university of the arts london
london college of fashion

An *ex vivo* comparison of the tensile strengthening properties of protein derivatives on damaged hair

Sherine Nicholson[2], Gabriela Daniels[1], Peter Grant-Ross[1], Slobodanka Tamburic[1]

[1]School of Management and Science, London College of Fashion, University of the Arts London, United Kingdom
[2]Prim Nails and Beauty Ltd, London, UK

Introduction

At a microstructural level, the mechanical properties of the hair largely reflect the integrity of the proteins in the crystalline structures of the cortex and the surrounding amorphous keratin association proteins (KAPS). Inter and intra-chain disulfide bridges stabilise the cortical structure and confer mechanical strength (Feughleman, 1997, Swift, 1997). Bleaching, and perming to a smaller extent, have been found to disrupt disulfide bonds in the hair proteins (Robbins and Kelly, 1969) thus mechanically weakening the hair. Furthermore, the regular use of high temperature styling appliances leads to the progressive loss of water via the disruption of hydrogen bonds; the exposure to T>180°C, a temperature now commonly achieved and exceeded by hair straightening irons, has been found to result in the decomposition of the crystalline structures (Milczarek et al, 1992).

Developing haircare products that effectively repair damaged hair remains a major challenge for the formulators. Conditioning agents such as cationic polymers and silicones have been found too large to penetrate into the cortex (Reutsch and Kamath, 2005), hence cannot improve the internal structural strength of the hair fibre. On the other hand, protein hydrolisates, which share chemical similarities with the amino acid composition of the hair, are believed to bond to the cortical and cortex proteins, and have been found to enhance the tensile strength of damaged hair (Teglia and Secchi, 1999).

Aim

This study aims to compare the effects of three protein-derived conditioning actives (keratin, wheat and collagen hydrolysates) on the tensile strength of three types of damaged hair: bleached, permed and thermally treated.

Materials and Methods

Materials

Protein hydrolysates with different amino acid profiles, reflecting their different origins and different molecular weights were selected for this investigation (Table 1).

Table 1. Protein-derived conditioning actives

Source/ Derived from*	INCI Name (% active as supplied)	Average Molecular Weight * (Da)	pH *
Animal/ Wool	Hydrolyzed Keratin **HK** (20%)	600	4.0-5.0
Plant/Wheat	Hydrolyzed Wheat Protein (and) Wheat Starch **HWP/WS** (85%)	1,500	4.0-5.0 (in 10% water)
Animal (Bovine hide) /Collagen	Hydrolyzed Collagen **HC** (95%)	9,000	5.5-6.5 (in 10% water)

*Information as provided by the suppliers of actives

Each investigated material was added to a stable emulsion base at the following active level concetrations:
HK: 0.05%w/w; HWP/WS: 0.05%w/w; HC: 2%w/w.
These active levels were identified via a preliminary concentration response study, employing the single-fibre tensile strength testing method also used in this investigation.
Caucasian brown virgin hair tresses with weight=1.5g and length=150mm were used as test substrates.

Methods

Hair bleaching and perming: carried out using commercially available products and in accordance with the manufacturers' instructions.

Thermal treatement: comprised four consecutive cycles of washing, blow drying and intermittent applications of flat straightening ceramic iron (210°C), equating to a total of 3 minutes (McMullen and Janchowicz, 1998).

Conditioning treatments of the damaged hair: 2ml of Sodium Laureth Sulfate were applied to each damaged tress, massaged for 30 seconds and the hair was rinsed off under running water (35°C) for 1 minute. A conditioning treatment (0.7g per 1g of hair) was then applied, massaged for 30 seconds and left on the hair for 5 minutes at room temperature. The tress was rinsed off for 1 minute under running water (35°C).

The conditioning treatments comprised a control emulsion (without protein actives) and the three formulations containing the respective protein hydrolysates. In total, twelve combinations of hair damage and respective conditioning treatments were tested in wet and dry state.

