



Short Review

Effects of solar radiation on hair and photoprotection



Michelli F. Dario *, André R. Baby, Maria Valéria R. Velasco

Departament of Pharmacy, University of São Paulo, 580 Prof. Lineu Prestes Avenue, Bl-13/15, 05508-000 São Paulo, Brazil

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ABSTRACT

In this paper the negative effects of solar radiation (ultraviolet, visible and infrared wavelengths) on hair properties like color, mechanical properties, luster, protein content, surface roughness, among others, will be discussed. Despite knowing that radiation damages hair, there are no consensus about the particular effect of each segment of solar radiation on the hair shaft. The hair photoprotection products are primarily targeted to dyed hair, specially auburn pigments, and gray shades. They are usually based on silicones, antioxidants and quaternary chemical UV filters that have more affinity for negatively charged hair surface and present higher efficacy. Unfortunately, there are no regulated parameters, like for skin photoprotection, for efficacy evaluation of hair care products, which makes impossible to compare the results published in the literature. Thus, it is important that researchers make an effort to apply experimental conditions similar to a real level of sun exposure, like dose, irradiance, time, temperature and relative humidity.

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1. Introduction

Hair fiber may be divided in three main layers: cuticles, cortex and medulla [1,2]. The medulla is the innermost portion of hair shaft. The cortex represents as much as 90% of the total weight of hair. This layer gives the hair strength, flexibility, elasticity and color (due to natural melanin and artificial pigments from hair dyes). The cortex is surrounded by a single layer of overlapping transparent, scalelike cells of cuticle (the outermost layer of hair fiber) [3,4].

The hair is composed mainly of proteinaceous material (specially keratin), lipids and other molecules like melanin that may be degraded

by exposure to sun radiation. The impact of solar radiation on the hair fibers are very discussed, but there is no consensus in the literature regarding the specific effects of different ranges of radiation (ultraviolet, visible and infrared) on the characteristics of hair fiber, like color, mechanical properties, luster, protein content, surface roughness and others. This difficulty is related to the lack of radiation exposure parameters harmonization such as dose, irradiance, temperature and relative humidity, as will be discussed in the text.

Solar radiation comprises the ultraviolet (UV) radiation (280–400 nm), visible (VIS) light (400–700 nm) and infrared (IR) (750–2800 nm). The UV radiation can be divided into three groups, according to the wavelength: UVA (315–400 nm), UVB (280–315 nm) and UVC (100–280 nm). The ozone layer blocks the entry of UVC, allowing the pass of 1–10% UVB and 90–99% UVA [5,6].

* Corresponding author.

E-mail address: michelli.dario@usp.br (M.F. Dario).

Table 1
Effects of different radiation wavelengths on hair fiber characteristics. Legend: D = Radiation dose; I = irradiance; TEM = Transmission Electronic Microscopy; SEM = Scanning Electronic Microscopy; t = time; T = temperature; ROS = reactive oxygen species; RH = relative humidity; VIS = visible radiation; UV = ultraviolet radiation; IR = Infrared radiation.

