International Journal of Pharmaceutics 415 (2011) 181–184

Contents lists available at ScienceDirect

International Journal of Pharmaceutics

journal homepage: www.elsevier.com/locate/ijpharm

Sunscreen products: What do they protect us from?

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ARTICLE INFO

Article history:
Received 16 February 2011
Accepted 26 May 2011
Available online 12 June 2011

Keywords:
SPF
PF-UVA
In vitro test
Non-melanoma skin cancer
Erythema

ABSTRACT

Whereas for fifty or so years acquiring a tan has been the trend for aesthetic reasons relating to current beauty criteria, the health authorities are now advocating vigilance in this area, prompted by the knowledge of the harmful effects of the sun, especially from its ultra-violet rays. In the European Union, sunscreen products are considered cosmetics and tests on their effectiveness can be performed *in vivo* or *in vitro* to determine four effectiveness indicators: the SPF (Sun Protection Factor), the PF-UVA (UVA Protection Factor), the SPF/PF-UVA ratio and the critical wave length. It is the erythemal SPF which is measured in the vast majority of cases: it can therefore be confirmed that sunscreen products protect us from sunburn under good conditions of use. We thought it would be interesting to calculate other indicators to assess protection against non-melanoma skin cancers (NMSC) and to quantify the effectiveness of the product against UVA1 or UVA2. To characterize the products tested, we have determined *in vitro* different SPF and PF-UVA values, by using not just the erythemal weighting factor but also the weighting factor relating to the non-melanocytic skin cancer (SPF_{cnm} and $PF\text{-}UVA_{cnm}$), by getting away from any weighting factor (SPF_m and $PF\text{-}UVA_m$) and lastly, by varying the integration limits to quantify the effectiveness of the tested product in the UVB (290–320 nm), UVA1 (340–400 nm) and UVA2 320–340 nm) fields. In this way, and using these new indicators, we have been able to qualify eleven commercial products—ten cosmetic products and one medical device. It can be interesting to take into account the non-melanocytic skin cancer protection in order to qualify the sunscreen products.

1. Introduction

For many years, until really quite recently, the fashion for pale complexions outstripped that of tanned complexions (Witkowski and Parish, 2001). Parasols, hats, etc. were the physical methods used to avoid tanning as much as possible. It was not until the 1930s that this trend was reversed and tanned complexions took centre stage. The first sun creams and oils also made their appearance during this period (Gastou, 1923). The lack of regulations in this field left the door wide open to manufacturers who could market a wide variety of products (Urbach, 2001). One example is the Sun-bi-Sun® product from the Ducray laboratories, made up of a double cream mixing in variable proportions when squeezed from the tube; the active ingredient was bergapten, a photosensitising molecule which is now banned in cosmetics. Regulations since the 1970s have changed radically and sunscreen products are now required to meet a certain number of criteria: the SPF/PF-UVA ratio must be less than or equal to 3 and the critical wave length of the product (wave length below which the product is 90% effective) must be higher than or equal to 370 nm. As the method to determine the SPF *in vivo* (Colipa) was based on a ratio of doses likely to trigger solar erythema and the PF-UVA on a ratio of doses likely to trigger the Meirowski phenomenon, it can be said that any sunscreen product marketed and compliant with the Commission recommendations no. 2006/647/EC of 22 September 2006 (OJEU of 26.09.2006) protects from sunburn. Action to prevent skin cancers occurring is essential, more than action to prevent sunburn. Based on this, we have tested and compared various products on the market with the same index providing cover for different situations in terms of photoprotection.

2. Experimental

2.1. Materials

The various marketed products tested are presented in Table 1. They are mainly cosmetic products, with the exception of Daylong actinica® which has the status of class I medical device.

2.2. Experimental methods

Thirty milligrammes of product exactly weighed were spread on PMMA plates (Europlast, Aubervilliers, France) over the whole surface (25 cm^2) using a cot-coated finger. 15 mg remains on the finger

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doi:10.1016/j.ijpharm.2011.05.071

Table 1
Characteristics of the products tested.

