In vitro sun protection factor determination of herbal oils used in cosmetics

Chanchal Deep Kaur, Swarnlata Saraf

University Institute of Pharmacy, Pt. Ravishankar Shukla University, Raipur (C.G.) - 492 010, India

Submitted: 10-10-2009 Revised: 22-11-2009 Published: 13-03-2010

ABSTRACT

The aim of this study was to evaluate ultraviolet (UV) absorption ability of volatile and nonvolatile herbal oils used in sunscreens or cosmetics and express the same in terms of sun protection factor (SPF) values. Sun protection factor is a laboratory measure of the effectiveness of sunscreen; the higher the SPF, the more protection a sunscreen offers against the ultraviolet radiations causing sunburn. The *in vitro* SPF is determined according to the spectrophotometric method of Mansur *et al*. Hydroalcoholic dilutions of oils were prepared, and *in vitro* photoprotective activity was studied by UV spectrophotometric method in the range of 290-320 nm. It can be observed that the SPF values found for nonvolatile oils were in between 2 and 8; and for volatile oils, in between 1 and 7. Among the fixed oils taken, SPF value of olive oil was found to be the highest. Similarly among essential oils, SPF value of peppermint oil was found to be the highest. The study will be helpful in the selection of oils and fragrances to develop sunscreens with better safety and high SPF. Oily vehicles are more effective for producing a uniform and long-lasting film of sunscreen on the skin, and their emollient properties protect the skin against the drying effects of exposure to wind and sun. Volatile oils are used as perfumes in cosmetics.

Key words: Erythema, herbal oils, spectrophotometric method, sun protection factor, sunscreens

INTRODUCTION

Solar ultra violet radiations (UVR) is divided into three categories: UV-C (200-280 nm), UV-B (280-320 nm) and UV-A (320-400 nm). UV-C is the most biologically damaging radiation, but it is filtered out by ozone layer. Currently UV-B radiation and to a lesser extent UV-A radiation are responsible for inducing skin cancer. Sunscreens and sun blocks are chemicals that absorb or block UV rays and show a variety of immunosuppressive effects of sunlight.[1] The use of skin care products supplemented with several effective agents working through different pathways in conjunction with the use of sunscreens may be an effective approach for reducing UV-B-generated ROS-mediated photo-aging.[2]

Many liquid oils extracted from fruit and vegetable seeds are light, low in viscosity and less occlusive than hydrocarbon oils. Their penetrating and carrying properties, as well as their natural content of tocopherols, carotenoids and essential fatty acids, make them highly valuable. Several natural-base sunscreen lotions, including the oils of almond, avocado, coconut, cottonseed, olive, peanut, sesame and soyabean, have been reported to have UV filters. In general, when applied to skin, the vegetable oils are easily absorbed and show great spreadability. Volatile oils include odorous principles, which are found in various parts of plants, and are used as a fragrance and evaporate at room temperature. Essential oils have three distinct modes of action: Physiological (e.g., anti-inflammatory effects), psychological (e.g., aromatherapy) and cosmetic (e.g., preservative effects because of antibacterial or antioxidant properties), with corresponding benefits. Essential oils are used in the perfume industry as fragrances and in skin care products to promote hormonal balance to combat the buildup of toxins and for emolliency of skin.[3] We have selected a few herbal oils (volatile as well as nonvolatile) that are commonly used in cosmetics.

Address for correspondence:
Dr. Swarnlata Saraf, University Institute of Pharmacy,
Pt. Ravishankar Shukla University, Raipur (C.G.) - 492 010, India.
E-mail: swarnlata_saraf@rediffmail.com

DOI: 10.4103/0974-8490.60586

The efficacy of a sunscreen is usually expressed by the sun protection factor (SPF), which is defined as the UV energy required to produce a minimal erythemal dose (MED) in protected skin, divided by the UV energy required to produce an MED in unprotected skin (equation 1):

$$SPF = \frac{\text{minimal erythema dose in sunscreen-protected skin}}{\text{minimal erythema dose in nonsunscreen-protected skin}}$$

The minimal erythemal dose (MED) is defined as the lowest time interval or dosage of UV light irradiation sufficient to produce a minimal, perceptible erythema on unprotected skin.[4,5] The higher the SPF, the more effective is the product in preventing sunburn.