Radiation	Exposition parameters	Hair/fiber	Evaluated parameters	Mainly results	Ref. Year
UVA/UVB VIS/IR Global	UVA – 20 W; UVB – 400 W, VIS – 575 W; IR – 600 W; Global – 600 W; t = 1008 h; RH > 70%	Virgin black and light brown hair	Color, amino acids and cysteine content	VIS – color changed; UVA/UVB – changed amino acids in the cuticle, reduced cysteine, proline and valine in light brown hair; UVA/VIS – ↑ cysteine acid in the cuticle	[36] 1995
UVA/UVB VIS/IR Global	UVA – 20 W; UVB – 400 W, VIS – 575 W; IR – 600 W; Global – 600 W; t = 1008 h; RH > 70%	Virgin black and light brown hair	Color, melanin content	VIS – color change; UVA – ↓ melanin content of light brown hair; Irradiation did not affect black hair melanin; Photostability: eumelanin > pheomelanin	[25] 1995
UVA/UVB VIS/IR Global	UVA – 48 W/m ² ; UVB – 2.5 W/m ² ; VIS – 463 W/m ² ; IR – 440 W/m ² ; Global – 1037 W/m ²	Brown hair submitted to permanent, bleaching or treated with auburn dye	Color, mechanical properties, lipid content	UVA – ↓ protein content, ↓ mechanical resistance; VIS – color and lipids changed	[35] 1997
UV UV + VIS	UV = 5.06 mW/cm ² at 95% RH; UV + VIS = 41.272 mW/cm ² ; RH = 95%	Brown hair	Fiber surface (MEV)	High RH is essential to merge the cuticle layers in rigid and brittle structure, with loss of elasticity; melanin granules intact	[37] 2000
Natural and artificial sunlight	Natural (91 h); UVB (7 W/m ²) + UVA (23 W/m ²) + VIS (260 W/m ²) Artificial (56 to 448 h): UVB (9 W/m ²) + UVA (27 W/m ²) + VIS (100 W/m ²)/T = 30 ± 2 °C/RH = 50 ± 2%	Brown, blond, auburn, black and curly brown virgin hair	Protein loss, mechanical properties, fiber surface (MEV)	UVB – causes protein loss, UVA – color change Lighter hair – ↑ color changes, no effects on mechanical properties and cuticle aspect	[38] 2004
UV/VIS	I = 1600 W/m ² or 600 W/m ² ; 138.24 MJ/m ² ; T = 50 °C; RH = 85 or 20%	Blond hair	Mechanical properties, color	1600 W/m ² – structural damage; 600 W/m ² – color change; 85% RH – ↑ color change	[39] 2004
Artificial sunlight UV + VIS	D = 220 kJ/m ² ; RH = 50%; T = 55 ± 10 °C I = 149.7 J/h cm ² (400–800 nm); t = 8–32 h; RH = 35%; T = 45–50 °C	Blond hair treated with auburn dye containing silicones White, brown and bleached hair treated with light, medium and dark auburn dye	Color, combing Color	Silicones (trimethylsilyloxysilicate or propylphenylsilsesquioxane) protected color; dimethiconol and silicone resin gel improved combing Melanin protected color	[40] 2004 [22] 2005
VIS UV	T = 25–35 °C; RH = 20–30%	Red and blond hair	Color, melanin granules (SEM)	VIS – Blond hair lightened more than red UV – Red hair lightened more than blond Percentage of disappeared melanin granule higher in red hair	[30] 2005
UV + VIS + IR	UV + VIS + IR UVA + VIS + IR IR (oven) T = 30 ± 2 °C; RH = 50 ± 2%	Virgin white, dark brown, blond and auburn hair	Color	White hair: yellowing under IR Auburn and dark brown (UV + VIS + IR): yellowing Blond (UV + VIS + IR): bleaching and melanin degradation	[41] 2007
UVB + UVA + VIS/UVB + VIS	t = 1344 h (mercury lamp); 200 h (xenon lamp)	Virgin or bleached dark brown hair	Mechanical properties	UVB – ↓ mechanical resistance	[41] 2007
UV	UVA = 28.3 mW/cm ² ; UVB = 9.6 mW/cm ²	Black and brown hair	Melanin signal by electron spin resonance (ESR) spectroscopy studies	UV generated melanin radical	[7] 2008
UVA UVB	UVA = 6680 J; UVB 58.32 J; RH = 30%	Virgin brown hair	Cuticle integrity; protein and lipid content	UVB – cuticle damage; UVA and UVB – ↓ lipids; UVA – ↑ protein loss	[8] 2008
UVB UVA + VIS	I = 35337 W/m ² ; t = 48 h I = 283 W/m ² (t = 45 ou 90 min); I = 500 W/m ² (t = 9, 18, 24, 36 and 48 h)	Wool Virgin auburn hair	Color; tryptophan content Protein loss; tryptophan content; lipid peroxidation; ROS generated	Tryptophan degradation mainly in cortex Protein loss; 283 W/m ² → ROS produced after 90 min of exposition; 500 W/m ² → tryptophan degradation and lipid peroxidation	[14] 2010 [13] 2012
UV	I = 500 W/m ² ; t = 18, 24, 36 and 48 h.	Virgin brown and hair treated with auburn dye	Mechanical properties, protein loss, tryptophan degradation, lipid peroxidation, MEV, color	After 18 h – protein loss, lipid peroxidation; 24 h – tryptophan degradation; 36 h – cuticle lifted (MEV), color change	[33] 2012
UVA UVB	UVA = 3.97 mW/m ² ; UVB = 0.79 mW/m ²	Black hair, eumelanin and pheomelanin isolated	Ration PTCA free/total (indicator of melanin degradation); ratio TTCA/4-AHP (indicator of pheomelanin degradation)	UVA – ↓ eumelanin and pheomelanin	[29] 2012
UVB	Doses from 0–4 J/cm ²	Hair obtained from 20 females (25 to 31 years)	Cuticles morphology and organic functional groups	No significant cuticle damage, conversion of α-helix to β-sheet	[42] 2012
UVA/UVB	UVA = 20 J (t = 12 h); 40 J (t = 24 h); UVB = 8 J (t = 12 h); 16 J (t = 24 h); RH = 30%; room temperature	Asian, Caucasian and African hair	Hair surface (MEV), cuticle damage (MET); lipid content	UVB – cuticle damage and African hair is the most affected; UV – ↓ content of lipids except for Asian hair	[43] 2013
UV + VIS + IR VIS + IR	Artificial: VIS + IR; UV + VIS + IR – periods of 8 h, followed by a periods of 16 h in the dark; t > 200 h; T = 28 ± 2 °C; RH = 35 ± 9%. Natural: from 10 am to 3 pm; VIS + IR; solar full-spectrum (UV + VIS + IR); t = 50 h; T = 28 ± 2 °C; RH = 56 ± 14%	White hair	Color	VIS – photobleaching in white hair Free radicals formed during the irradiation continues acting in the dark period Yellowing after thermal degradation at 81 °C Sunlight – photoyellowing and photobleaching UV and heat – yellowing	[26] 2014

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