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Assessing UV Damage and Antioxidant Influence on Human Hair Using a Combination of Spectroscopic, Thermal and Physical Measurements

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Introduction:

Human hair is constituted of protein, protein-bound sulfur, and lipid; components that are labile to oxidative damage induced by photo energy and reactive oxygen species [1, 2]. Ultraviolet (UV, 200-400 nm) can provoke hair protein degradation, the photochemical process is known to oxidize the sulfur-sulfur bond within hair cortex, reducing hair strength and diminishing hair color [2, 3]. The proteins of hair cuticle can also be compromised by UV, the destruction causes hair to become dry, dull, stiff, and difficult to manage [4, 5]. While different approaches have been applied to study the degree of hair damage caused by UV irradiation, because the level of UV damage is linked to exposure dosage, hair condition, and preventing treatment, there are still unknown characters to be discovered. In this study, we explored the combined approach of employing various spectroscopic and physical measurement techniques to study UV induced damage of medium brown hair after exposed to controlled dose of UVA, recurrent cycles of UV/Ozone, accumulative exposure of UVA/UVB, and the antioxidant protection effect of Hydrolyzed Cicer Seed Extract from both solution and conditioner treated hair.

Materials & Methods:

- **Hair sample**

European medium brown hair purchased from International Hair Importers, 8729 Myrtle Ave, Glendale, NY 11385.

- **Testing formulation**

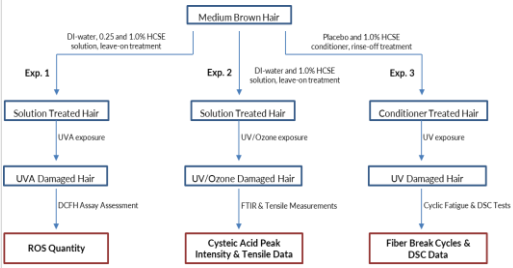
1) 0.25% and 1.0% active Hydrolyzed Cicer Seed Extract (HCSE) solution
2) Conditioner formulation:

Ingredients (wt.%)	Placebo	HCSE-0.25	HCSE-1.00
De-ionized Water	93.0	91.4	86.5
Behentrimonium Methosulfate (and) Cetyl Alcohol (and) Butylene Glycol	6.0	6.0	6.0
Phenoxyethanol (and) Ethylhexylglycerin	1.0	1.0	1.0
Hydrolyzed Cicer Seed Extract (15.39% active)	0.0	1.6	6.5

- **Testing instrument**

1) Xenon Weather-Ometer CI3000+, Atlas, Mount Prospect, IL, USA.
2) NO2/NO/O3 generator Model 713, 2B Technologies, Boulder, CO, USA.
3) Automatic Tensile Tester MTT690, Dia-Stron, Andover SP10 5NY, UK.
4) Cyclic Tester CYC802, Dia-Stron, Andover SP10 5NY, UK.
5) Differential Scanning Calorimeter (DSC) Q250, TA Instrument, DE, USA.
6) FTIR spotlight System 400, PerkinElmer, Inc., Waltham, MA, USA.

- **Experimental Protocol:**



Results & Discussion:

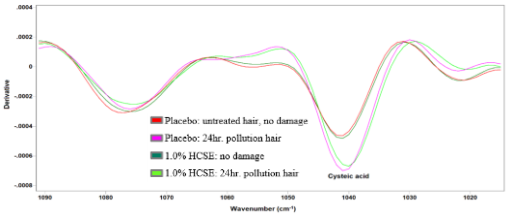
Exp. 1, DCFH assay results of leave-on solution treated hair

Hair treatment	No UVA, Fluorescence*	10J/cm² UVA, Fluorescence*	%Fluorescence change vs. no UVA	%Fluorescence reduction vs. untreated
Untreated hair	15402, +/- 1852	38094, +/- 726	147	Reference
0.25% HCSE solution	8511, +/- 371	15069, +/- 1682	77	-70**
1.0% HCSE solution	7514, +/- 31	13152, +/- 773	75	-72**

*: Arbitrary fluorescence units; **: difference is significant.

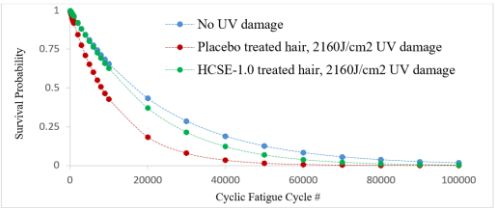
DCFH data in Exp. 1 indicates that antioxidant Hydrolyzed Cicer Seed Extract reduced ROS quantity of hair from UVA exposure by 70% vs. unprotected hair.

Exp. 2, Second derivative spectra from average FTIR spectra (cysteic acid region)



FTIR peak intensity of hair treated with antioxidant shows 13.6% less cysteine was oxidized to cysteic acid vs. the unprotected hair.

Exp. 3, Weibull survival probability of undamaged and UV damaged hair



Weibull analysis suggests that antioxidant protected hair has higher survival probability in comparison with that of unprotected hair.

Conclusions:

- The study results confirm that the intensity of fluorescence from DCFH-DA assay reflects quantity of reactive oxygen species generated due to photo oxidation of hair proteins. Internal structure damage of hair can be detected by FTIR using intensity of cysteic acid peak as indicator. DSC data validates cross-link density of hair matrix, as denaturation temperature and enthalpy of UV damaged hair decrease correspondingly to the increased exposure UV dosage.
- Tensile and cyclic fatigue data are consistent with results from DCFH-DA, FTIR and DSC measurements, which indicates that the internal structure damage of hair weakens the natural strength of hair. The collective UV damaging impact and antioxidant protection effect, such as with Hydrolyzed Cicer Seed Extract, can be best verified with a combined approach of employing various spectroscopic and physical measurement techniques.

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