Test samples for wet and dry hair

At the end of each respective treatment, six wet hair fibres from a hair tress were randomly selected and removed for immediate wet tensile strength testing. Each hair tress was then blow dried at 50°C for 5 minutes, and six single hair fibres were removed for dry tensile strength testing.

Single-fibre tensile test

A single hair fibre was stretched at a constant speed of 15mm/s. The applied force F (Newtons), which caused the hair to break was recorded. The test was carried out with TA.X Texture Analyser and the results were recorded by the Texture Exponent Software (Stable Microsystems, UK).

Statistical analysis

Analysis of Variance (ANOVA) for multiple factors, followed by a Tukey Honest Definition Test (THDT), using the R programming language were used.

Probabililty values $p<0.05$ were considered significant.

In additon, the tensile strength increase (**TSI**) for each treatment was calculated using the following formula:

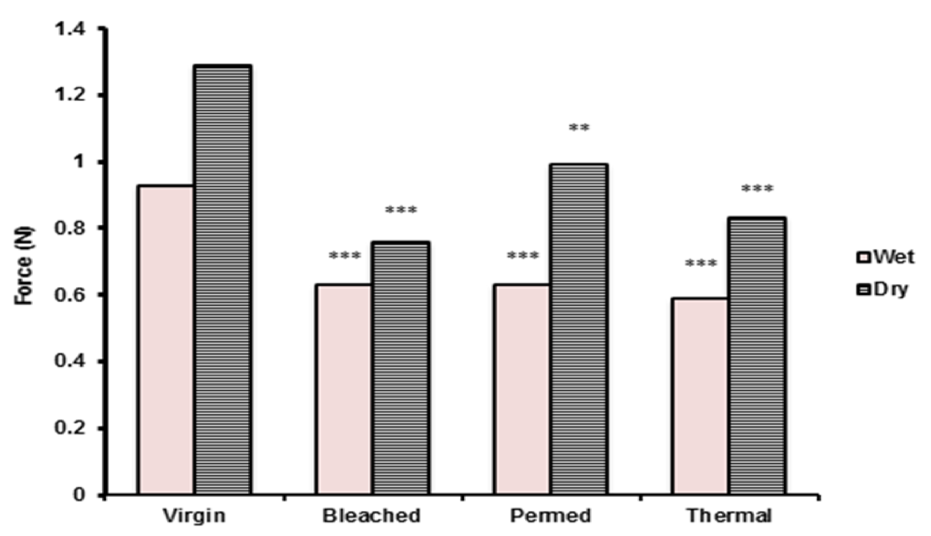
$$\%\ TSI=(Ft-Fd)/Fd$$

Ft=break force of treated damaged hair
Fd=break force of untreated damaged hair

Results and Discussion

Statistically significant differences between the tensile break strength of each damage type and virgin hair (Figure 1) as well as between the wet and dry states of each damaged hair type, were detected.

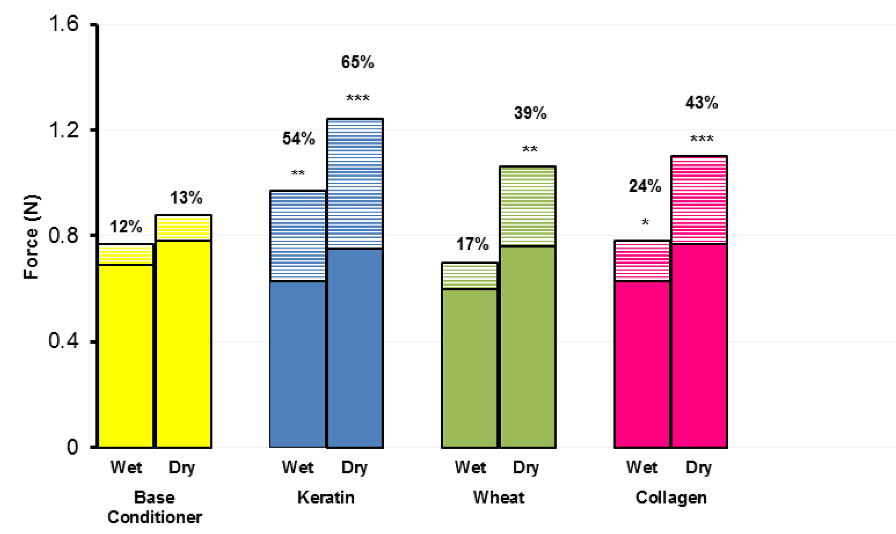
Figure 1. Comparison of the mean tensile strength of virgin, bleached, permed and thermally straightened hair in wet and dry state; (***)p<0.001, (**)p<0.01.



