Repair Factor for Oxidative Damage to Hair Fiber

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Abstract

The degradation of protein chains or the repair obtained by cosmetic treatments in the face of the oxidative effects suffered by the hair fiber, can be evaluated by the behavior of the groups –S-S- and SO_3-, that make up human hair. Combability is an attribute measurable through the total energy expended due to friction between the comb and the external surface of the hair tress. This work aimed to evaluate the repair attribute of oxidative damage, using Infrared Spectroscopy, FTIR-ATR (Fourier Transform Infrared Spectroscopy using Attenuated Total Reflectance) combined with the wet and dry hair combing technique.

Key-words: Hair, Hair Oxidative process, Repair Factor for Oxidative Damage, FTIR-ATR (Fourier Transform Infrared Spectroscopy using Attenuated Total Reflectance), Combability.

Introduction

Hair damage is cause by several factors like chemical treatments, heat styling, environmental pollutants, grooming and ultraviolet exposure [1]. Damaged hair loses its natural shine, elasticity, and strength, leading to issues like split ends, breakage, and frizz [2].

Robbins and Bahl [3] studied photochemical damage to hair caused by exposure to A and B ultraviolet solar radiation. Their studies showed that the mechanical properties of fibers change when exposed to ultraviolet radiation. According to the authors, this alteration is caused by chemical degradation of protein chains, particularly S-S bonds attributed to cystine amino acid. According to the mechanism of photolysis proposed by Tolgyesi [4], cystine, tyrosine, phenylanine and tryptophane residues absorb ultraviolet radiation, and this leads to buildup of free radicals.

Degradation of protein chains and the protection delivered by cosmetic products from oxidizing effects can be assessed through the behavior of the –S-S- e SO3- groups that compose human hair [4].

Analysis of hair using Fourier Transform Infrared Attenuated Total Reflection (FTIR-ATR) spectroscopy are basically when an infrared radiation passed through a hair sample via an ATR crystal, which causes changes in the infrared spectrum based on the chemical composition of the sample [5]. Hair fibers from human scalp can be analyzed by spectroscopic investigations. By means of infrared spectroscopy or Raman spectroscopy, it is possible to discriminate between untreated fibers and cosmetically treated fibers through visual inspection of the spectra. Spectroscopic techniques such as infrared and Raman supply information on the -SS- groups via reduction and oxidation. The prominence and intensity of vibration of the SO3- band at 1040 cm-1 showed that disulphite bonds (-S-S-) had been cleaved and then oxidized down to residues of cysteic acid due to the action of hydrogen peroxide in bleaching, exposure to ultraviolet solar radiation and chemical hair straightening procedures, among others [6,7].

Degradation of protein chains and the protection delivered by cosmetic products from oxidizing effects can be assessed through the behavior of the –S-S- e SO3- groups that compose human hair. The S-S fission route is the most relevant pathway to report the chemical oxidation in relation to permanent waves, straightening and reducing agents [6,7].

Based on the previous studies, the bands at 510, 525, and 540 cm^{-1} are assigned to the gauche-gauche-gauche, gauche-gauche-trans and trans-gauche-trans conformations of S-bridges. The band characteristic to disulfide is observed at 525 cm^{-1} [8].

The lower area ratio value indicates the reduction of 1040 cm^{-1} (characteristic cysteic acid peak) that indicates that the product evaluated repair of cysteic acid oxidation damage (S=O ligations) [3].

Combability is the ease with which hair can be detangled and styled without causing damage or breakage. Healthy hair typically exhibits good combability, meaning it is smooth, flexible, and resistant to tangling. However, damaged hair often experiences poor combability due to factors such as roughened cuticles, weakened protein bonds, and increased friction between hair fibers [9].

Materials and methods

Hair tresses

Study groups: Caucasian hair tresses were used (natural and double bleached) – 2,5g / 25cm – 3 tresses of each hair type. The tresses were submitted to the application of shampoo and conditioner as described on **Table 1.**

Table 1. Procedure of products application

Treatment	Procedure
Shampoo	Wet 20s. Apply 0,2 ml/g of hair, massage 30s. Rinse 30s.
Conditioner	Wet 20s. Apply 0,2 ml/g of hair, massage 30s. Leave it rest 2min. Rinse 30s.

Hair Combability

The wet and dry combabilities were evaluated to conditions Natural, Bleached and Final (after treatments). Instron 23-2S (software Bluehill 4.21) test equipment was used, with a fixed holder with a standard comb, coupled to a previously calibrated 100.0 N load cell.

