Improving sensoriality of W/O mineral sunscreen

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ABSTRACT

Sensoriality is a key factor in sunscreen products, as they must be applied several successive times to ensure effectiveness. To formulate a nice sensorial sunscreen product is not an easy task. In addition, sunscreens must be designed not only focusing on skin protection and water resistance, but also considering the human health impact of cosmetics and environmental aspects such as the prevention of ocean pollution by using safe ingredients. Sunscreens are mostly formulated as emulsions (creams and lotions) that incorporate UV filters both organic and inorganic ones. Inorganic UV filters are considered more ocean friendly, and they are easier to formulate in a water-in-oil (W/O) than in an oil-in-water (O/W) system. Nevertheless, inorganic UV filters can produce a whitening effect, and a high amount of oil phase is needed to disperse them. This can lead to a greasy and heavy feeling after application. Moreover, W/O emulsions show fewer lighting textures and heavier residues on the skin than O/W systems. In order to overcome these formulation challenges, Kao proposes the use of two specific ingredients: Exceparl LM-LC (Lauryl Lactate) as a solubilizer for UV filters with high solubility capacity and a low whitening effect, and Penetol GE-IS (Isostearyl Glyceryl Ether) as an emulsifier that forms liquid crystals in W/O emulsions with a higher internal phase content, affording a lighter and non-oily feel of the skin.

Formulating sunscreens is really challenging. Achieving a stable formulation with high enough sun protection can be difficult. Moreover, one of the claim categories of sun care products that have experienced the largest growth over the last three years is the Ethical and Environmental claim, based on Mintel database sources.

This brings us to another key driving factor in the sun care industry: eco-sustainable sunscreens. Considering the wealth of information readily available to the public, it is no wonder that new generations of consumers are nowadays more conscious about the environmental and human health impact of conventional cosmetics, and are pushing for more sustainable product formats that utilize safe, ethically sourced and eco-friendly ingredients.

As a result of this demand, sunscreens need to be re-designed based on skin protection and oceans respect. Some factors to take into account are the use of safe ingredients without compromising efficacy or skin feel while also focusing on biodegradable, inorganic ingredients and water resistance formulas to respect the ocean environment.

The challenges in the process of re-designed sunscreen formulation include the following.

Sun protection factor (SPF)

The SPF level is the key purchase driver for sunscreens. Very large amounts of UV filters are needed to achieved SPF above 30. Combinations of UV filters can help to secure a higher SPF and broad spectrum rating.

Among the vehicle excipients, emollients are essential in sunscreens, since their main role is to solubilize solid UV filters to render them efficient.

UV filters and environmental aspects

Many UV filters are increasingly being regulated or outrightly banned in formulations, owing to environmental and human health safety concerns. Inorganic UV filters are gaining popularity due to their softness and lack of penetration into the skin compared to organic UV filters, in addition to other factors such as their natural mineral origin.

These filters are easier to formulate in a W/O system than in an O/W system. Furthermore, W/O emulsions show greater water resistance than O/W emulsions, in which the addition of polymers with water resistance is necessary.

Sensoriality

This is a key factor for sunscreen products. Sensory aspects can clearly influence the behavioural pattern in terms of the amount and frequency with which a consumer uses a sunscreen product; sensory aspects thus need to be carefully controlled and optimized.

To ensure that the product will be appreciated, applied and reapplied, and therefore prove effective, light textures with no heavy residue are of interest.

This article describes how the use of two specific ingredients in the re-designed sunscreen formulations can overcome the formulation challenges in order to produce eco-sustainable sunscreens.

These specific ingredients are Lauryl Lactate (Exceparl LM-LC) as a solubilizer for UV filters with a high solubility capacity and low whitening effect, and Isostearyl Glyceryl Ether

(Penetol GE-IS) as an emulsifier that forms liquid crystals in W/O emulsions with higher internal phase content, thereby affording a lighter and non-oily feel of the skin.

