university of the arts london
london college of fashion

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

Gabriela Daniels[1], Kristin Katakami[1,2], 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]Laleham Healthcare, UK

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 occurres during shampooing. This effect is caused by the diffusion of chromaphores 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 chromaphores, the porosity of the hair fibres, and the properties of the used surfactants. Various studies have demonstrated that the colour resistance to washing of hair dyed red is inferior to that of hair dyed black or brown (Medice and Joekes, 2013; Zough, 2009), an effect attributed to the relatively smaller chromaphores producing the red colour.

Optimising the cleansing efficacy of shampoos in relation to colour protection claims is of interest to formulators. Studies have demonstrated improved colour retention when substituting sulfates with other milder anionics and by the addition of amphoterics (Kiplinger et al, 2008). Other investigations have shown that conditioning additives, such as polycationic and silicone polymers, can further enhance colour protection due to the formation of hydrophobic coating on the hair fibres (Jaynes et al, 2006; Zough at al 2009, Rigoletto et al, 2009).

Aim

This study investigates the effects of two co-surfactants, Cocoamidopropyl Betain and Coco-Glucoside, and a range of conditioning additives, two polycationic and one silicone-based, on the colour fading of hair tresses coloured with red oxidative hair dye.

Materials and Methods

Materials

Surfactants included in the screening tests: **S**odium **L**aureth **S**ulfate (**SLES**), **C**oco**a**mido**p**ropyl **B**etain (**CAPB**), **C**oco-**G**lucoside (**CG**), **D**isodium **L**aureth **S**ulfosuccinate, and a **surfactants blend** of Sodium Trideceth Sulfate, Sodium Lauroamphoacetate and Coco Monoethanolamine
Investigational materials included in the treatment tests: primary surfactant, co-surfactants and conditioning additives (*Table 1*).

Raw materials: INCI names	Control CAPB % w/w	Control CG % w/w	CAPB +PQ-22 % w/w	CAPB+ PQ-55 % w/w	CAPB+ Dimethicone % w/w	CG+ PQ-22 % w/w	CG+ PG-55 % w/w	CG+ Dimethicone % w/w
SLES	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
CAPB	2.5	-	2.5	2.5	2.5	--	-	-
CG	-	2.5	-	-	-	2.5	2.5	2.5
Polysorbate-80	-	-	-	-	5.0	-	-	5.0
Dimethicone					1.0			1.0
PQ – 22	-	-	1.0	-	-	1.0	-	
PQ – 55	-	-		1.0	-	-	1.0	
Citric acid (20% w/w solution)	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Aqua (deionised)	to 100	to 100	to 100	to 100	to 100	to 100	to 100	to 100

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

Identical Caucasian virgin brown hair tresses (weight=3g, lengh=15cm) were first bleached and then dyed, using standardised protocol and a commercially available oxidative red hair dye.

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.

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

Treatment wash tests

Treatment solutions were prepared comprising SLES, the selected co-surfactants, and three conditioning additives *(Table 1).* A dyed 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 measurments

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 colour change ΔE for each treatment was calculated, based on pre and post treatment measurements of each hair tress:

$$\Delta E = \sqrt{(\Delta L^2+\Delta a^2+\Delta b^2)}.$$

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

%= ΔE (active treatment) - ΔE (control) x100/ΔE (control)

Results and Discussion

Following the soak tests, CAPB and CG were selected for further investigation, as they demonstrated good potential for colour retention (ΔE=5.7 and ΔE=3.78, respectively), and for mitigating the colour fading induced by SLES (ΔE=7.97 and ΔE=7.02, respectively). The colour changes measured after the wash-and-dry treatments with different conditioning additives are displayed in Figure 1. The control treatment formulations comprised the combination of SLES and each co-surfactant respectively.