Infrared Spectroscopy, FTIR-ATR

Spectroscopy analyses were performed using the equipment Infrared spectrophotometer (Model Frontier - PerkinElmer) with ATR cell (Pike Technologies) and ZnSe crystal.

The ratio data between the areas 1040 cm^{-1} (asymmetric stretching of the S=O bond) and 1650 cm^{-1} (primary amide C=O bond) for the treatments.

Statistics

Comparison between Natural, Double bleached hair and doubled bleached hair treated with Shampoo and Conditioner: the combability energy values and spectroscopic analyses values (cysteic acid/ amide area ratio and disulfide bond area) were compared using one-way ANOVA, followed by a Dunnett's post-test, considering a 95% confidence interval (p-value ≤0.05 for statistically significant differences). Statistical comparations were performed using the software GraphPad Prism, version 8.3.4.

Calculation of Hair's Damage Repair Factor

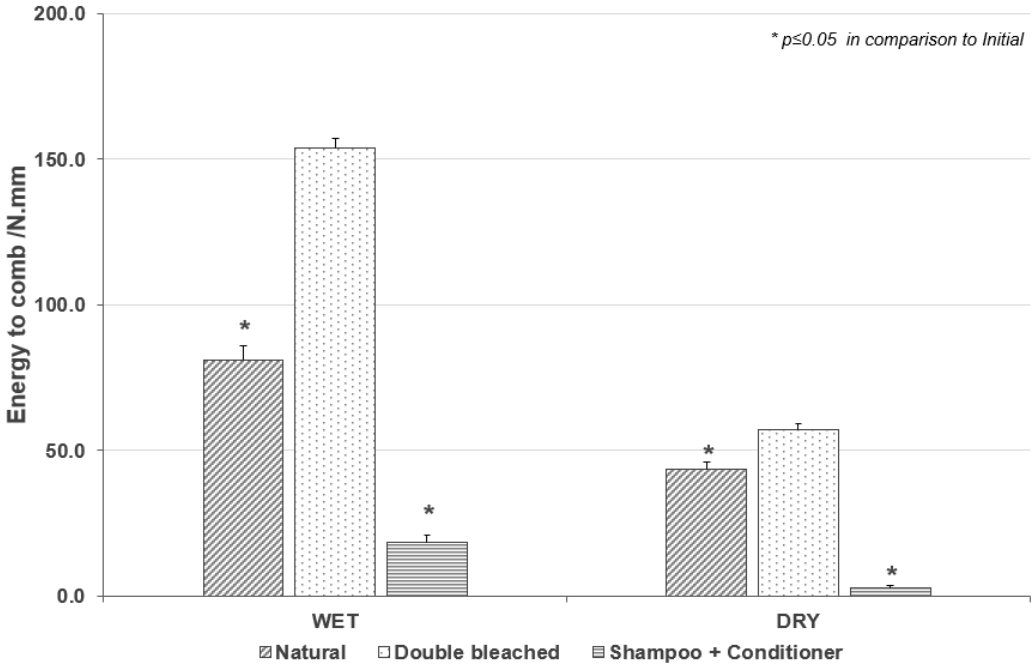
A coefficient Q of combability energy was calculated to wet and dry to Doubled bleached tresses and doubled bleached tresses treated with shampoo and conditioner in relation to Natural condition.

Then, a slope (curve's interpolation) of energy to comb values and cysteic acid/ amide area ratio (1040 cm^{-1}/1650 cm^{-1}) was made resulting in a number (N) that correlates the two parameters. If there is a statistical difference between the double bleached tresses after treatment with shampoo and conditioner is possible to calculate a Hair's Damage Repair Factor. This factor is a ratio between the number calculated to N of doubled bleached and doubled bleached hair treated with shampoo and conditioner.

Results

Graph 1 illustrates the data for Energy (N.mm) obtained for combability of **wet** and **dry** tresses.

Graph 1. Results of Energy (N.mm) for Wet and Dry combability.



