Formulating sun protection products that people will use
Designing broad-spectrum, photostabilized sunscreens with favourable aesthetics

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ABSTRACT: Photostabilized ultraviolet (UV) filter systems that incorporate both ultraviolet A (UVA) and ultraviolet B (UVB) filters (referred to as “broad spectrum” in the United States of America) are an excellent way to deliver broad-spectrum sun protection. However, they do not ensure that sunscreen users are protected in and of themselves. These systems must be incorporated into formulation bases that deposit uniform films, resist rinse-off and rub-off, and deliver aesthetics that encourage consistent and ongoing consumer use. This article presents successful approaches to formulating sunscreen spray, gel, balm, stick, cream and lotion products that satisfy the needs of different types of consumers.

INTRODUCTION

Sunscreen ingredients researchers have made considerable progress in defining and demonstrating the processes by which various UV filters photodegrade and the critical role photostabilizers play in ensuring that sunscreen products deliver broad-spectrum sun protection (1-4). Proper use of such products reduces the amount of UVA (320-400 nm) and UVB (290-320 nm) radiation that reaches the skin, providing numerous protective benefits.

Short-term benefits include an increase in the amount of time that can be spent in the sun without burning or tanning. When used consistently over years of sun exposure, long-term benefits include reduced photo-aging of skin (primarily a consequence of UVA exposure (5, 6), manifested as fine wrinkles, leathery texture, sagging, keratoses, freckles, discoloration and roughness); and reduced potential of developing skin cancers (primarily the result of UVB exposure (7, 8), which include basal cell and squamous cell carcinomas and malignant melanomas).

Simply including UV filters and photostabilizers in a sunscreen formulation does not ensure maximum benefits for consumers. The finished product must apply easily and uniformly, remain in place after application, produce no untoward cutaneous effects (9), and have an acceptable appearance and feel for consumers to use it effectively - or at all. Formulators must consider substantivity (e.g., rub-off, rinse-off and pooling resistance) and aesthetics (e.g., transparency, feel during rub-on and after dry-down) to produce a photostable broad-spectrum sunscreen that consumers will use properly and regularly.

SUBSTANTIvITY

A photostable sunscreen is most efficient when applied to the skin as a film of uniform thickness that remains so for the duration of use. A uniform film may seem easy to achieve, since the skin appears to be generally flat to the naked eye. However, given the small amount that is applied (approximately 2 mg/cm²), the effects of skin topography on product distribution become substantial.

These effects are particularly obvious in alcohol-based sunscreen sprays. A readily mobile sunscreen solution pools in low areas, leaving peaks in the skin under-protected. A yield-value additive, which resists flow at rest, such as fumed silica (e.g., Silica Dimethyl Silylate) (10) or a film-forming polymer (e.g., Acrylates/
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While the above formulations provide a variety of application, after-feel and visual characteristics, they are not suitable for everyone. In particular, daily wear sunscreen users may dislike the glossy appearance and oily skin feel imparted by some spray products, or the tacky/draggy feel associated with sticks and balms. Oil-in-water (O/W) emulsion-based lotions and creams provide a better base from which to formulate products for these consumers, as they impart a less shiny appearance and a less oily/greasy feel.

The type of emulsifier used to generate an O/W emulsion has a direct impact on the amount of time the product can be distributed across the skin prior to it starting to set up, on the product feel during application, and on the appearance and feel of the product after dry-down. The oil phase, which contains solid and liquid UV filters, sunscreen solvents to dissolve the solid UV filters, and photostabilizers, also affects these characteristics. As the proportion of the oil phase increases, so does the finished product viscosity - resulting in a thicker product. A thicker product requires increased time for dry down and imparts a more emollient (oily or greasy) feel. In addition, polymers added to reduce rinse-off and rub-off affect product dry-down, particularly as it nears completion.

Several approaches, used individually or in combination, address product oiliness or greasiness in O/W emulsions. Each is appropriate for use in colour (decorative) cosmetic applications.