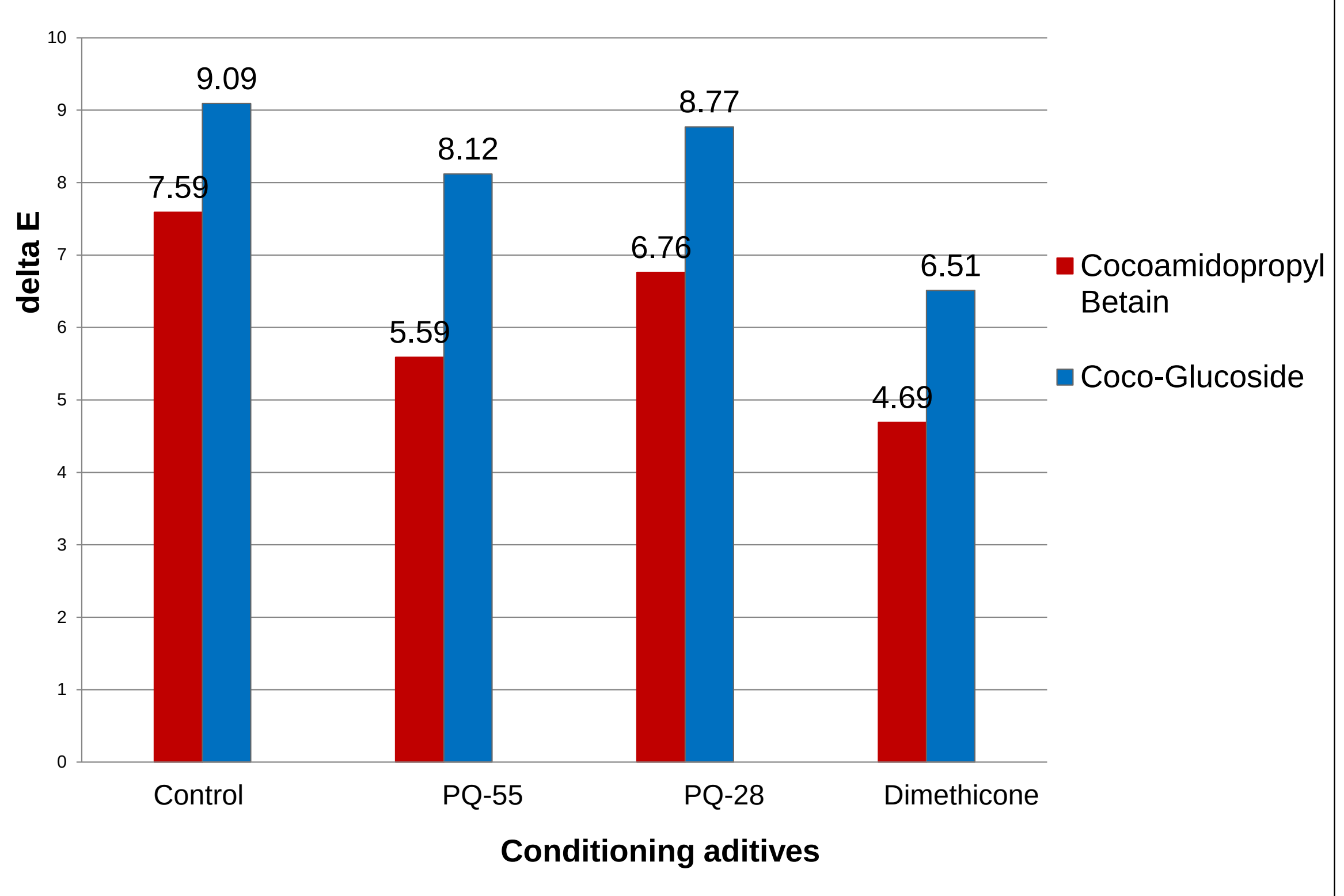


***Figure 1**. Total colour changes in hair tresses treated with the formulations containing SLES, one of the two co-surfactants (CAPB or CG) and one of the conditioning additives (PQ-55, PQ-28 or Dimethicone) vs. control formulations without conditioning additives*

CAPB (amphoteric) reduced colour fading (ΔE) more effectively than CG (non-ionic), which is reflected in the colour retention value (Figure 2). Free surfactant molecules (SLES) enhance cuticle wetting and water penetration into the cortex, thus speeding the rate of the red chromaphore dissolution and consequent removal from the cortex. It is suggested that CAPB's capacity to reduce the availability of free SLES within the solution, by lowering the critical micelle concentration (CMC) of the system, is contributing to the colour retention.