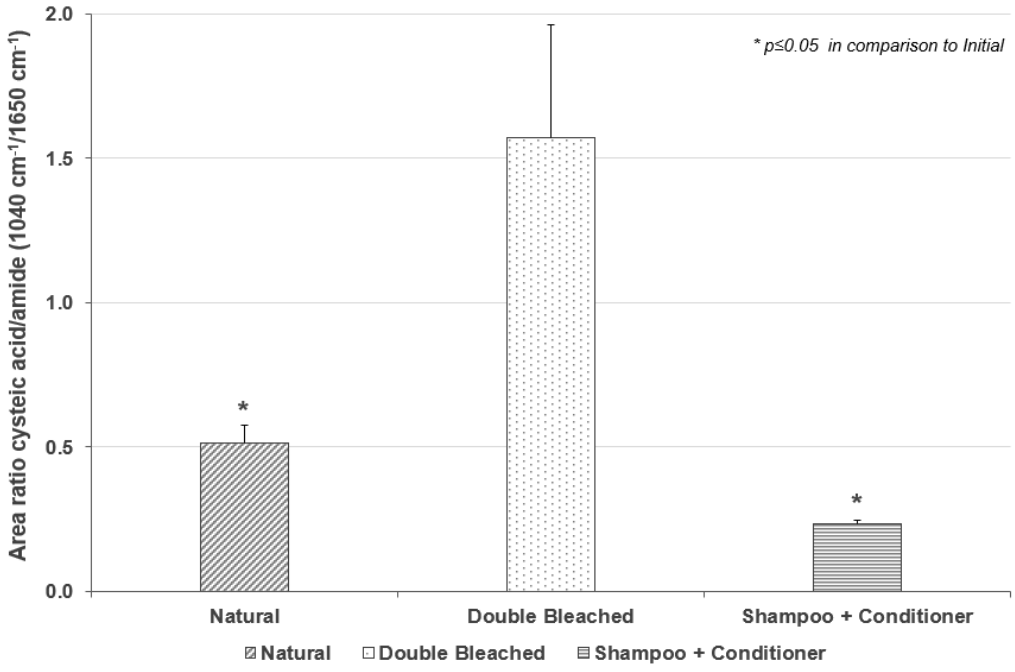
Mean ± standard deviation.

In the study, a statistically significant lower energy to comb wet and dry of doubled bleached hair treated with Shampoo and Conditioner when compared to natural hair (p value <0.0001) and when compared to doubled bleached hair (p value <0.0001). A statistically significant lower energy to comb wet and dry of natural hair when compared to doubled bleached hair (p value <0.0001).

The doubled bleached hair treated with Shampoo and Conditioner was 88% (or 8 times) easier to comb wet and 95% (or 19 times) easier to comb dry.

Graph 2 illustrates the area values obtained at ratio data between the areas 1040 cm^{-1} (asymmetric stretching of the S=O bond) and 1650 cm^{-1} (primary amide C=O bond) for the treatments.

Graph 2. Results of Infrared Spectroscopy, FTIR-ATR



Values of spectroscopy analyses values at cysteic acid/amide area ratio (1040 cm^{-1}/1650 cm^{-1}). Mean ± standard deviation.

In the study, a statistically significant higher value cysteic acid/amide area ratio of natural hair (p value <0,0001) and doubled bleached hair treated with Shampoo and Conditioner (p value <0,0001) when compared to doubled bleached hair. There are no significant differences of cysteic acid/amide area ratio when natural hair and doubled bleached hair treated with Shampoo and Conditioner (p value = 0.1762) compared to each other.

Graph 3 illustrates the spectra obtained for the treatments between the range of 1700 – 900cm^{-1}.

