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

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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 (KAPP). Inter and intra-chain disulfide bridges stabilise the cortical structure and confer mechanical strength (Feighanlem, 1997, Swift, 1997). Bleaching, and perming to a smaller extent, have been found to disrupt disulfide bonds in the hair proteins (Robbins and Kello, 1996), thus mechanically weakening the hair. Furthermore, the regular use of high temperature styling appliances adds to the progressive loss of weak inter- and intrachain disulfide 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 (Miczarek et al., 1992).

Developing haircare products that effectively repair damaged hair remains a major challenge for the formulators. Conditioning agents such as surfactants, polymers and silicones have been found too large to penetrate into the cortex (Reutsch and Kamath, 2003), hence cannot improve the internal structural strength of the hair fibre. On the other hand, protein hydrolysates, which share chemical similarities with the amide and amine 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 Secchio, 1999).

Aim
This study aims to compare the effects of three protein-derivated conditioning actives (keratin, wheat and collagen) on the tensile strength of hair, which is widely considered a measure of the strength 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>
<thead>
<tr>
<th>Protein-derived conditioning actives</th>
<th>Average Molecular Weight (kDa)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Wool Hydrolyzed Keratin HK (20%)</td>
<td>600</td>
<td>4.0-5.0</td>
</tr>
<tr>
<td>Plant wheat Hydrolyzed Wheat Starch HWP/WS (83%)</td>
<td>1,500</td>
<td>4.0-5.0 (in 10% water)</td>
</tr>
<tr>
<td>Animal (Bovine hide) Collagen HC (95%)</td>
<td>9,000</td>
<td>5.5-6.5 (in 10% water)</td>
</tr>
</tbody>
</table>

*Information as provided by the respective suppliers of active

Each investigated material was added to a stable emulsion base at the following active level concentrations:
- 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 and brown virgin hair tresses with weights 1.5g and length=150mm were used as test substrates.

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

Thermal treatment: comprised four consecutive cycles of washing, blow drying and intermittent applications of flat straightening ceramic iron (200°C), equaling to a total of 2 minutes (McKinnon and Jachowicz, 2005). Tensile treatment: comprised of four consecutive cycles of washing, blow drying and intermittent applications of flat straightening ceramic iron (200°C), equaling to a total of 2 minutes (McKinnon and Jachowicz, 2005).

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 using running water (35°C) for 1 minute. A conditioning treatment (0.75g 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 in 1 minute under running water (35°C).

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

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 states; (**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, which the base emulsion did not improve tensile strength (Figure 1). The 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 bleached tresses after treatment for wet and dry state, respectively; (**p<0.001, ***p<0.01).

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.

Tensile strength of 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 statistically significant differences for either state (Figure 3).

Conclusion
- All protein hydrolysates, representatives of various molecular weights and compositions, achieved statistically significant improvements in tensile strength to at least two types of damaged hair, thus can be utilised in bleached targeted multi-purpose products.
- The wet and dry hair states of the active-treated hair had variable responses to the different treatment methods, with the best treatment comprising one protein hydrolysate is unlikely to deliver optimal hair strengthening.
- Further work should focus on assessing the effects of combinations of protein hydrolysates.

References