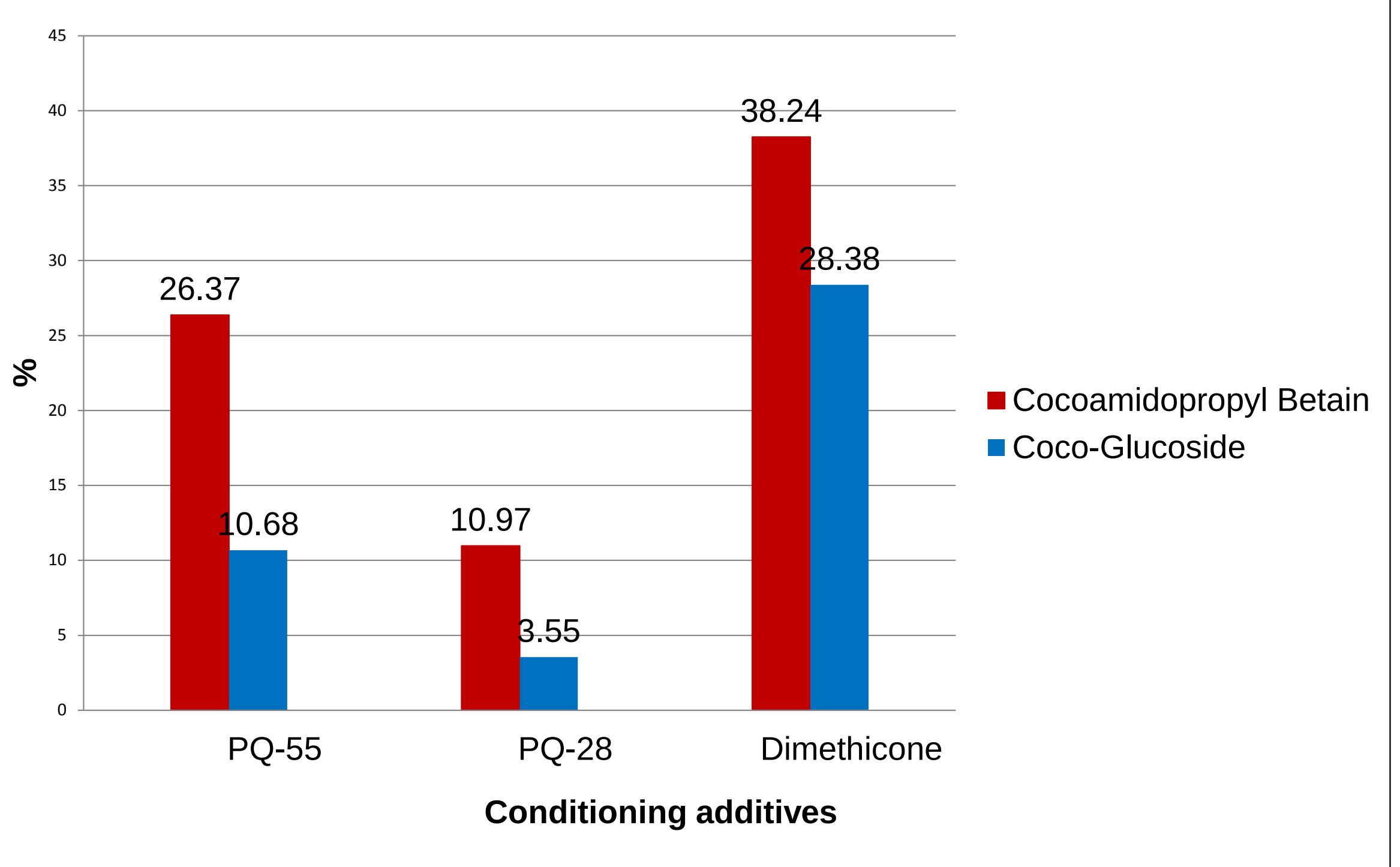
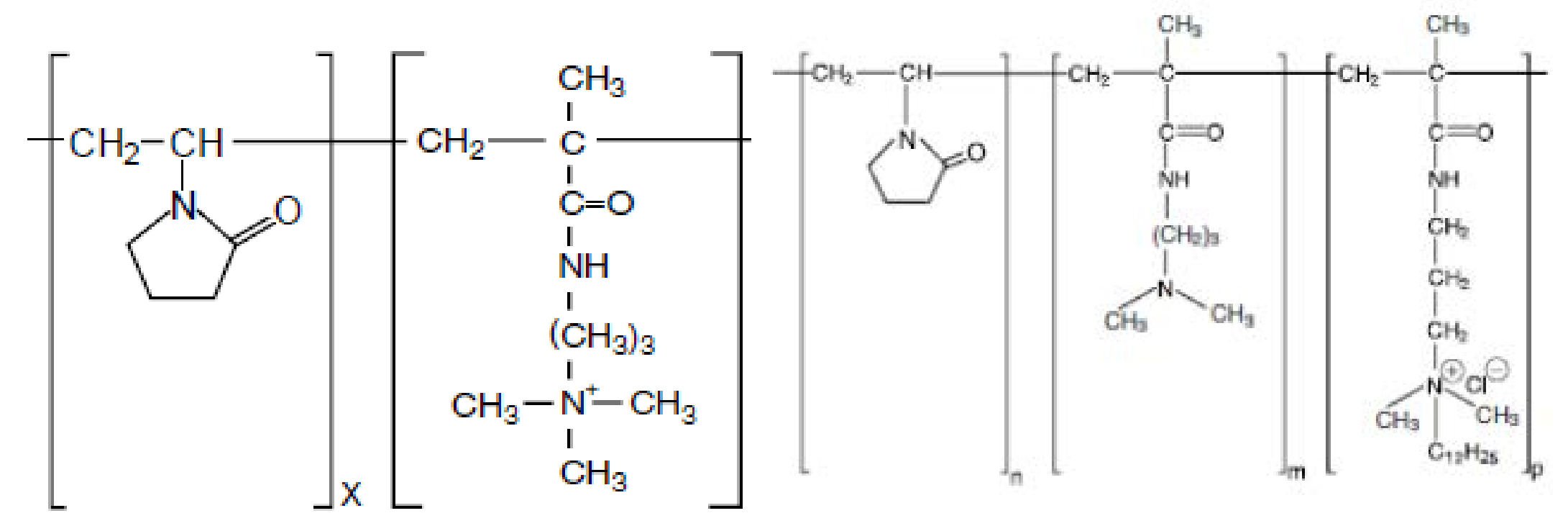