No.	Trade name (Laboratory)	SPF labelled	Statut
1	Lait solaire très haute protection Enfant à l'extrait de calendula (Klorane)	50+	Cosmetic product
2	Photoderm max fluide (Bioderma)	50+	Cosmetic product
3	Photoderm max spray solaire (Bioderma)	50+	Cosmetic product
4	Soins soleil à l'uncaria d'Amazonie lait velouté corps (Galénic)	30	Cosmetic product
5	Nivéa sun Spray protecteur hydratant (Beiersdorf)	50+	Cosmetic product
6	Ambre solaire UV sensitive spray protecteur peaux intolérantes au soleil (Garnier)	10	Cosmetic product
7	Eucerin Sun lotion (texture extra légère) (Eucerin)	50	Cosmetic product
8	Hyseac – fluide solaire – protection haute peaux mixtes à grasses (Uriage)	30	Cosmetic product
9	Polysianes Crème veloutée hydratante, non grasse – Haute protection visage (Klorane)	30	Cosmetic product
10	Polysianes crème veloutée hydratante, non grasse – Protection moyenne visage (Klorane)	20	Cosmetic product
11	Daylong actinica (Spirig)	–	Medical device

cot. SPF and PF-UVA of the creams were measured *in vitro*. Three plates were prepared for each product to be tested and 9 measures were performed on each plate. Transmission measurements were carried out using a spectrophotometer equipped with an integrating sphere (UV Transmittance Analyzer UV1000S, Labsphere, North Sutton, US) (Couteau et al., 2007, 2008; Alami et al., 2007).

To characterize the products tested, we have determined different SPF and PF-UVA values, by using not just the erythemal weighting factor but also the weighting factor relating to the non-melanocytic cancer (SPF_{cnm} and $PF\text{-}UVA_{cnm}$) (Fig. 1), by getting away from any weighting factor (SPF_m and $PF\text{-}UVA_m$) and lastly, by varying the integration limits to quantify the effectiveness of the tested product in the UVB (290–320 nm), UVA1 (340–400 nm) and UVA2 (320–340 nm) fields (Table 2).

For each product the following ratios R and R' were calculated, according to:

$$R = \frac{SPF}{FP\text{-}UVA}$$

$$R' = \frac{SPFcnm}{SPF}$$

Ratio R maintains compliance of the sunscreen product with the European recommendation. Ratio R' is a new indicator translating an effectiveness in preventing non-melanoma skin cancers.

The ratio R makes it possible to make sure of the conformity of the solar product with the European recommendation. The R' ratio constitutes a new indicator in order to evaluate effectiveness in the field of prevention of the non-melanoma skin cancer.

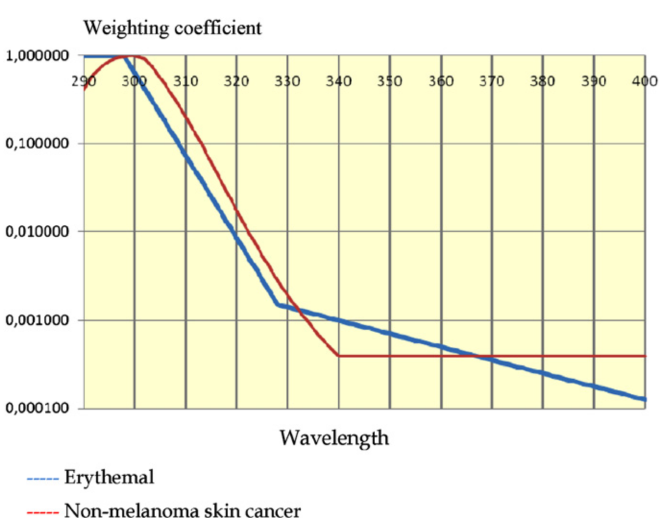

Fig. 1. Variations of weighting coefficients for each wavelength concerning erythema and non-melanoma skin cancer (Norme CEI 60335-2-27, 2002).

Table 2
Formulas used to determine various SPF and PF-UVA.

