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"Hair and environmental stress: evaluation of the protective effect of a cosmetic product against "particle and UV pollution" stress by instrumental methods"

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1. Introduction

Hair, like the skin, is subject to many environmental stresses that will degrade its surface condition and structure, leading to an alteration in its appearance. For example, air pollution (fine particles, exhaust fumes, etc.) will weaken the hair fiber, making the hair duller, drier and brittle. Exposure to the sun's ultraviolet rays will degrade keratin, the main protein in the hair, making it brittle, and can cause natural hair discoloration. It is important to be able to protect hair with cosmetic products in order to maintain their integrity.

The objective of this work is to evaluate the protective effect of a patented natural cosmetic active ingredient, coming from *Passiflora edulis* fruits seeds and rich in polyphenolic compounds, on hair strands against an environmental stress of type «particle and UV pollution" using three different approaches: measurement of the gloss from photographs (effect on surface finish), counting of the number of broken hair after combing (anti-brittle effect) and measurement of the color loss after 1, 5, 10 and 15 shampoos of colored hair strands (color hold effect).

2. Materials and Methods

Environmental stress applied to hair

The strands of hair were subjected to a damaging process simulating a "particle and UV pollution" stress. For that, the hair was subjected to a cycle consisting of:

- 12-hours of UV irradiation.
- Exposure to the "Arizona Dust" for 5 minutes (1.35g/g of grams of dust per gram of hair).

Exposure to ultraviolet radiation was conducted for 12 hours using a specific ultraviolet solar radiation simulator equipped with xenon lamps.

Arizona Dust is a standardized dust defined in the ISO12103-1. It has a defined particle size and chemical composition (Table 1) which makes it possible to standardize environmental particle stress. The finest particle size was used ("ultrafine" powder). The exposure of the hair to dust is carried out in a specific chamber.

Element	% of weight	Element	% of weight
Silicon	69.0-77.0	Calcium	2.5-5.5
Aluminum	8.0-14.0	Magnesium	1.0-2.0
Iron	4.0-7.0	Titanium	0.0-1.0
Sodium	1.0-4.0	Potassium	2.0-5.0

Table 1. Arizona Dust composition.

Hair classification

For some tests the hair used were selected according to the André Walker classification. This classification system ranging from 1A to 4B is represented Figure 1.

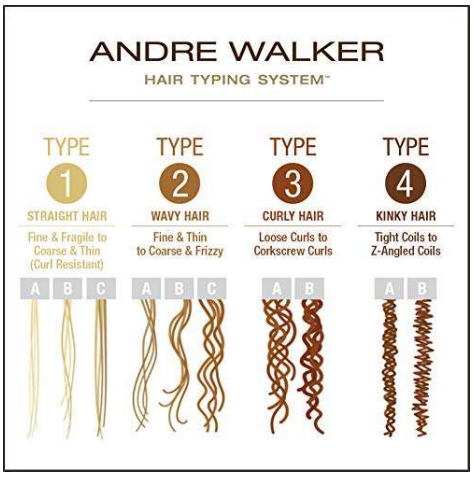

Figure 1. Andre Walker hair typing system.

Products

Before applying the environmental stress to the hair, a formula containing 3% of the Active ingredient, a Placebo or no treatment were applied to 3 different groups of strands from the same hair batch.

Measurement of the protective effect by assessing gloss from photographs

The protective efficacy of the Active ingredient on the gloss of hair was compared to a Control and a Placebo conditions on hair strands damaged by the environmental stress using photographs.

Hair gloss is one of the most important efficacy attributes related to the formulation of a shampoo or treatment. When light is focused on the hair fibers, it spreads over the uneven surface of the hair and reflects from different angles. The absorption of certain wavelengths and the emission of the respective complements also take place. The conjunction of these phenomena,

generically known as diffuse reflection, is at the origin of the brightness and color of the material. However, some of the reflected light hits the viewer from the same angle, providing greater light intensity. This phenomenon is known as specular reflection, brilliance or gloss and it is enhanced by reduced diffuse light, i.e., increased surface regularity.

Fifteen strands, weighing 5.0 g each and measuring 25 cm long (5 strands per group) were prepared (natural brown hair, André Walker classification 1 A-B). The hair was wet for 20 seconds, excess water removed and no product (Control), Placebo or Active (0.5 mL of Placebo and Active) were rub on hair for 60 seconds. No rinsing was performed.

After the application of the products and the application of the environmental stress, the gloss was assessed. For that, the hair strands are placed on a standardized support and an image is taken using a digital camera. From the same area obtained by the photographs before and after the treatments, the digital images are converted to grayscale, binarized and the “gloss” pixels are counted. Raw and processed pictures are shown in the Figure 2 below.