Tensile strength of bleached hair after conditioning treatment

The HK treatment produced the highest TSI for both wet and dry hair with very high degree of statistical significance, whist the base emulsion did not improve tensile strength (Figure 1).

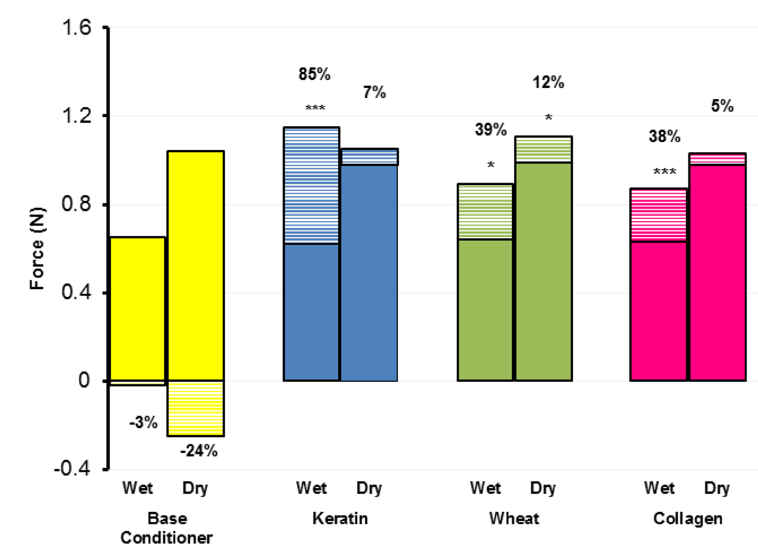
Figure 2. Break point force (N) and TSI for bleached tresses after treatment for wet and dry state, respectively; (***)p=0.000, (**)p=0.001



Tensile strength of permed hair after conditioning treatment

All active treatments were more effective in the wet state, with the HK treatment producing the highest TSI (Figure 2).
A decrease in tensile strength was observed for the base emulsion treatment, although this difference was statistically insignificant.

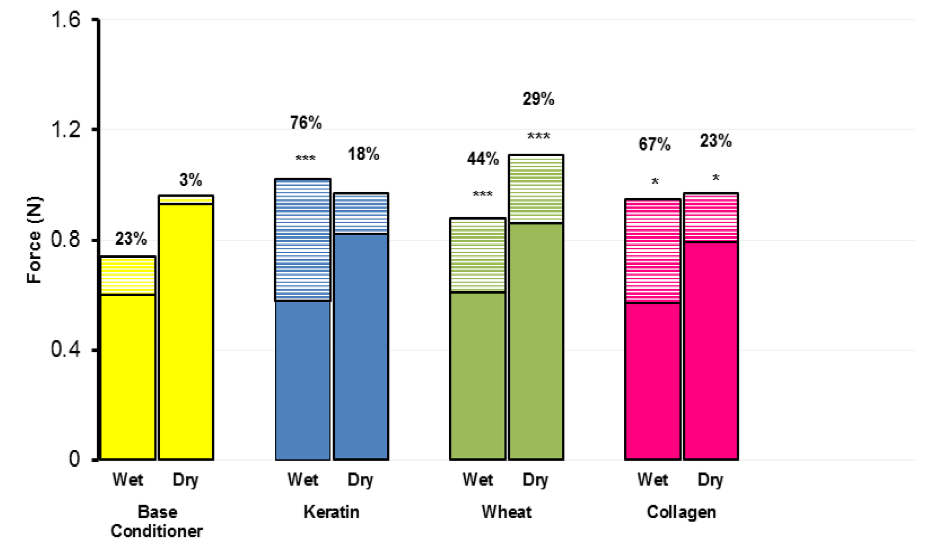
Figure 3: Break point force (N) and TSI for permed tresses after treatment for wet and dry state, respectively; (***)p=0.000, (*)p=0.01.