Lauryl Lactate: a natural solubilizer and dispersing agent of UV filters

Lauryl Lactate is a clear, colourless liquid with a 100% natural origin (ISO 16128). It is a fatty alcohol and fatty acid ester, and so has properties of both molecules, providing moisture or improving the lipid content of the skin.

It offers viscosity builder action in aqueous cleansing systems, and can also be used as a solubilizer and dispersing agent for hydrophobic molecules, such as some UV filters.

Proper dispersion of inorganic UV filters is crucial for the stability, UV protection, transparency and physical properties of solar products. In this study we used two inorganic UV filters (Zinc Oxide and Titanium Dioxide) combined with Lauryl Lactate or C12-15 Alkyl Benzoate used as reference.

The evaluation of dispersion was carried out taking into account three factors: the interaction of the emollients with the powder of the mineral filters; the minimum level of emollient required to wet the powder; and the viscosity of the dispersion.

The optimum selection would be to identify an oil-powder combination which can produce relatively low viscosity dispersion, with fast interaction, but without too fast a rate of sedimentation, in order to balance between dispersibility and stability.[1]

The use of Lauryl Lactate with mineral UV filters shows a good balance between dispersibility and stability, requiring less emollient to wet the UV filters powders. This is positive, because it affords 'free' emollient left available for the emulsification or solubilization of other UV filters. Moreover, low dispersion viscosity is obtained, related to better handling and providing an indication of potential viscosity addition to the final sunscreen product.

Lauryl Lactate also has good solubilizer properties for organic UV filters, allowing the solubilization of greater quantities of some common UV filters than standard solubilizers such as C12-15 Alkyl Benzoate.

Power dispersion factors:	UV filter	C12-15 Alkyl Benzoate	Lauryl Lactate
Emollient interaction 0.7g of powder to 45g of oil	ZnO	Fast	Medium
	TiO_2	Slow	Slow
Minimum emollient required to wet	ZnO	65mL/100g	35mL/100g
	TiO_2	110mL/100g	90 mL/100g
Viscosity of dispersions	25% ZnO	10000 cP	247 cP
	35% TiO_2	51200 cP	11102cP

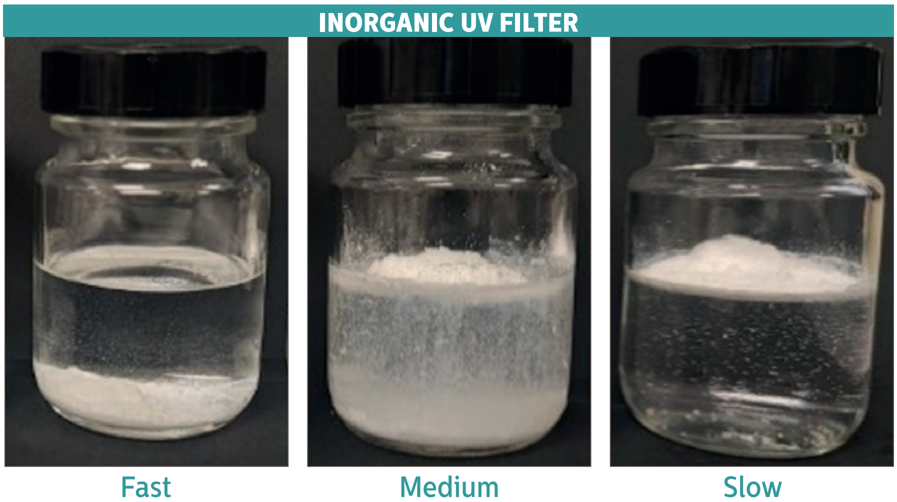

Figure 1: Summary of the dispersion evaluation of two emollients with TiO_2 and ZnO UV filters

The solubility properties of Lauryl Lactate from solid organic UV filters was characterized in terms of the % of solid organic UV filters soluble in 100 ml of emollient at 20 °C, and in terms of the UV absorbance characteristics. Figure 2 illustrates that Lauryl Lactate versus the reference exhibits greater solubility in the Diethylamino Hydroxybenzoyl Hexyl Benzoate (DHHB) and Ethylhexyl Triazone (EHT) UV filters.