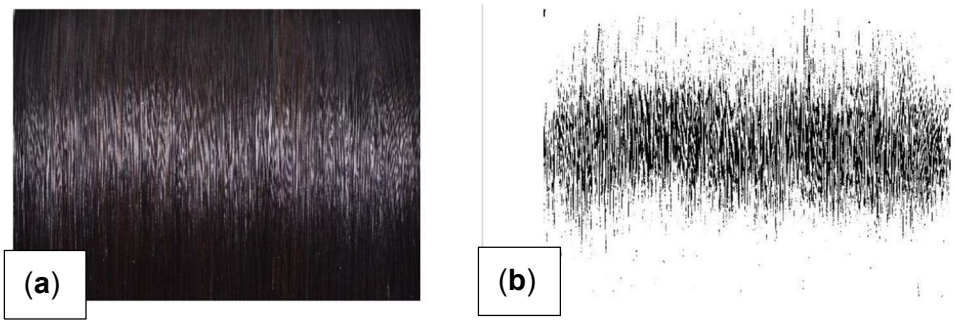

Figure 2. (a) Raw picture from digital camera and (b) binarized picture used to count “gloss” pixels.

The gloss parameter is determined as the percentage of black pixels in the area that refer to the area obtained after binarization.

Study of the anti-brittle effect by evaluating the number of hairs broken after combing

The protective efficacy of the Active ingredient on the “anti-brittle property” of hair was compared to a Control and a Placebo conditions on hair strands damaged by the environmental stress by an evaluation of the number of broken hairs after combing.

In the present study, colored natural Caucasian hair (6.66 tone "red" color) was used. Fifteen strands were prepared weighing 5.0 g each and measuring 25 cm long (5 strands per group). The hair was wet for 20 seconds, excess water removed and no product (Control), Placebo or Active (0.5 mL of Placebo and Active) were rub on hair for 60 seconds. No rinsing was performed.

After the application of the products and the application of the environmental stress, the hair underwent 5 successive combing cycles using an automated hair comber. Each cycle consisted of 1000 combing at 25 rpm in a controlled environment at 55 ± 5% relative humidity and 22 ± 2 °C. After the 5 cycles, hair has been removed from the equipment and broken hair fibers have been counted.

Study of the maintenance of the color of colored hair strands

The protective efficacy of the Active ingredient on the color maintenance of hair was compared to a Control and a Placebo conditions on hair strands damaged by the environmental stress by an evaluation of the color after 1, 5, 10 and 15 shampoo washes.

In the present study, colored natural Caucasian hair (6.66 tone "red" color) was used. Nine strands were prepared weighing 5.0 g each and measuring 25 cm long (3 strands per group).

The hair was subjected to the following cycle 15 times:

- The hair was wet for 20 seconds, excess water removed and no product (Control), Placebo or Active (0.5 mL of Placebo and Active) were rub on hair for 60 seconds. No rinsing was performed.
- The environmental stress was applied.
- A shampoo wash was performed.

Color measurements of hair has been carried out after 1, 5, 10 and 15 washes using a colorimeter. For each strand, an average color value was obtained with 10 color measurements. The measurement of the color was calculated in the international colorimetric system CIE-L*a*b*, developed by the CIE (International Commission on Illumination) as illustrated in the Figure 3 below.

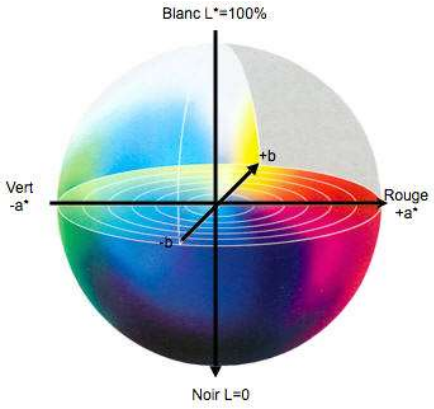

Figure 3. CIE-L*a*b* colorimetric system.

Determining color difference can be done using various equation. The CIE94 color system, developed in 1994 by CIE, is widely used by the graphics industry to evaluate color. The equation used to calculate the color differences was established on the basis of light parameters, matrix and chromaticity. Dynamic compensation factors have been introduced to achieve better correlations with human eyesight. In the CIE94 color system, the color difference, called ΔE*94, is considered visually perceptible to human sight when it reaches values greater than 1.0. The Equation 1 below shows the calculation of ΔE*94.

$$\Delta E^*_{94} = \sqrt{\left(\frac{\Delta L^*}{k_L s_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{k_c s_c}\right)^2 + \left(\frac{\Delta CH^*_{ab}}{k_h s_h}\right)^2}$$

Equation 1. ΔE*94 formula for calculating total color variation. L: luminosity, C: chromaticity, H: hue. Details can be found at reference [1].

