity (ability to adhere to the skin) of the formula.

Sun Protection Factor (SPF)
The preliminary (n=6 subjects) sun protection factor (SPF) of the base cream plus the UV filters (18.9 ± 2.7) and the test product is 5.2 points higher than the base cream plus the UV filters SPF value (13.7 ± 3.2). This result indicates that the test ingredient is able to boost the SPF. The boosting efficacy can be related to a better distribution of the UV filters over the skin as demonstrated by the Wood lamp test.

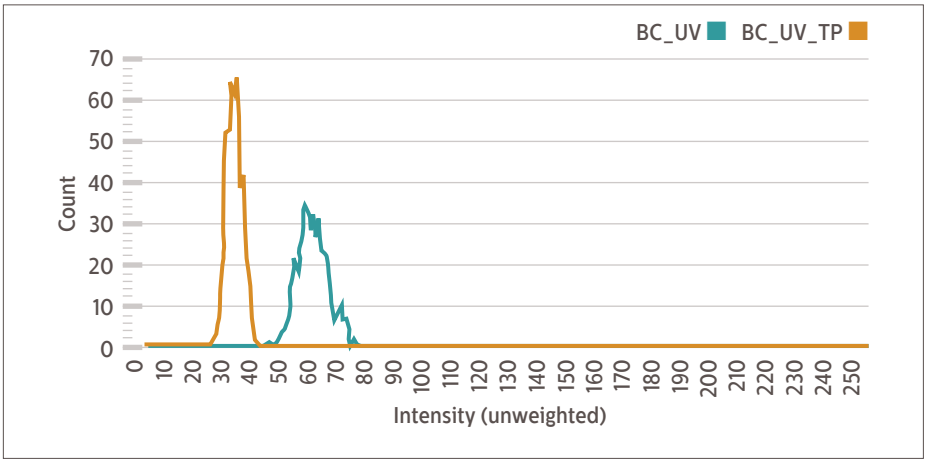

Figure 2: Histogram of colour distribution. BC_UV: base cream + UV filters (positive control); BC_UV_TP base cream + UV filters + Celus-Bi® Feel.

Discussion and conclusion

Sunscreens are a valid protection against the dangerous effects derived from UV radiation. However the UV filters used in sunscreens have concerns for both the humans and the environment.[2-6] Sunscreen formulators then need to take into account the need of decreasing the UV filters while improving the sunscreen performances. Different techniques[10-12] exist to evaluate the homogeneity and the retention on the skin of sunscreens, however these techniques can represent a limiting factor for effective routinary screening of sunscreen.

In our preliminary study we used two very simple and available techniques to assess the surface properties of sunscreens application on the skin. The property of sunscreens to emit fluorescence under UV light (Wood lamp) was used to evaluate the distribution of the sunscreen; while the skin stripping technique and the UV fluorescence were used to evaluate the retention on the skin of the sunscreen. An image analysis parameter was then implemented to make semiquantitative the UV pictures evaluation. Even if the results are preliminary and further studies are needed, this simple technique seems to be a rapid and cost-effective screening tool during the optimisation of sunscreen formulations taking into account the toxicological and environmental concerns of the UV filters. **PC**

References

1. Hayden CG, Cross SE, Anderson C, Saunders NA, Roberts MS. Sunscreen penetration of human skin and related keratinocyte toxicity after topical application. *Skin Pharmacol Physiol.* 2005;**18**(4):170-4.
2. Gustavsson Gonzalez H, Farbrot A, Larkö O. Percutaneous absorption of benzophenone-3, a common component of topical sunscreens. *Clin Exp Dermatol.* 2002;**27**(8):691-4.
3. Jiang R, Roberts MS, Collins DM, Benson HA. Absorption of sunscreens across human skin: an evaluation of commercial products for children and adults. *Br J Clin Pharmacol.* 1999;48(4):635-7.
4. Hayden CG, Roberts MS, Benson HA. Systemic absorption of sunscreen after topical application. *Lancet.* 1997;**350**(9081):863-4.
5. Treffel P, Gabard B. Skin penetration and sun protection factor of ultra-violet filters from two vehicles. *Pharm Res.* 1996;**13**(5):770-4.
6. Siller A, Blaszak SC, Lazar M, Olasz Harken E. Update About the Effects of the Sunscreen Ingredients Oxybenzone and Octinoxate on Humans and the Environment. *Plast Surg Nurs.* 2019;**39**(4):157-160.
7. Sohn M, Amorós-Galicia L, Krus S, Martin K, Herzog B. Effect of emollients on UV filter absorbance and sunscreen efficiency. *J Photochem Photobiol B.* 2020;205:111818.
8. Peres DD, Sarruf FD, de Oliveira CA, Velasco MVR, Baby AR. Ferulic acid photoprotective properties in association with UV filters: multifunctional sunscreen with improved SPF and UVA-PF. *J Photochem Photobiol B.* 2018;185:46-49.
9. Battistin M, Dissette V, Bonetto A, Durini E, Manfredini S, Marcomini A, Casagrande E, Brunetta A, Ziosi P, Molesini S, Gavioli R, Nicoli F, Vertuani S, Baldisserotto A. A New Approach to UV Protection by Direct Surface Functionalization of TiO2 with the Antioxidant Polyphenol Dihydroxyphenyl Benzimidazole Carboxylic Acid. *Nanomaterials (Basel).* 2020;**10**(2):231.
10. Chatelain E, Gabard B, Surber C. Skin penetration and sun protection factor of five UV filters: effect of the vehicle. *Skin Pharmacol Appl Skin Physiol.* 2003;**16**(1):28-35.
11. Cozzi AC, Perugini P, Gourion-Arsiquaud S. Comparative behavior between sunscreens based on free or encapsulated UV filters in term of skin penetration, retention and photo-stability. *Eur J Pharm Sci.* 2018 ;121:309-318.
12. Vergou T, Patzelt A, Richter H, Schanzer S, Zastrow L, Golz K, Doucet O, Antoniou C, Sterry W, Lademann J. Transfer of ultraviolet photon energy into fluorescent light in the visible path represents a new and efficient protection mechanism of sunscreens. *J Biomed Opt.* 2011;**16**(10):105001.