The *in vitro* screening methods may represent a fast and reasonable tool reducing the number of *in vivo* experiments and risks related to UV exposure of human subjects, when the technical test parameters are adjusted and optimized.[6] The *in vitro* methods are in general of two types: Methods that involve the measurement of absorption or the transmission of UV radiation through sunscreen product films in quartz plates or biomembranes, and methods in which the absorption characteristics of the sunscreen agents are determined based on spectrophotometric analysis of dilute solutions.[7-11]

Calculations to determine UV protection factors as defined by the COLIPA standard and other regulatory agencies involve measurement of the percent transmission of a sunscreen lotion sample across the UV spectrum weighted by the erythemal weighting factors at different wavelengths.[12]

The *in vitro* SPFs were determined according to the method described.[9,13,14] The observed absorbance values at 5 nm intervals (290-320 nm) were calculated by using the formula

$$\mathrm{SPF}_{\mathrm{spectrophootmetric}} = \mathrm{CF} \times \sum_{290}^{320} \mathrm{EE}(\lambda) \times \mathrm{I}(\lambda)\mathrm{Abs}(\lambda)$$

where CF = correction factor (10), EE (λ) = erythmogenic effect of radiation with wavelength λ, Abs (λ) = spectro photometric absorbance values at wavelength λ. The values of EE × I are constants. They were determined by Sayre *et al.*,[15] and are showed in Table 1.

However, there are many factors affecting the determination of SPF values, like the use of different solvents in which the sunscreens are dissolved; the combination and concentration of the sunscreens; the type of emulsion; the effects and interactions of vehicle components, such as esters, emollients and emulsifiers used in the formulation; the interaction of the vehicle with the skin; the addition of other active ingredients; the pH system and the emulsion rheological properties, among other factors, which can increase or decrease UV absorption of each sunscreen. The effect that different solvents and emollients have upon the wavelength of maximum absorbance and upon the UV absorbance of several sunscreen chemicals, alone or in combination, is well known and documented.[16,17] Excipients and other active ingredients can also produce UV absorption bands, thus interfering with those of UV-A and UV-B sunscreens. This effect is reflected in a finished formulation, especially for lotions with an SPF greater than 15.[18]

Vehicles used for sunscreens are hydroalcoholic lotions, water-in-oil or oil-in-water emulsions and oily lotions. The sunscreening preparation must spread on the skin, should remain in place as a continuous film, should closely adhere to the surface and should resist washing off by perspiration. When a hydroalcoholic solution is used, the water and alcohol quickly evaporate, leaving behind a self-plasticizing film of sunscreen which completely covers the skin and adheres closely to it. Standard techniques for spectrophotometric evaluation of sunscreens or suntan preparations involve solution of a known weight of the screen or preparation in an ultraviolet transparent solvent.

MATERIALS AND METHODS

Ethanol (Merck®) analytical grade. Oils of various manufacturers were purchased from local pharmacies. The solubility of oils was determined in different ratios of ethanol and distilled water. It is reported that maximum of 50% of ethanol could be used in cosmetics. Hence solubility of oils was detected taking 10% to 50% of ethanol in distilled water. The maximum solubility was observed in 40% ethanol and 60% distilled water solution.

Initial stock solution was prepared by taking 1% v/v of oil in ethanol and water solution (40:60). Then from this stock solution, 0.1% was prepared. Thereafter, absorbance values of each aliquot prepared were determined from 290 to 320 nm, at 5-nm intervals, taking 40% ethanol and 60% distilled water solution as blank, using Shimadzu UV-Visible spectrophotometer (Shimadzu 1800, Japan); values are shown in Table 1. It was found that if we increased the concentration of oil, then turbidity increased; and on decreasing the concentration, a negative reading was obtained.

Sun protection factor determination

The aliquots prepared were scanned between 290 and 320 nm, and the obtained absorbance values were multiplied with the respective EE (λ) values. Then, their summation was taken and multiplied with the correction factor (10).

RESULTS AND DISCUSSION

The SPF is a quantitative measurement of the effectiveness of a sunscreen formulation. To be effective in preventing sunburn and other skin damage, a sunscreen product should have a wide range of absorbance, viz., between 290 and 400 nm. The *in vitro* SPF is useful for screening test during product development, as a supplement of the *in vivo* SPF measure. In this research, volatile and nonvolatile herbal oils were evaluated by UV spectrophotometry applying Mansur mathematical equation.[9] SPF values of samples obtained using the UV spectrophotometric method are shown in Tables 1 and 2.