The color difference for each group is evaluated by calculating the ΔE*94 parameters between the initial strands after colouring, and the strands that have undergone environmental stress and have been washed 1, 5, 10 and 15 times.

3. Results

Data Statistics

For each measurement, a comparison between each group (Control, Placebo, Active) is made. As the number of measurements is small, the data are considered to follow a normal distribution and the Student's test for matched data is performed, all the hair tested coming from the same batch. In the tables, the means (m) and standard deviations (σ) are calculated for each group and are noted (m±σ). In the figures, a significant p-value below the threshold $\alpha<0.05$ between 2 groups is noted by a solid bar.

Protective effect by assessing the gloss from photographs

The percentage of “gloss” pixel measured for the Control, Placebo and Active groups are illustrated Figure 4 below.

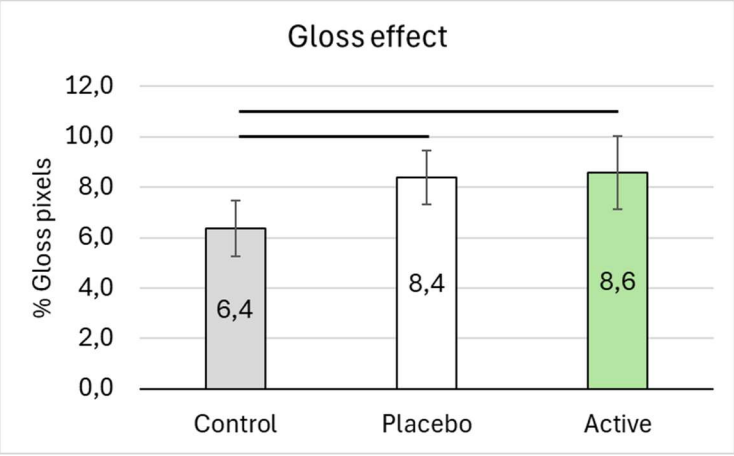

Figure 4. percentage of gloss pixels counted from photographs.

The data for each group and the statistical results are in the Table 2 below.

Groups	1st Group (m ± σ)	2nd Group (m ± σ)	Δ(Group 2-Group 1) (m ± σ)	Δ%(Group 2 /Group 1)	P value
Control vs Placebo	6,36±1,07	8,38±1,1	2,02±1,14	31,8%	<0,05 - S
Control vs Active	6,36±1,07	8,56±1,45	2,2±1,24	34,7%	<0,05 - S
Placebo vs Active	8,38±1,1	8,56±1,45	0,18±1,19	2,2%	NS

Table 2. Data of gloss measurement.

The results show a significant protective effect of the Active on the gloss measured from photographs compared to the group of damaged strands (+34.7%).

Protective effect by assessing the number of hairs broken after combing

The number of broken hair counted for the Control, Placebo and Active groups are illustrated Figure 5 below.

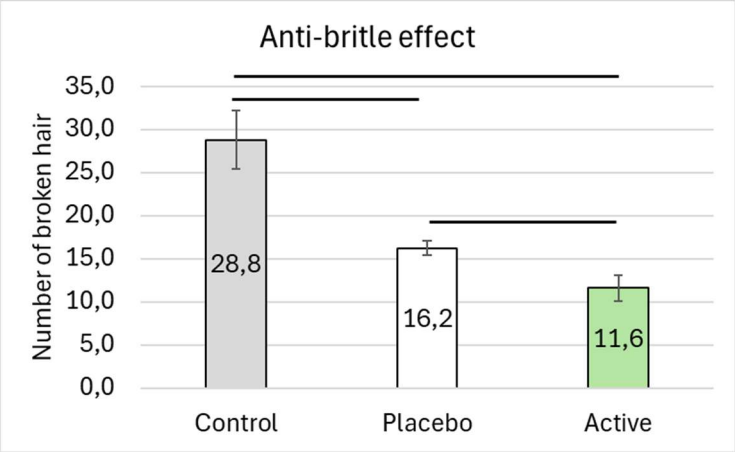

Figure 5. Number of broken hair counted.

The data for each group and the statistical results are in the Table 3 below.

Groups	1st Group (m ± σ)	2nd Group (m ± σ)	Δ(Group 2-Group 1) (m ± σ)	Δ%(Group 2 /Group 1)	P value
Control vs Placebo	28,8±3,42	16,2±0,84	-12,6±3,85	-43,8%	<0,05 - S
Control vs Active	28,8±3,42	11,6±1,52	-17,2±4,15	-59,7%	<0,05 - S
Placebo vs Active	16,2±0,84	11,6±1,52	-4,6±0,89	-28,4%	<0,05 - S

Table 3. Data of anti-brittle measurement effect.

The results show a significant anti-brittle effect of the Active compared to the group of damaged strands (-59.7%) and compared to the group of strands treated with Placebo (-28.4%).

