An ex vivo study of the effects of co-surfactants and conditioning additives on hair colour protection

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Introduction
The colour fading of hair treated with oxidative dyes is attributed to the effects of ultraviolet light and other environmental factors, but mostly it occurs during shampooing. This effect is caused by the diffusion of chromophores from within the cortex towards the cuticle surface. The colour fading of dyed hair during shampoo washing is determined by a range of factors, most significantly by the chemistry of the chromophores, the porosity of the hair, the pH and the properties of the used surfactants. Various studies have demonstrated that the colour resistance to washing of dyed hair red is inferior to that of hair dyed black or brown (Medice and Joekes, 2013; Zough, 2009), an effect attributed to the relatively smaller chromophores producing the red colour.

Optimising the cleansing efficacy of shampoo in relation to colour protection is essential for formulators. Studies have demonstrated improved colour retention when substituting sulfates with other milder anionics and by the chemistry of the chromaphores, the porosity of the hair, and the properties of the used surfactants. Various studies have demonstrated that the colour resistance to washing of dyed hair red is inferior to that of hair dyed black or brown (Medice and Joekes, 2013; Zough, 2009), an effect attributed to the relatively smaller chromophores producing the red colour.

Aim
This study investigates the effects of two co-surfactants, Cocamidopropyl Betain and Coco-Glucose, in combination with two polycationic and one silicone-based, on the colour fading of hair tresses coloured with red oxidative hair dyes.

Materials and Methods
Materials
Surfactants included in the screening tests: Sodium Laureth Sulfate (SLES), Cocamidopropyl Betain (CAPB), Coco-Glucose (CG), Diolaurum Sulfsuccinate, and a surfactants blend of Sodium Triethel Sulfate, Sodium Lauroamphoacetate and Coco Monopentanolamine. Investigational materials included in the treatment tests: primary surfactant, co-surfactants and conditioning additives (Table 1).

Methods
Co-surfactant screening tests
Two surfactant screening tests were carried out in order to establish the sensitivity of the method, and to narrow the choice of investigational co-surfactants. Co-surfactants soak test (adaptation from Zhou et al 2008): 400ml solutions of 5% w/w of each respective surfactant were prepared and a test hair tress was immersed in each solution and allowed to soak for one hour. The hair tress was then removed from the surfactant solution, rinsed under constant tap water (t=approx 20°C) for two minutes and blow dried for five minutes at t=50°C. Co-surfactants+SLES soak test: 400ml solutions comprising 2.5% w/w of a respective co-surfactant mixed with 5% w/w SLES were prepared. The remaining stages of this test were identical to the co-surfactant soak test.

Treatment wash tests
Treatment solutions were prepared comprising SLES, the selected co-surfactants, and three conditioning additives (Table 1). A dried hair tress was immersed in a 2.5% solution of each test combination (preheated to 40°C) for four minutes, under controlled mechanical agitation. The remaining stages of the test were the same as the screening test. The cycle was repeated ten times for each hair tress. Three hair tresses were tested per variable.

Colour measurements
Before and after a complete wash-and-dry cycle each treated hair tress was attached securely to a white ceramic tile and spectrophotometric measurements were taken at three points evenly distributed along its length (Spectrophotometer CM-2600D, Konica Minolta, Japan, illuminator D65 (daylight), viewing angle = 10°).

The average change in color ΔE for each treatment was calculated, based on pre and post treatment measurements of each hair tress:

ΔE = √[(ΔL+ + Δa+ + Δb+)]

The colour retention value for each formulation combination, containing a co-surfactant and a conditioning additive, was calculated as follows:

% colour retention = 100 - (ΔE/ΔE (control) x 100)

Results and Discussion
Following the soak tests, CAPB and CG were selected for further investigation, as they demonstrated good potential for colour protection (ΔE=5.7, 5.7, respectively), and for mitigating the colour fading induced by SLES (ΔE=7.97 and 7.02, respectively). The colour changes measured after the wash-and-dry treatment with different conditioning additives are displayed in Figure 1. The control treatment formulations comprised the combination of SLES and each co-surfactant respectively.

Figure 1. Total colour changes in hair tresses treated with the formulations containing SLES, one of the two co-
surfactants (CAPB or CG) and one of the conditioning additives (PQ-55, PQ-28 or Dimethicone) vs. control
formulations without conditioning additives

Table 1. Experimental materials: INCI names, abbreviations and concentrations in the treatment formulations

<table>
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<tr>
<th>Material</th>
<th>INCI names</th>
<th>Abbreviation</th>
<th>Control</th>
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% colour retention value (Figure 2). Free surfactant molecules (Table 1).

Figure 2. Colour protection values of hair tresses treated with different surfactants and one of the three conditioning additives

The positive effect of CAPB on colour retention was further enhanced by the presence of hair substantive materials such as polycationics and silicone polymers with ΔE and % colour retention values showing a statistically significant difference (One-way ANOVA, followed by Tukey HSD test). In particular, Dimethicone offered superior colour retention compared to PQ-28 (p<0.001). This performance can be related to Dimethicone’s effective deposition on the hair shaft during lathering and rinsing, indicating that the hydrophobic forces of attraction between Dimethicone and the hair surface are particularly strong.

PQ-55 delivered significantly better colour protection than PQ-28 when combined with CAPB. Polypeptides interact with anionic surfactants to form aggregates, which at certain ratios can be insoluble, but are solubilised in the presence of an anionic detergent (Goddard and Grubber, 1999). The deposition of cationic polymers occurs at the time of rinsing, whilst the polymer charges are still partially paired, hence hydrophobic forces between the aggregates and the hair fibre will be beneficial for enhancing this process. Thus, the PQ-55 superior efficacy can be explained by its higher hydrophobicity and consequently enhanced deposition on the hair (Figure 3).

Conclusion
This investigation demonstrates that certain ingredients can improve the colour retention of red oxidative dye coloured hair during shampooing. The choice of co-surfactant was shown to have an effect on the reduction of the colour fading induced by SLES. The 28% improvement in colour retention was demonstrated, in particular, was proven to offer statistically significant colour protection efficacy in shampoo formulations.

This effect could be further enhanced by the addition of non-ionic materials. Dimethicone was identified as the most effective conditioning additive in this study, providing superior colour protection in combination with the CAPB and the CG group of formulations.

References

Acknowledgments
This research was supported by technical assistance of Mrs Carmel Lally and Dr Rouble Naik.

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