In Figure 3, the absorbance curves of the UV filters combination (Bis-Ethylhexyloxyphenol Methoxyphenyl Triazine (BEMT) + 2-Ethylhexyloxyphenol Methoxyphenyl Triazine (EHMC) + Titanium Dioxide (TiO_2) at 3:3:1 ratio and 14% total active) dissolved in Lauryl Lactate or in C12-15 Alkyl Benzoate show that the combination of UV filters dissolved in Lauryl Lactate exhibits a hyperchromic effect, which allows greater efficiency, especially in the UVB region.

These results demonstrate that Lauryl Lactate is a good candidate for solubilizing and/or dispersing UV filters, which could have a positive impact upon UV protection efficacy and SPF.

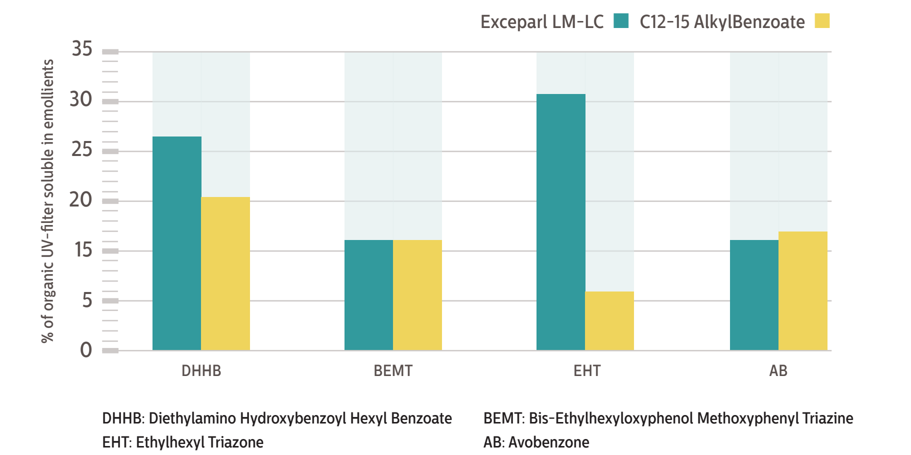

Figure 2: UV-filter solubility of Lauryl Lactate versus C12-15 Alkyl Benzoate

Isostearyl Glyceryl Ether: emulsifier for W/O emulsions with high water content

The emulsifier selected for re-designed sun protection products is crucial for defining the type of emulsion. The present study selected Isostearyl Glyceryl Ether (GE) with a very low HLB number, i.e. 2, which allows us to formulate water-in-oil emulsions.

It is known to Kao Chemicals that Isostearyl Glyceryl Ether forms a stable transparent liquid crystalline phase of a reversed hexagonal type with water. This was confirmed by small angle X-ray scattering (SAXS) measurements on the emulsifying characteristics of GE, investigated by Yuji Suzuki and Hisao Tsutsumi.[2]

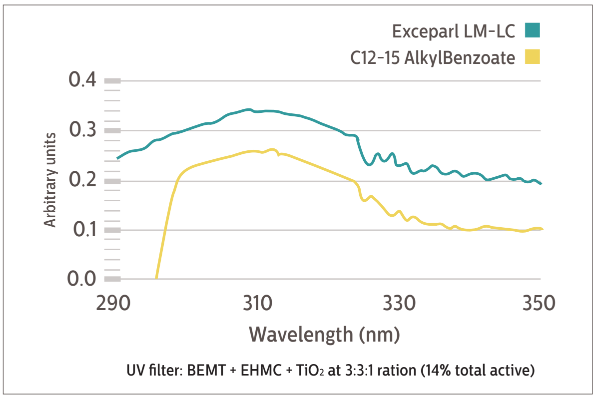

Figure 3: Absorbance spectrum of Bis-Ethylhexyloxyphenol Methoxyphenyl Triazine (BEMT) + 2-Ethylhexyloxyphenol Methoxyphenyl Triazine (EHMC) + Titanium Dioxide (TiO_2) dissolved in C12-15 Alkyl Benzoate (grey line) and in Lauryl Lactate (green line)