Graph 3. Infrared Spectroscopy, FTIR-ATR spectra

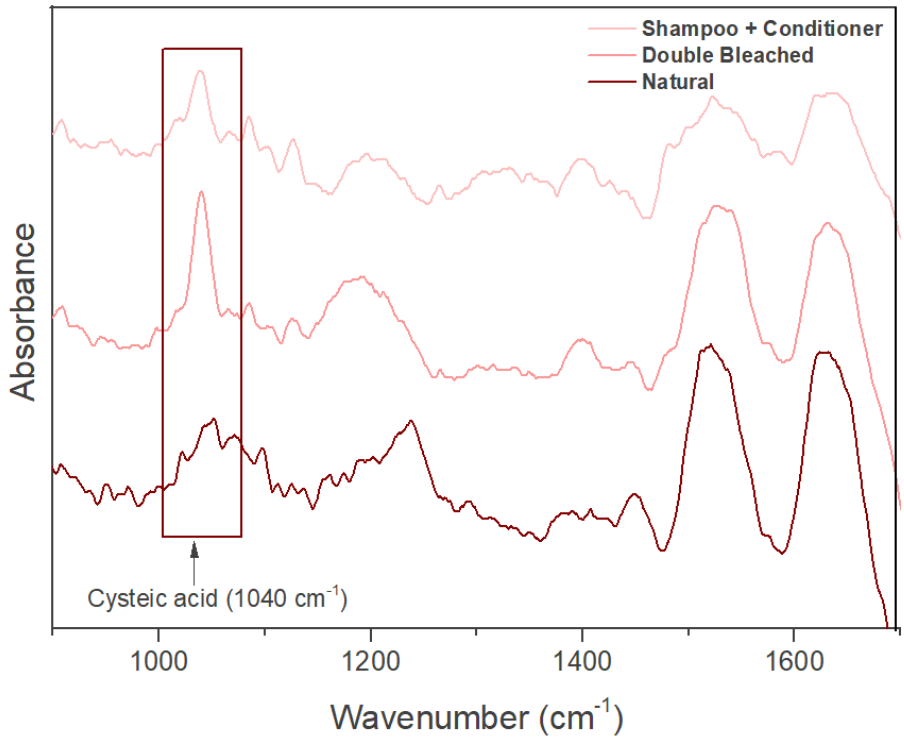


Table 2 resumes the calculated parameter of correlation between FTIR and combability - slope (curve's interpolation) of energy to comb values and cysteic acid/ amide area ratio (1040 cm^{-1}/1650 cm^{-1}) and the Damage Repair Factor.

Table 2. Correlation parameter and Damage Repair Factor promoted by the Shampoo + Conditioner application.

TRESS	*Correlation Parameter*		*Damage Repair Factor*
	Double Bleached	**Shampoo + Conditioner**	
1	6.67	0.31	***22***
2	6.34	0.25	***25***
3	6.03	0.20	***30***
4	6.51	0.29	***23***
5	6.18	0.20	***31***
Mean	**6.35**	**0.25**	*26*
Standard Deviation	**0.26**	**0.05**	*4*

Discussion

The study demonstrated that double bleached hair treated with shampoo and conditioner required significantly lower energy to comb wet and dry compared to natural hair and untreated double bleached hair. Additionally, natural hair required significantly less energy to comb compared to untreated doubled bleached hair.

These findings are consistent with the notion that bleached hair tends to become more damaged and difficult to manage compared to natural hair. The effectiveness of the shampoo and conditioner treatment in improving the combability of bleached hair underscores the importance of proper hair care products in mitigating damage and enhancing manageability.

Both natural hair and double bleached hair treated with shampoo and conditioner exhibited lower cysteic acid/amide area ratios compared to untreated double bleached hair. These results suggest that the shampoo and conditioner treatment effectively restored some of the

damaged protein structures in bleached hair, as evidenced by the decrease cysteic acid/amide area ratio. This restoration may contribute to the improved combability observed in the treated hair. The lower area ratio value indicates the reduction of 1040 cm^{-1} (characteristic Cysteic Acid peak) that indicates that the product evaluated (repair of Cysteic Acid oxidation damage S=O ligations).

The Hair's Damage Repair Factor calculated to doubled bleached hair treated with shampoo and conditioner shows that possible correlate two differences parameter that represents the repair of damage on surface of hair: Combability and structural hair bonds.

The damaging effects of bleaching on hair structure can lead to protein degradation and loss of structural integrity in hair fibers [10] and the potential benefits of using hair care products, such as shampoo and conditioner, while effective hair care treatments can help repair and strengthen damaged hair [11].

Conclusion

The study showed significant differences in combability between natural hair, untreated double bleached hair, and doubled bleached hair treated with shampoo and conditioner and the correlation with superficial structural hair bonds. Doubled bleached hair, known to be more damaged and difficult to manage, exhibited improved combability when treated with the products, indicating the efficacy of proper hair care in mitigating damage and enhancing manageability. Additionally, the treatment resulted in a restoration of damaged protein structures in bleached hair, as evidenced by increased cysteic acid/amide area ratios, which likely contributed to the observed improvement in combability.

The evaluation of hair's damage repair factor further underscores the correlation between combability and structural hair bonds, emphasizing the importance of targeted repair mechanisms in hair care products. Overall, these findings emphasize the significance of

tailored hair care routines in maintaining healthy and manageable hair, especially in the context of chemical treatments like bleaching.

Acknowledgments

We would like to express our sincere gratitude to the researchers Kosmoscience Group for their invaluable assistance and collaboration in this study. Their expertise and support were instrumental in the successful completion of our research. Thank you for your dedication and contributions.

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