Table 1: Absorbances of hydroalcoholic nonvolatile herbal oils (fixed oils)

Wavelength (nm)	EE (λ) employed	Olive oil	Coconut oil	Castor oil	Almond oil	Mustard oil	Chaulmoogra oil	Sesame oil
290	0.0150	0.8002	0.6223	0.6268	0.5397	0.2144	0.1767	0.2800
295	0.0817	0.7807	0.6199	0.6054	0.5121	0.2113	0.1726	0.2311
300	0.2874	0.7675	0.6167	0.5858	0.4858	0.2070	0.1619	0.1970
305	0.3278	0.7537	0.6134	0.5659	0.4616	0.2018	0.1610	0.1653
310	0.1864	0.7403	0.6104	0.5488	0.4418	0.2013	0.1585	0.1539
315	0.0837	0.7286	0.6083	0.5314	0.4235	0.1979	0.1586	0.1456
320	0.0180	0.7177	0.6054	0.5156	0.4078	0.1948	0.1583	0.1433

Table 2: Absorbances of hydroalcoholic volatile herbal oils

Wavelength (nm)	EE (λ) × I Employed	Peppermint oil	Tulsi oil	Lemon grass oil	Lavender oil	Orange oil	Lemon oil	Tea tree oil	Eucalyptus oil	Rose oil
290	0.0150	1.1858	0.9752	1.1521	1.0147	0.2322	0.5381	0.6861	0.4288	0.0306
295	0.0817	0.8724	0.8523	0.8321	0.6909	0.2288	0.3872	0.3654	0.3516	0.0278
300	0.2874	0.6957	0.7857	0.6523	0.5647	0.2365	0.3022	0.1824	0.2899	0.0269
305	0.3278	0.5759	0.6321	0.5321	0.5394	0.2529	0.2629	0.1324	0.2500	0.0243
310	0.1864	0.4838	0.5274	0.4624	0.5345	0.2742	0.2439	0.1217	0.2236	0.0238
315	0.0837	0.3212	0.4312	0.3120	0.5203	0.3030	0.2287	0.1168	0.2035	0.0234
320	0.0180	0.2148	0.3102	0.2103	0.4832	0.3319	0.2133	0.1143	0.1908	0.0231

Table 3: Spectrophotometrically calculated sun protection factor values of herbal oils

Name of herbal oil taken	SPF value calculated spectrophotometrically
Olive oil	7.549
Coconut oil	7.119
Castor oil	5.687
Almond oil	4.659
Mustard oil	2.105
Chaulmoogra oil	2.019
Sesame oil	1.771
Peppermint oil	6.668
Tulsi oil	6.571
Lemon grass oil	6.282
Lavender oil	5.624
Orange oil	3.975
Lemon oil	2.810
Eucalyptus oil	2.625
Tea tree oil	1.702
Rose oil	0.248

It can be observed from Table 3 that the SPF values found for nonvolatile oils were in between 2 and 8; and for volatile oils, in between 1 and 7. Out of these nonvolatile or fixed oils taken, the SPF value of olive oil and coconut oil was found to be around 8; castor oil, around 6; almond oil, around 5; mustard oil and chaulmoogra oil, around 3; and sesame oil, around 2. Hence it can be concluded that olive oil and coconut oil have the best SPF values, a finding that will be helpful in the selection of fixed oil during the formulation of sunscreens.

Similarly SPF values for volatile oils were found to be in between 1 and 7. Out of these essential oils taken, the SPF value of peppermint oil and tulsi oil was found to be around 7; lavender oil, around 6; orange oil, around 4; eucalyptus oil, around 3; tea tree oil, around 2; and rose oil, around 1. Hence it can be concluded that peppermint oil and *tulsi* oil have the best SPF values, a finding that will be helpful in the selection of perfumes during the formulation of sunscreens.

Thus to develop sunscreens with better safety and high SPF, the formulator must understand the physicochemical principle, not only the UV absorbance of the actives but also vehicle components, such as esters, emollients, emulsifiers and fragrances used in the formulation, since sunscreens can interact with other components of the vehicle, and these interactions can affect the efficacy of sunscreens.

