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Mineral filters in sunscreen products – comparison of the efficacy of zinc oxide and titanium dioxide by *in vitro* method

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European legislation currently authorizes 26 sun filters among which, there is only one mineral filter: titanium dioxide. In the United States, two mineral filters are authorized: titanium dioxide in a maximum dose of 25% and zinc oxide. Zinc oxide is authorized in Europe, but its concentration level is not limited. A large number of commercial products are containing one of these mineral filters. The difference between these products lies in the percentage of the active substance, the way they are incorporated into the final product and the size of the primary particles. Depending on the ingredient used, there is a large variation in efficacy. The efficacy of the products tested was determined by an *in vitro* method using a spectrophotometer equipped with an integration sphere. Titanium dioxide was thus seen to be much more effective than zinc oxide; indeed no commercial form of zinc oxide tested can give a sun protection factor (SPF) higher than 10 at its maximum dose of use, unlike titanium dioxide which in its coated form (coated with alumina and with stearic acid, amongst others) gives a SPF of 38. This study has also allowed us to dispel the theory that talc – a raw material which has been used empirically for years in foundation in the belief that it has photoprotective effects – has an effect against sun rays. Talc proved to be particularly ineffective, as when it is used at a level of 25%, it only gives a totally negligible SPF of one unit.

1. Introduction

Sunscreen products are topical products designed to protect the skin from the unwanted effects of the sun. The efficacy of the products in question is represented by a figure affixed on the packaging of sun products, known as the SPF (Sun Protection Factor), an indicator of the anti-erythemal efficacy which can be considered as universal, given the standardisation of the methods used. The Colipa method is currently recognised worldwide; however this method poses ethical problems due to the fact that healthy volunteers are irradiated (Sayre et al. 1980; Diffey and Robson 1989). That is why we have developed an *in vitro* method. In order to obtain efficacy there must be an active ingredient. Different active ingredients are at the formulator's disposal.
In Europe, 26 filters can be used (25 organic filters and a mineral one: titanium dioxide); in the United States, 16 filters are available (14 organic filters and 2 mineral filters (titanium dioxide and zinc oxide)). These sunscreens cannot be used at levels over 25%. In Europe, zinc oxide can be found in a large number of products on the market, even if it is not on the list of authorized filters, the same list which also indicates that the products are regulated in terms of dose of use. Indeed, this substance is not banned and is of certain interest in the field of photoprotection. The mineral sunscreens have certain advantages in comparison with organic filters: they are completely harmless (Schwarz et al. 2001; Pflücker et al. 2001; Rouabhia et al. 2002; Gamer et al. 2006) and are very stable over time (Mitchnick et al. 1999; Pinnell et al. 2000; Lademann et al. 2000). There are many suppliers of ingredients and a wide variety of products on the market which contain either one of the aforementioned mineral filters. This variety is linked to the increasing use of micronized powders (the size of the primary particles can reach dimensions in the order of 14 nm) and coated powders (the coating can include alumina, silica, glycerides, silicone oil). Depending on the products used, we can note that the percentage of active matter is variable. Faced with this great diversity of raw materials at our disposal, we thought it would be interesting to draw up an appraisal by comparing the efficacy of the main screens available on the market. In order to do this, we contacted 7 companies dealing in raw materials for use in cosmetics who kindly supplied us with the following sunscreens: 8 commercial forms of zinc oxide and 8 commercial forms of titanium dioxide. We also wanted to know more about the potential efficacy of talc, a product used historically and empirically in the field of photoprotection.

2. Investigations, results and discussion

The choice of our method of determination was naturally an *in vitro* one, due to ethical reasons, since the irradiation