***Figure 2**. Colour protection values of hair tresses treated with SLES-based shampoos with different co-surfactants and one of the three conditioning additives*

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 Dimethone's more 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. Polyquaterniums interact with anionic surfactants to form aggregates, which at certain ratios can be insoluble, but are solubilised in the presence of an excess of surfactant in the shampoo formulations (Goddard and Grubber, 1999). The deposition of cationic polymers occurs at the time of rinsing, whilst the polymer charges are still partially screened, 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).



Polyquaternium-28 **Polyquaternuim-55**

***Figure 3**. Chemical structure of the quaternised polymers selected for this study*

There was no significant difference between the ΔE and % colour retention of the formulations in the CG group. However, the Dimethicone formulation outperformed those containing polycationics, suggesting that shampoos containing non-ionic materials could potentially reduce colour fading too. Further investigation is needed in this area.

Finally, Two-way ANOVA tests, comparing the ΔE values of conditioning additives and co-surfactant variables, confirmed a statistically significant difference between the efficacy of the CAPB and the CG group of formulations.

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 amphoteric co-surfactant **Cocoamidopropyl Betain,** in particular, was proven to offer statistically significant colour protection efficacy in shampoo formulations.

This effect could be further enhanced by the addition of appropriate conditioning materials. **Dimethicone** was identified as the most effective conditioning additive in this study, providing superior colour protection in combination with both CAPB or CG, followed by **Polyquaternium-55** mixed with CAPB.

References

Goddard, E. and Grubber, J. 1999. Principles of Polymer Science and Technology in Cosmetics and Personal Care, ed.1999. Synthetic *Polymers in Cosmetics*. Marcel Dekker, New York, pp. 217-274

Jaynes, B.S., Jennings, J. and Andrianov, C., 2006. An evaluation of cationic polymers for the prevention of fading in oxidative hair dyes. 24th IFSCC Congress Osaka 2006

Kiplinger, J., Bendejacq, D., Leroy, E. and Adamy, M., 2009. A study on the influence of surfactants on hair color fading. *Annual Scientific Meeting and Technology Showcase of the Society of Cosmetic Chemists* (SCC)

Medice,A.L.A. and Joekes, I., 2013. Colour fading in permanent dyed hairs. *22nd IFSCC 2013 Conference Brazil, 2013.*

Rigoletto, R. and Zhou, Y., 2009. Polyelectrolyte complex for mending damaged hair. Cosmetics & Toiletries, 124 (3), pp. 76-87

Zhou, Y., Foltris, L., Moore, D.J. and Rigoletto, R., 2008. Protection of oxidative colour fading from shampoo washing by hydrophobically modified cationic polymers. *Journal of Cosmetic Science,* **60** (March/April), pp. 217-238.

Acknowledgments

The authors wish to acknowledge the excellent technical assistance of Mrs Carmel Lally and Ms Senait Tewolde. This work is presented at the IFSCC Paris 2014 Congress with financial support from the Society of Cosmetic Scientists (United Kingdom).