CONCLUSIONS

The proposed UV spectrophotometric method is simple, rapid, employs low-cost reagents and can be used in the *in vitro* determination of SPF values in many cosmetic formulations. The proposed methodology may be useful as a rapid quality-control method. It can be used during the production process, in the analysis of the final product, and can give important information before proceeding to the *in vivo* tests. The knowledge of SPF values of nonvolatile oils will help in the selection of oils for the formulation of various cosmetic dosage forms as oil is the most important constituent of creams and lotions.

Similarly SPF values of volatile oils will be helpful in the selection of perfumes.

ACKNOWLEDGMENTS

One of the authors wishes to thank UGC [major project, F. No. 32-133/2006(SR)], New Delhi, for financial support; and Head, Cosmetic Laboratory, University Institute of Pharmacy, Pt. R.S.S.University, Raipur, for providing facilities to use the required instruments.

REFERENCES

1. Ferrero L, Pissavini S, Marguerite, Zastrow L. Sunscreen *in vitro* spectroscopy: Application to UV A protection assessment and correlation with invivo persistent pigment darkening. Int J Cos Sci 2002;24:63-70.
2. Afaq F, Mukhtar H. Botanical antioxidants in the prevention of photocarcinogenesis and photoaging. Exp Dermatol 2006; 15:678-84.
3. Wolf R, Wolf D, Morganti P, Ruocco V. Sunscreens. Clin Dermatol 2001;9:452-9.
4. Aburjai T, Natsheh FM. Plants used in cosmetics. Phytotherapy Res 2003;17:987-1000.
5. Bendová H, Akrman J, Krejcí A, Kubác L, Jírová D, Kejlová K, *et al*. *in vitro* approaches to evaluation of Sun Protection Factor. Toxicol *in vitro* 2007;21:1268-75.
6. Wood C, Murphy E. Sunscreens Efficacy. Glob Cosmet Ind Duluth 2000;167:38-44.
7. Fourneron JD, Faraud F, Fauneron A. Sur la mesure *in vitro* de la protection solaire de crèmes cosmétiques. C R Acad Sci II 1999;2:421-7.
8. Gordon VC. Evaluation du facteur de protection solaire. Parfum Cosmet Arom 1993;112:62-5.
9. Mansur JS, Breder MNR, Mansur MCA, Azulay RD. Determinação Do Fator De Proteção Solar Por Espectrofotometria. An Bras Dermatol Rio De Janeiro 1986;61:121-4.
10. Pissavini M, Ferrero L, Alaro V, Heinrich U, Tronnier H, Kockott D, *et al*. Determination of the *in vitro* SPF. Cosmet Toiletries Oak Park 2003;118:63-72.
11. Walters C, Keeney A, Wigal CT, Johnstom CR, Cornelius RD. The spectrophotometric analysis and modeling of sunscreens. J Chem Educ 1997;74:99-102.
12. Allen MW. Measuring the sun protection factor of sunscreens. Thermo Scientific, 2007.
13. Santos EP, Freitas ZM, Souza KR, Garcia S, Vergnanini A. *in vitro* and *in vivo* determinations of sun protection factors of sunscreen lotions with octylmethoxycinnamate. Int J Cosmet Sci 1999;21:1-5.
14. Ashawat MS, Saraf S, Saraf S. Photo protective properties of Boerhavia diffusa, Biosciences. Biotech Res 2006;3:257-60.
15. Sayre RM, Agin PP, LeVee GJ, Marlowe E. Comparison of *in vivo* and *in vitro* testing of sunscreening formulas. Photochem Photobiol 1979;29:559-66.
16. Riegelman S, Penna RP. Effect of vehicle components on the absorption characteristics of sunscreens compounds. J Soc Cosmet Chem 1960;11:280-91.
17. Agrapidis-Paloympis LE, Nash RB, Shaath NA. The effect of solvents on the ultraviolet absorbance of sunscreens. J Soc Cosmet Chem 1987;38:209-21.
18. Dutra EA, Oliveira DA, Kedor-Hackmann ER, Santoro MI. Determination of sun protection factor (SPF) of sunscreens by ultraviolet spectrophotometry. Braz J Pharma Sci 2004;40:381-5.

Source of Support: Nil, **Conflict of Interest:** None declared.