Table 1: Efficacy of filters tested

Trade name	SPF = f(c)	Correlation coefficient r	SPF at 25%
Zinc oxide neutral	$y = -0.0021 x^2 + 0.3855 x + 0.0021$	0.988	8.33
Zinc oxide NDM	$y = -0.0092 x^2 + 0.4796 x + 0.1193$	0.997	6.35
Z-Cote	$y = -0.0108 x^2 + 0.5137 x + 0.0732$	0.995	6.17
Z-Cote max	$y = -0.0065 x^2 + 0.5762 x - 0.2118$	0.983	10.13
Z-Cote HP1	$y = -0,0094 x^2 + 0,4744 x + 0,0571$	0.998	6.04
Tego Sun Z500	$y = -0.0055 x^2 + 0.4011 x - 0.0371$	0.998	6.55
Tego Sun Z800	$y = -0.0014 x^2 + 0.3569 x + 0.0564$	0.998	8.10
Nanox 200	$y = -0.0107 x^2 + 0.4694 x + 0.2061$	0.990	5.25
Nanox gel 200 TN	$y = -0.0005 x^2 + 0.2080 x + 0.1093$	0.988	5.00
Talc	$y = 0.0177 x + 0.7822$	0.957	1.22
Oxyde de titane standard	$y = -0.0177 x^2 + 0.4825 x + 0.2602$	0.987	5.01
Eusolex T-Oleo	$y = -0.0039 x^2 + 0.3756 x + 0.2521$	0.994	7.20
Eusolex T-Aqua	$y = -0.0048 x^2 + 0.3454 x + 0.2096$	0.994	5.84
Eusolex T-Avo	$y = 0.0037 x^2 + 1.0241 x + 0.2093$	0.998	28.12
Eusolex T-2000	$y = -0.0033 x^2 + 1.0887 x - 0.1596$	0.993	25.00
Eusolex T-Eco	$y = 0.0256 x^2 + 0.8081 x + 0.4293$	0.986	36.63
Eusolex T	$y = 0.0046 x^2 + 0.3124 x + 0.3346$	0.996	11.02
Eusolex-TS	$y = -0.0293 x^2 + 2.2199 x + 1.4018$	0.992	38.60

Table 2: Characteristics of filters studied

Trade name	INCI name	Active matter	Suppliers
Zinc oxide neutral	Zinc oxide	Min 95%	Symrise, Neuilly sur Seine, France
Zinc oxide NDM	Zinc oxide, Dimethicone	Min 92%	Symrise, Neuilly sur Seine, France
Z-Cote	Zinc oxide	99–100%	BASF, Levallois Perret, France
Z-Cote Max	Zinc oxide, Diphenyl Capryl Methicone	96–99%	BASF, Levallois Perret, France
Z-Cote HP1	Zinc oxide Trietoxycaprylylsilane	98%	BASF, Levallois Perret, France
Tego-Sun Z500	Zinc oxide	>99.5%	Goldschmidt, Montigny le Bretonneux, France
Tegosun Z800	Zinc oxide, Trimetoxycaprylylsilane	>94%	Goldschmidt, Montigny le Bretonneux, France
Nanox 200	Zinc oxide	99%	SACI-CFPA, Paris, France
Nanox gel 200 TN	C12–15 alkyl benzoate, Zinc oxide, Polyhydroxystearic acid	55%	SACI-CFPA, Paris, France
Oxyde de titane standard	Titanium dioxide	99–100%	LCW, St Ouen L'Aumône, France
Eusolex T-Oleo	Titanium dioxide, Butylene glycol dicaprylate/dicaprate, Silica, Polyglyceryl-2 dipolyhydroxystearate	30%	Merck, Fontenay sous bois, France
Eusolex T-Aqua	Titanium dioxide, Aqua, Alumina, Sodium metaphosphate, Phenoxyethanol, Sodium methylparaben	25.8%	Merck, Fontenay sous bois, France
Eusolex T-Avo	Titanium dioxide, Silica	79.6%	Merck, Fontenay sous bois, France
Eusolex T-2000	Titanium dioxide, Alumina, Simethicone	80.3%	Merck, Fontenay sous bois, France
Eusolex T-Eco	Titanium dioxide, Alumina, Simethicone	79.6%	Merck, Fontenay sous bois, France
Eusolex T	Titanium dioxide, Simethicone	77.5%	Merck, Fontenay sous bois, France
Eusolex T-S	Titanium dioxide, Alumina, Stearic acid	73–79%	Merck, Fontenay sous bois, France

of healthy volunteers did not seem to be the best solution for testing sunscreen products (Couteau et al. 2007).
The trend curves realised for each product allowed us to obtain equations from which we can predict the SPF according to the concentration in the screen. We can thus predict the expected SPF for any percentage of concentration added to the formula (Table 1). This study allowed us to draw up a ranking of sunscreens in ascending order of efficacy:

Talc < Titanium dioxide < Z-Cote < Zinc oxide NDM < Tegosun Z500 < Tegosun Z800 < Zinc oxide neutral < Nanox gel 200 TN < Z-Cote max < Eusolex T < Eusolex T-Aqua < Eusolex T-Oleo < Eusolex T2000 < Eusolex T-Avo < Eusolex T-Eco < Eusolex TS.

In addition to this ranking, this study allowed us to draw certain conclusions. Talc is reputed to be an effective photoprotector without good reason, as whatever the percentage used, the SPF obtained is negligible (about 1 SPF unit). Zinc oxide, whatever commercial form was tested, has a lower efficacy than titanium dioxide, zinc oxide coated in silicone seeming to be the most effective zinc oxide on the market. The different technologies of preparation of the sunscreens (micronisation and coating) represent a clear step ahead and have allowed formulators to have access to more efficient raw materials compared to the screens used a few years ago. Indeed these two techniques lead to a certain comfort in terms of formulation and application (the disappearance of what was once known as the "Pierrot's Mask" effect) as well as an increase in efficacy (Villalobos-Hernandez et al. 2005). The titanium dioxide-based speciality which proved to be the most effective is about 8 times more efficient than non-micronised titanium dioxide (standard titanium dioxide).