AESTHETICS

The ever-evolving diversity of product forms and formulation bases in the sun care marketplace clearly demonstrates the value of tailoring sunscreen product aesthetics to specific customer needs and desires. The “sun worshiper” at the beach may prefer a sun-protection product that provides a glistening shine to the skin, while a user of daily wear sunscreen that has been incorporated into cosmetic foundation likely would not. The formulation base itself is a good place for a formulator to achieve specific aesthetics for a particular product.

Alcohol-based sprays deliver a cooling sensation during application, rapid film formation after application and a high gloss to the skin. They may be converted to gels with a low level of cellulosic polymer (e.g., Hydroxypropylcellulose) [17]. However, the cellulosic polymer becomes insoluble once the alcohol evaporates, and may appear as flecks on the skin that can flake off.

Volatile silicone-based sprays provide shine, but do not have the cooling effect of alcohol-based sprays or set as rapidly; alcohol is more volatile. They may be converted to gels by incorporating a relatively high level of a copolymer (e.g., Ethylene/VA Copolymer) [18]. These gels will not cause the flaking issues associated with alcohol-based gels.

Wax-based balms and sticks perform well on the lips, where less mobile, more transfer-resistant product properties are desired. A blend of plant-, insect- and/or petroleum-derived waxes (e.g., Euphorbia Cerifera [Candelilla] Wax, Copernicia Cerifera [Canuaboa] Wax, Beeswax, Ozokerite, Microcrystalline Wax, Paraffin, is often employed both to deliver the appropriate product quantity and to ensure that it does not exhibit syneresis (secrete liquid droplets on the surface of a semi-solid product) during storage. The transfer resistance of wax-based products is exhibited in their noticeable tack and/or drag.

Octylacrylamide Copolymer) [11-12] should be included in the formulation to increase the sunscreen yield-value and so increase its performance.

Achieving a uniform film is less problematic in creams and lotions, since yield values are inherent to most emulsification systems. Gels, pomades and sticks typically have even higher yield values but are often less shear thinning, so careful application is required. Once a uniform film is established, it must be sustained. This is usually not a problem for daily wear sunscreen products used in climate-controlled settings by people who are not particularly active. But sports and fitness enthusiasts, manual labourers, swimmers or beachcombers who work up a sweat or are regularly exposed to water require differently formulated products with an additional component.

Specifically, sunscreen products for these individuals require the incorporation of polymers that improve water- and rub-off resistance (e.g., VP/Eicosene Copolymer, C30-38 Olefin/Isopropyl Maleate/MA Copolymer, PPG-17/IPDI/DMPA Copolymer, or Octylodecyl Citrate Crosspolymer) [13]-[16]. Sufficient amounts of these polymers enable “water-resistant” or “very-water-resistant” claims to be made in certain geopolitical areas under appropriate testing.
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The first approach incorporates essentially spherical inert particles (e.g., Aluminum Starch Octenylsuccinate, Silica) (19-21), which act like microscopic ball bearings for easier product dispersion across the skin. Some of these spherical particles (e.g., Styrene/ Acrylates Copolymer) (22) very efficiently scatter ultraviolet radiation, thereby boosting the sun protection factor of the finished product.

The second uses silicone elastomers (e.g., C30-45 Alkyl Cetearyl Dimethicone Crossover Polymer, Polysilicone-11) (23-24) to impart a silky feel during application and after. The third approach substitutes microfine inorganic UV filters for a portion of the organic filters, thereby reducing the amount of oil in the formulation. This approach requires incorporation of a phosphate-based emulsifier (e.g., Potassium Cetyl Phosphate) (25) to maintain Avobenzone photostability (26-27).

CONCLUSION

Formulators face many challenges as they develop new sun care products. Judicious selection of organic versus inorganic UV filters, sunscreen solvents, photostabilizers, emulsifying agents, emulsion stabilizers, film formers and yield value additives allows the preparation of a wide array of sunscreen product formulations to address both the performance and aesthetic requirements of a diverse population. Readily accessible examples exist of the various formulation strategies presented in this article (28-29).

REFERENCES AND NOTES

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