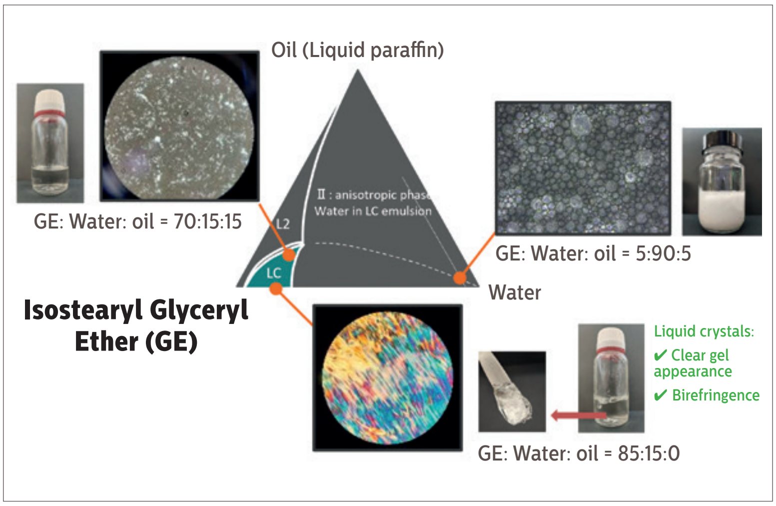

Figure 4: Ternary phase diagram of the GE/water/liquid paraffin system at 25°C

When water was gradually added to GE, a highly viscous and transparent gel was formed, with a weight fraction of water (Ø) of 0.08 to 0.23. Polarized Light Microscopy observation (Figure 4) confirmed that the gel-like composition is a reverse hexagonal-type liquid crystal. When Ø exceeded 0.23, the water phase was separated from the liquid crystalline phase. No change in phase structure occurred with the further addition of water, i.e. the water and liquid crystalline phases coexisted.

In liquid crystal emulsification, an oil phase was dispersed directly into the liquid crystalline phase composed of GE and water to prepare a gel-like oil-in-liquid crystal emulsion. This was followed by dilution with the remaining water to produce an emulsion. Thus, it was concluded that the W/O emulsions stabilized with GE are in fact water-in-liquid crystal emulsions where the liquid crystal containing oil is a continuous phase.

	W/O emulsions with **high water**		Standard **W/O** emulsions	
Function	Ingredients	% wt	Ingredients	% wt
Emulsifier	**Isostearyl Glyceryl Ether**	**2.4%**	**Sorbitan Oleate or Glyceryl Oleate**	**6.4%**
Emollient	PPG-3 Caprylyl Ether	2.0%	PPG-3 Caprylyl Ether	2.0%
Emollient	Tricaprylin	5.0%	Tricaprylin	5.0%
Solubilizer	**Lauryl Lactate**	**2.5%**	**C12-15 Alkyl Benzoate**	**8.0%**
UV filters	**BEMT+EHMC+TiO_2**	**14.0%**	**BEMT+EHMC+TiO_2**	**14.0%**
Humectant	Glycerine	3.0%	Glycerine	3.0%
Stabilizer	Magnesium Sulphate	1.0%	Magnesium Sulphate	1.0%
Preservative	Phenoxyethanol (and) Ethylhexylglycerin	0.5%	Phenoxyethanol (and) Ethylhexylglycerin	0.5%
Water	**Deionized water**	**70%**	**Deionized water**	**60%**

Table 1: Compositions test: W/O emulsion with high water content stabilized with GE and Lauryl Lactate as solubilizer for UV filters, and standard W/O emulsions stabilized with Sorbitan Oleate or Glyceryl Oleate and C12-15 Alkyl Benzoate as solubilizer for UV filters

Due to their organization, water-in-liquid crystal emulsions offer multiple benefits in beauty formulations, producing a stable emulsion against a coalescence of water droplets and sensoriality, where the liquid-crystalline structure impacts product consistency and contributes to the fluidity and dynamism of this meshwork when applied to the skin.