Indicator	Formula
SPF	$\frac{\sum_{290}^{400} Ee_\lambda S_\lambda \Delta\lambda}{\sum_{290}^{400} E_{e\lambda} S_\lambda T_\lambda \Delta\lambda}$
PF-UVA	$\frac{\sum_{320}^{400} Ee_\lambda S_\lambda \Delta\lambda}{\sum_{320}^{400} Ee_\lambda S_\lambda T_\lambda \Delta\lambda}$
Ratio R	$\frac{SPF}{FP-UVA}$
SPF medium (SPF_m)	$\frac{\sum_{290}^{400} (1/T_\lambda)\Delta\lambda}{\sum_{290}^{400} \Delta\lambda}$
PF-UVA medium ($PF\text{-}UVA_m$)	$\frac{\sum_{320}^{400} (1/T_\lambda)\Delta\lambda}{\sum_{320}^{400} \Delta\lambda}$
PF-UVA2 erythemal (PF-UVA2)	$\frac{\sum_{320}^{340} E_{e\lambda} S_\lambda \Delta\lambda}{\sum_{320}^{340} Ee_\lambda S_\lambda T_\lambda \Delta\lambda}$
PF-UVA1 erythemal (PF-UVA1)	$\frac{\sum_{340}^{400} E_{e\lambda} S_\lambda \Delta\lambda}{\sum_{340}^{400} E_{e\lambda} S_\lambda T_\lambda \Delta\lambda}$
SPF non-melanoma skin cancer (SPF_{nmsc})	$\frac{\sum_{290}^{400} Enmsc_\lambda S_\lambda \Delta\lambda}{\sum_{290}^{400} Enmnc_\lambda S_\lambda T_\lambda \Delta\lambda}$
Ratio R'	$\frac{SPFnmsc}{SPF}$
PF-UVA non-melanoma skin cancer ($PF\text{-}UVA_{nmsc}$)	$\frac{\sum_{340}^{400} Enmsc_\lambda S_\lambda \Delta\lambda}{\sum_{340}^{400} Enmsc_\lambda S_\lambda T_\lambda \Delta\lambda}$
PF-UVA2 non-melanoma skin cancer ($PF\text{-}UVA2_{nmsc}$)	$\frac{\sum_{320}^{340} Enmsc_\lambda S_\lambda \Delta\lambda}{\sum_{320}^{340} Enmsc_\lambda S_\lambda T_\lambda \Delta\lambda}$
PF-UVA1 non-melanoma skin cancer ($PF\text{-}UVA1_{nmsc}$)	$\frac{\sum_{340}^{400} Enmsc_\lambda S_\lambda \Delta\lambda}{\sum_{340}^{400} Enmsc_\lambda S_\lambda T_\lambda \Delta\lambda}$

With $E_{e\lambda}$, CIE erythemal spectral effectiveness, $E_{nmsc\lambda}$ non-melanoma skin cancer spectral effectiveness, S_λ solar spectral irradiance and T_λ spectral transmittance of the sample.

3. Results and discussion

The products all comply with the recommendations published in the EUOJ of 26 September 2009 (Table 3). We have calculated a

Table 3
Conformity of marketed products tested.

No.	SPF M ± DS	PF-UVA M ± DS	R	Critical wavelength λ_c (nm)
1	74 ± 9	27 ± 3	2.76	378
2	76 ± 5	53 ± 3	1.43	382
3	76 ± 4	53 ± 3	1.44	382
4	58 ± 7	20 ± 2	2.93	375
5	82 ± 6	38 ± 2	2.16	380
6	18 ± 2	12 ± 1	1.46	381
7	59 ± 4	33 ± 3	1.75	381
8	41 ± 6	21 ± 3	1.96	381
9	36 ± 3	12 ± 1	2.93	376
10	49 ± 3	18 ± 1	2.75	374
11	104 ± 11	39 ± 4	2.69	380

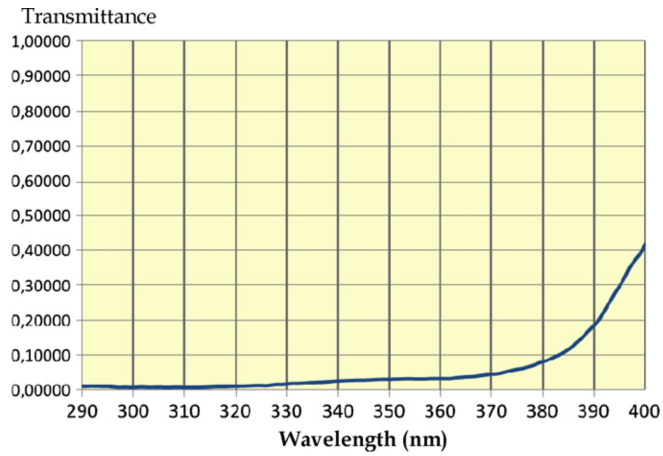

Fig. 2. Transmittance curve for product 1.