Protective effect by assessing the maintenance of the color of colored hair strands

The color variation ΔE*94 measured for the Control, Placebo and Active groups between the initial color of the hair and 1, 5, 10 and 15 washes are illustrated Figure 6 below.

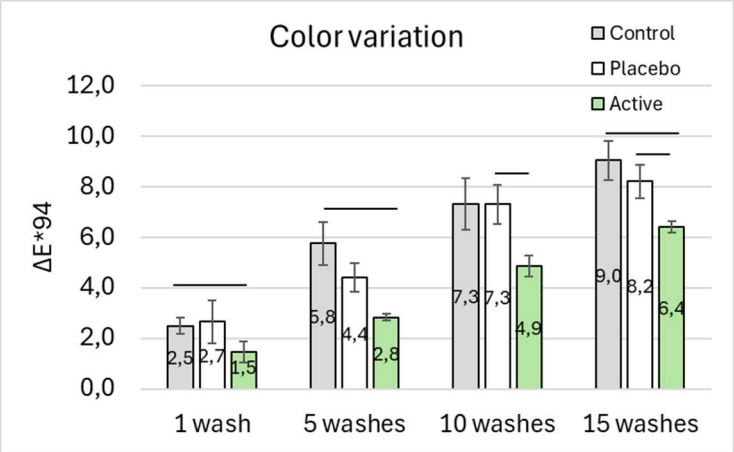

Figure 6. Color variations ΔE*94 measured for the Control, Placebo and Active groups.

The data for each group and the statistical results are in the Table 4 below.

Groups	1st Group (m ± σ)	2nd Groupe (m ± σ)	Δ(Group 2-Group 1) (m ± σ)	Δ%(Group 2 /Group 1)	P value
Control w1 vs Placebo w1	2,49±0,33	2,66±0,84	0,17±1,06	6,8%	NS
Control w5 vs Placebo w5	5,76±0,84	4,4±0,57	-1,36±1,19	-23,7%	NS
Control w10 vs Placebo w10	7,34±1,02	7,32±0,78	-0,02±1,16	-0,3%	NS
Control w15 vs Placebo w15	9,05±0,78	8,22±0,67	-0,82±1,08	-9,1%	NS
Control w1 vs Active w1	2,49±0,33	1,46±0,42	-1,03±0,2	-41,5%	<0,05 - S
Control w5 vs Active w5	5,76±0,84	2,84±0,15	-2,92±0,75	-50,7%	<0,05 - S
Control w10 vs Active w10	7,34±1,02	4,86±0,41	-2,48±1,4	-33,7%	NS
Control w15 vs Active w15	9,05±0,78	6,42±0,21	-2,63±0,71	-29%	<0,05 - S
Placebo w1 vs Active w1	2,66±0,84	1,46±0,42	-1,2±0,98	-45,2%	NS
Placebo w5 vs Active w5	4,4±0,57	2,84±0,15	-1,56±0,71	-35,5%	NS
Placebo w10 vs Active w10	7,32±0,78	4,86±0,41	-2,45±0,78	-33,5%	<0,05 - S
Placebo w15 vs Active w15	8,22±0,67	6,42±0,21	-1,8±0,5	-21,9%	<0,05 - S

Table 4. Data of color variations ΔE*94 (w=wash).

The Placebo has no effect compared to the Control group. The Active has a positive effect on the maintenance of color-treated hair strands with a significant difference compared to the Control group after 1, 5, and 15 washes (reduction of the color loss of respectively 41.5%, 50.7% and 29%) and a significant positive effect compared to the Placebo after 10 and 15 washes (reduction of the color loss of 33.5% and 21.9% respectively).

4. Discussion

Taking care of hair is essential to protect it from external aggressions such as pollution, UV rays, wind or temperature changes. These factors can weaken the hair fiber, making it dry, brittle and dull. By adopting an adapted hair routine, the strength and health of the hair can be preserved. It is important that this hair routine has a protective effect against external aggressions since, unlike the skin, hair does not renew itself.

In this study, 3 different approaches were implemented to evaluate the protective effect of an Active ingredient on the problems of shine, resistance and color retention which are important. The advantage of these methods is that they can be implemented on hair strands in controlled environments allowing a high repeatability and reproducibility, thus minimizing the number of measurements needed to obtain robust results.

The measurement performed and results obtained highlight the effect of the Active Ingredient on untreated strands or treated with a Placebo. Other tests such as the evaluation of the condition of the scales using Scanning Electron Microscopy or the evaluation of the effect on combing facility could complete the evaluation of the effectiveness of this Active.

5. Conclusion

This natural Active would be a good candidate for a shampoo that takes care of shine, anti-brittle and color maintenance hair aspects.

References

[1]-https://opentextbc.ca/graphicdesign/chapter/4-4-lab-colour-space-and-delta-e-measurements/