Tensile strength for thermally damaged hair

The HK produced the highest TSI increase in the wet state and the HWP/WS in the dry state. The base emulsion did not show any significant differences in either state (Figure 3).

Figure 3. Break point force (N) and TSI for thermally damaged tresses after treatment for wet and dry state, respectively; (***)p=0.000, (*)p=0.01



Hydrolysed keratin (HK) improved most notably the wet tensile strengths of bleached (54%), permed (85%) and thermally treated hair (76%), thus emerging as the most efficacious treatment for wet hair. The results implied that HK has superior affinity to hair than the other two actives. This material is said to contain cysteine-rich residues, thus its composition, combined with low molecular weight, facilitated fast diffusion rates and high affinity to the areas of hair cortex where the damage has occurred. Overall, HK was the most effective treatment for bleached hair.

Hydrolysed wheat protein (and) Wheat starch (HWP/WS) was most effective in improving the tensile strength of dry hair, specifically bleached (39%) and thermally treated hair (29%). The results implied a slower diffusion rate into the wet hair fiber, compared to HK, which can be explained by the active's larger molecular size. Furthermore, the presence of wheat starch might have strengthened the hair fibre surface upon drying. Overall, HWP/WP performed best on thermally treated hair.

Hydrolised collagen (HC) also increased the wet tensile strength of all three types of damaged hair. It is stated that the HC is effective in restoring hydrogen bonds via its glycine-proline-hydroxyproline residue sequence. HC's most notable TSI effects were on wet thermally treated hair (67%) followed by dry bleached hair (43%).

Conclusion

- All protein hydrolysates, representatives of various molecular weights and compositions, conferred statistically significant improvements in hair tensile strength to at least two types of damaged hair, thus can be utilised in both, targeted and multi purpose products;
- The wet and dry hair states of the active-treated hair had variable responses to the different treatments, hence a treatment comprising one protein hydrolysate is unlikly to deliver optimal hair strenghtening;
- Further work should focus on assessing the effects of combinations of protein hydrolysates.

References

Feughelman, M. (1997) *Mechanical Properties and Structure of Alpha-keratin Fibers: Wool, Human Hair and Related Fibres.* Sydney: University of New South Wales Press.

Milczarek, P., Zielinski, M. & Garcia, M. L. (1992) 'The mechanism and stability of thermal transitions in hair keratin' *Colloid and Polymer Science.* Vol. 270, 1106-1113.

Robbins, C. R., and Kelly, C. (1969). Amino acid analysis of cosmetically altered hair, *Journal of Cosmetic Science.* Vol 2, pp 555-564.

Ruetsch, S.B. and Kamath, Y.K., (2005), Penetration of cationic conditioning compounds into hair fibers: A TOF-SIMS approach, *Journal of Cosmetic Science.* Vol 56, pp.323-360.

Swift, J. A. (1997). Cosmetic Science Monographs, Fundamentals of human hair science, Weymouth: Micelle Press pp.11-15.

Teglia, A. and Secchi, G. (1999) 'Proteins in Cosmetics' In: Goddard, E. D., and Gruber J, V.(ed.) Principles of Polymer Science and Technology in Cosmetics and Personal Care New York:Marcel Dekker. pp. 433-453.

Acknowledgments

The authors wish to acknowledge the excellent technical assistance of Mrs Carmel Lally and Ms Senait Tewolde.

Contact details: g.n.daniels@fashion.arts.ac.uk