3. Experimental

3.1. Chemicals

Three ingredients were tested: titanium dioxide, zinc oxide and talc. The characteristics of the different commercial products tested are set out in Table 1. The talc used was obtained from Cooper (Melun, France).

3.2. SPF determination

We studied the efficacy of each of these raw materials in the UVB field by drawing up the SPF = f(c) trend curve for each ingredient in order to establish a ranking of the products currently at the formulator's disposal. All of these sunscreens were incorporated in ascending quantities (5, 10, 15, 20 and 25%) in a previously described O/W emulsion (Couteau et al. 2007). The maximum concentration of titanium dioxide (25%) was chosen as the maximum concentration even for non regulated powders; indeed above 25% of powder in the base emulsion causes galenic problems.

About 15 mg of product exactly weighed were spread on PMMA plates over the whole surface (25 cm^2) using a cot-coated finger. Three plates were prepared for each product to be tested and 9 measures were performed on each plate. Transmission measurements between 290 and 400 nm were carried out using a spectrophotometer equipped with an integrating sphere (UV Transmittance Analyzer UV1000S, Labsphere, North Sutton, US). The standard used was the 8% homosalate standard mandated by the US Food and Drug Administration Sunscreen Monograph. The calculations for either term use the same relationship:

$$SPF = \sum_{290}^{400} E_\lambda I_\lambda \Delta_\lambda \Big/ \sum_{290}^{400} E_\lambda I_\lambda T_\lambda \Delta_\lambda$$

where E_λ is spectral irradiance of terrestrial sunlight at λ, I_λ is erythemal action spectrum at λ and T_λ is spectral transmittance of the sample at λ (Sayre et al. 1980).

References

Couteau C, Faure A, Fortin J, Paparis E, Coiffard LJM (2007) Study of the photostability of 18 sunscreens in creams by measuring the SPF *in vitro*. J Pharmaceut Biomed Anal 44: 270–273.

Couteau C, Pommier M, Paparis E, Coiffard LJM (2007) Study of the efficacy of 18 sun filters authorized in European Union tested *in vitro*. Pharmazie 62: 449–452.

Diffey BL, Robson J (1989) A new substrate to measure sunscreen protection factor throughout the ultraviolet spectrum. J Soc Cosmet Chem 40: 127–133.

Gamer AO, Leibold E, van Ravenzwaay B (2006) The in vitro absorption of microfine zinc oxide and titanium dioxide through porcine skin. Toxicol In Vitro, 20: 301–307.

Lademann J, Weigmann H, Schafer H, Muller G, Sterry W (2000) Investigation of the stability of coated titanium microparticles used in sunscreens. Skin Pharmacol Appl Skin Physiol 13: 258–264.

Mitchnick MA, Fairhurst D, Pinnell SR (1999) Microfine zinc oxide (Z-Cote) as a photostable UVA/UVB sunscreen agent. J Am Acad Dermatol 40: 85–90.

Pflücker F, Wendel V, Hohenberg H, Gärtner E, Will T, Pfeiffer S, Wepf R, Gers-Barlag H (2001) The human stratum corneum layer: an effective barrier against dermal uptake of different forms of topically applied micronised titanium dioxide. Skin Pharmacol Physiol 14 (Suppl 1): 92–97.

Pinnell SR, Fairhust D, Gillies R, Mitchnick MA, Kollias N (2000) Microfine zinc oxide is a superior sunscreen ingredient to microfine titanium dioxide. Dermatol Surg 26: 309–314.

Rouabhia M, Mitchell DL, Rhainds M, Claveau J, Drouin R (2002) A physical sunscreen protects engineered human skin against artificial solar ultraviolet radiation-induced tissue and DNA damage. Photochem Photobiol Sci 1: 471–477.

Sayre RM, Agin PP, Desrochers DL, Marlowe E (1980) Sunscreen testing methods: in vitro predictions of effectiveness. J Soc Cosmet Chem 31: 133.

Schwarz VA, Klein SD, Hornung R, Knochenmuss R, Wyss P, Fik D, Haller U, Walt H (2001) Skin protection for photosensitized patients. Laser Surg Med 29: 252–259.

Villalobos-Hernandez JR, Müller-Goymann CC (2005) Novel nanoparticulate carrier system based on carnauba wax and decyl oleate for the dispersion of inorganic sunscreens in aqueous media. Eur J Pharm Biopharm 60: 113–122.