certain number of parameters to qualify these products and thus show their effectiveness. We concentrated firstly on the SPF values obtained using three different calculation methods: the index which currently figures on the packaging or SPF calculated using transmittance (Fig. 2) weighted by an erythemal factor, the SPF_m which forgets all weighting factors and the SPF_{cnm} which, for each wave length between 290 and 400 nm, attributes a different weight to each wave length as to its involvement in this type of cancer. The results are presented in Table 4. Note that the SPF_m is generally lower than the SPF. Conversely, the SPF_{cnm} shows no significant difference from the SPF or indeed is higher, which is a positive result. It is known that the UVB are major factors in the genesis of basal cell carcinomas and squamous cell carcinomas (Lim and Stern, 2005; Cooper and Bowden, 2007; Oberyszyn, 2008; Grant, 2008). Note that products displaying the same index (50+ for example) can vary in terms of protection against the occurrence of non-melanocytic skin cancers. This was observed in our study as the products with index 50+ tested produced ratios R' from 0.98 to 1.08. We found it interesting to take this ratio R' into account as it should, preferably, be higher than 1. Similarly, we were able to calculate different protection indices in the UVA field (Table 5). Note that the PF-UVA_m is almost systematically higher than the PF-UVA value. Note also that the PF-UVA2 calculated for the region with the most energetic UVA is systematically lower than the PF-UVA value. Continuing in a perspective of public health, it will be necessary to take the PF-UVA2 into account given their involvement in the occurrence of miscellaneous types of skin cancer (Rünger, 1999; Bachelor and Bowden, 2004; Larsson et al., 2005). Similarly, the PF-UVA_{cnm} is almost systematically lower than the PF-UVA. It seems interesting, therefore, to take account of the PF-UVA_{cnm} to be assured of effective protection in the UVA field.

Table 4
Comparison of SPF obtained according various methods of calculating.

No.	SPF_m M ± DS	SPF_{cnm} M ± DS	R'
1	50 ± 6	79 ± 9	1.08
2	72 ± 5	75 ± 5	0.98
3	72 ± 4	75 ± 4	0.98
4	40 ± 5	63 ± 7	1.09
5	57 ± 5	83 ± 6	1.01
6	13 ± 2	18 ± 2	1.00
7	45 ± 4	59 ± 4	1.00
8	28 ± 4	43 ± 7	1.05
9	25 ± 2	41 ± 3	1.12
10	33 ± 2	53 ± 3	1.09
11	72 ± 8	108 ± 10	1.04

Table 5
Efficacy of tested products in UVA range.

No.	FP-UVA_m M ± DS	FP-UVA2 M ± DS	FP-UVA1 M ± DS	FP-UVA_{cnm} M ± DS	FP-$UVA2_{cnm}$ M ± DS	FP-$UVA1_{cnm}$ M ± DS
1	29 ± 4	15 ± 2	50 ± 6	22 ± 2	68 ± 8	9 ± 1
2	70 ± 5	39 ± 2	72 ± 5	38 ± 2	74 ± 5	19 ± 1
3	70 ± 4	38 ± 2	72 ± 4	38 ± 2	74 ± 4	19 ± 1
4	22 ± 3	11 ± 1	40 ± 5	16 ± 2	57 ± 7	6 ± 1
5	42 ± 3	25 ± 2	57 ± 5	29 ± 2	67 ± 5	13 ± 1
6	11 ± 1	9 ± 1	13 ± 2	11 ± 1	17 ± 2	6 ± 1
7	38 ± 3	22 ± 2	45 ± 4	25 ± 2	56 ± 4	12 ± 1
8	21 ± 3	17 ± 2	28 ± 4	18 ± 2	27 ± 4	11 ± 1
9	13 ± 1	7 ± 0	25 ± 2	11±1	36 ± 4	5 ± 0
10	19 ± 1	10 ± 1	33 ± 2	15 ± 1	47 ± 3	6 ± 0
11	46 ± 6	22 ± 2	72 ± 8	29 ± 3	92 ± 10	12 ± 1

Given the increasing development, for ethical and economic reasons, of methods for determining the effectiveness of sunscreen products *in vitro*, it could be interesting to exploit all the results potentially provided by these spectrophotometric methods, under a public health initiative. As these *in vivo* methods can only be based on the erythematogenic effect of UVB radiations (Schulze, 1956) and UVA pigmentations (Meirowsky, 1902), the SPF and PF-UVA values only give us fragmented information on the effectiveness of sunscreen products, results centered solely on two conditions—actinic erythema and instant pigment darkening. The *in vitro* methods, on the other hand, generate far more information, especially on the effectiveness of products tested depending on the spectral zone (UVB, UVA2, UVA2) based on such and such an effect (effect in relation to actinic erythema, effect in relation to non-melanoma skin cancers). We thought it useful to start reflecting on the advantages of introducing new effectiveness indicators in the field of topical photoprotection, to make the best use of the information compiled. Whereas the SPF values displayed are lower than the SPF_{cnm}, which is interesting in terms of public health, thought must be given to protecting against UVA, as it is clear after measuring a few products on the market that the current method of calculating the PF-UVA tends to over-estimate protection in this area.

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