The large amount of water trapped in the emulsion is available immediately when the cream is applied to the skin. For this reason, the emulsions have a shiny appearance and a light, fresh-touch texture similar to oil-in-water emulsions.

The sensory benefit of water-in-oil emulsions with a high external phase content has been demonstrated by the evaluation of two water-in-oil emulsions with UV filters content. The use of GE as an emulsifier for sunscreen formulations allows the formation of water-in-liquid crystal emulsions with 8% to 23% more water than standard non-ionic emulsifiers such as Sorbitan Oleate or Glyceryl Oleate.

Table 1 represents the composition of W/O test emulsions, one W/O with high water content based on Isostearyl Glyceryl Ether as emulsifier and Lauryl Lactate as solubilizer (ref. GE) and two standard W/O emulsions based on Sorbitan Oleate or Glyceryl Oleate as emulsifier and C12-15 Alkyl Benzoate as solubilizer (ref. SO & GO).

The sensory evaluation of the three sunscreen formulations was carried out with an expert panel (Figure 5). Panellists were asked to rate attribute intensity using structured five-point scales, scoring from 1 (low) to 5 (high) during and after emulsion application.

The test coordinator placed 14 ml (2 mg/cm² recommended amount of sunscreen to be applied; ISO 24444) on the inner side of the forearm of the panellists. The latter evaluated the following attributes: ease of spreading, absorption and oiliness.

Ease of spreading was evaluated during application; absorption was evaluated immediately after application; and oiliness was evaluated immediately after application and again after five minutes.[3]

The W/O emulsion stabilized with GE was perceived as a standard Sorbitan Oleate-based W/O emulsion in most of the sensory attributes tested, with the exception that it produced a less greasy skin feel than conventional W/O emulsions.

These results were consistent with the results obtained by sebum level quantification.

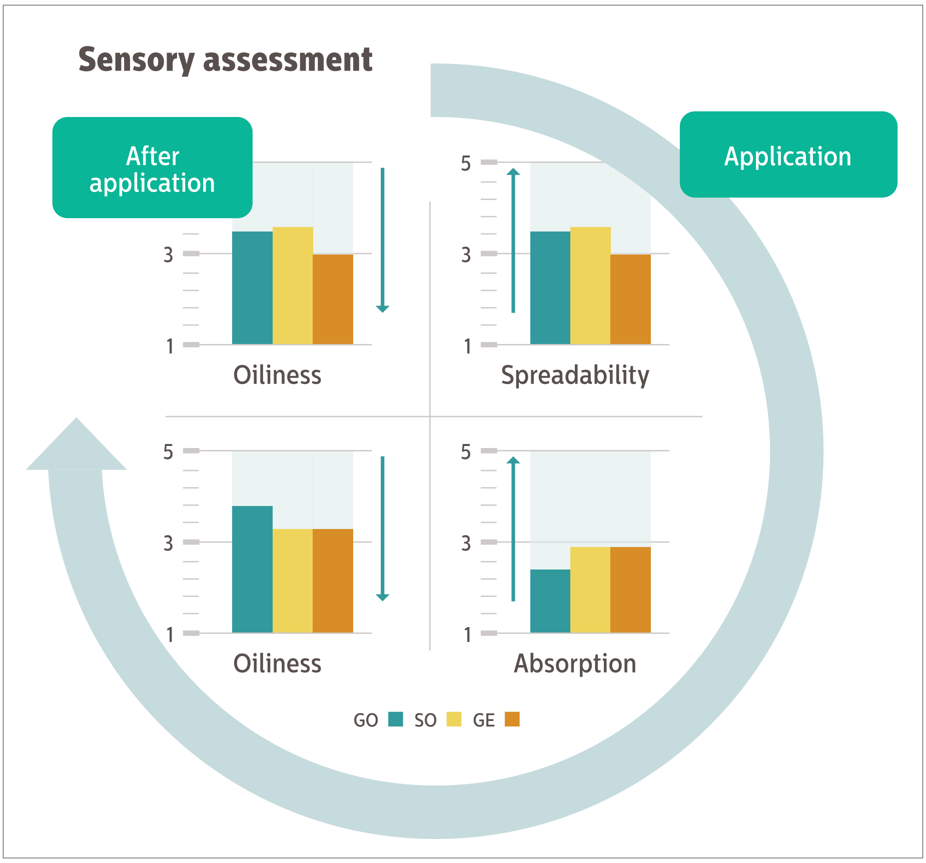

Figure 5: Sensory assessment profile during application and after application of the sunscreen formulations to the forearm of the panellists

Adhesive patches (Sebutape) were applied to the inner side of the forearm of the panellists where 14 ml of sunscreen formulation was applied.

The Sebutape was removed after 15 minutes and the sebum level was read using the criteria described in Figure 6. The water-in-oil emulsions with a high external phase content based on GE showed lower sebaceous secretion levels than standard W/O emulsions.

Conclusion

The use of Excepal LM-LC (Lauryl Lactate) and Penetol GE-IS (Isostearyl Glyceryl Ether) in the re-designed sunscreen formulations have overcome some of the formulation challenges with a view to developing eco-sustainable sunscreens.

We recommend the use of Excepal LM-LC as a solubilizer for sunscreens because it shows high solubilization capacity and good dispersion of inorganic UV filters with low viscosity.

Likewise, we recommend the use of Penetol GE-IS as an emulsifier to create water-in-liquid emulsions with a high content of external phase, providing benefits in the stability of emulsions where the organization of water in the liquid crystal emulsion prevents the coalescence process and affords a light and non-greasy touch on the skin.

In conclusion, a sunscreen formulation is obtained that can guarantee that it will be appreciated, applied and reapplied, thereby improving its effectiveness. **PC**

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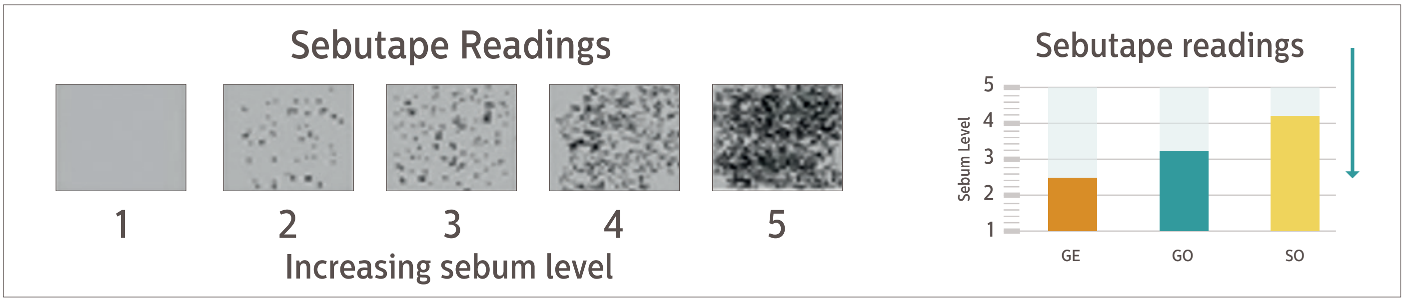

Figure 6: Sebaceous secretion levels for each sunscreen formulation, assessed with a scoring scale