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« **Colour protection for hair care products**

How long-lastingness is influenced in different colour shades»

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PEER REVIEWED

Colour protection for hair care products
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KEYWORDS: hair dyes, colour protection, colour shades, long-lastingness, washout, UV protection

Abstract In today's world, hair is coloured artificially for various reasons, and the number of different colours, shades and colour types is huge and growing. But as yet we do not have the perfect solution to people's requirement for artificial hair colour that remains consistently lustrous and intense – just like when it was first applied. It is generally accepted that shampoos are the greatest cause of fading, and most industry approaches to the problem target this aspect. But sunlight is also known to contribute to hair colour fading, and at DSM we found that the impact of these two factors differs depending on the colour shade. Shampoo is indeed the main cause of fading for red colours, with sunlight having less though still significant influence. With brown/auburn colours, in contrast, washing only initially causes visible fading, while the impact of UV radiation is much greater. In the final instance, however, protection against UV damage was found to be essential for all artificial colours – irrespective of colour type and tone – if they were to retain their original brilliance over the long term.

INTRODUCTION

Mega trends lead people to modify their behaviour, and one consequence of such trends has been an increase in hair colouring. Of course there are several reasons why people colour their hair, but an astonishing 72% of people, when asked, said it makes them feel more physically attractive, hence increasing their confidence and sense of wellbeing. (1, 2) So the last thing consumer needs is a colour that fades quickly to leave the hair looking dull and lifeless. However, market research indicates that current hair colour products are prone to fading, and that most colour protection products fail to live up to their promise. Unfortunately, 71% people are currently dissatisfied with the performance of market products and view claims as empty marketing speak (1, 2). Understandably, those consumers are eager for products that maintain a rich colour while keeping their hair looking vibrant and shiny, and feeling soft.

Two main groups of factors influence colour fading: the physical factors, which can be mostly attributed to wash-out during the shampooing process; and the chemical factors, which affect the chemistry of the colorants as such (3). Here, the influence of sunlight deserves special mention (4). In all the publications we found, these two groups of factors were investigated independently of each other (5-9).

So-called permanent colours are usually oxidative colorations, which are much less prone to washing out than direct dyes, which normally fade within about six washes. The challenge for colour protection products is to find a solution that effectively protects against fading due to all causes and works for all relevant hair colorations. The situation is complicated by the fact that many hair colorants on the market are a mix of oxidative and direct dyes.

Current market products commonly attempt to optimize the surfactant system of a shampoo in order to reduce harsh cleansing conditions and hence minimize dye diffusion out of the hair shaft. Another approach is to minimize colour fading by coating the hair shaft with ingredients such as polymers, silicones or special actives that are deposited from the shampoo. Some products strongly focus on protecting against UV damage by simply adding UV filters. Needless to say, if they are to deliver on the benefit and not simply be rinsed off, such UV protection ingredients must have substantivity to hair.

Another perspective on the game of colour protection involves looking at all the different shades that are available on the colouring market, both professional and retail. During recent years the best-selling colours have been shades of blond to brown, with red shades currently picking up fast. This diversity of colour shades is adding another level of complexity to care products with a colour protection benefit, as they need to be universally effective (10).

For new product development the key challenge is to consider all the different parameters relevant to the particular market product and not accept a compromise in performance. The specific scientific issue we want to consider here is the influence of the two key factors washout and sunlight damage on different colour shades.

MATERIALS AND METHODS

For the tests, bleached hair swatches (Kerling International Haarfabrik Art. Nr. 826204, KT dense, Euro-hair, mixed extra bleached, colour 10/0) were used, total length l(t)=120mm, free hair length l(f)=100mm. Prior to usage, the swatches were hand-washed, combed and dried overnight in a climate chamber at 20°C and 60% rel. humidity.

For the colouration tests, swatches were coloured and treated according to the instructions on the respective packaging. After washing out the colouration, the swatches were combed and dried in the climate room at 20°C and 60% rel. humidity.

Washing procedures
Hand washing was done according to the following procedures:
Apply 0. 5mL of standard shampoo (10% sodium laureth sulfate, 0. 5% sodium benzoate) with a syringe to the wet hair swatch. Foam the swatch with the fingers for a period of 30 sec. Then rinse the swatch under warm running tap water for 30 sec (38°C / 5L/min), during rinsing, strip the shampoo off carefully with the fingers.

Ultrasound bath method
For this procedure, an ultrasonic bath from Bandelin Sonorex (RK 100 SH) was used. The hair swatches were treated for 15 minutes at 40°C with 3% sodium laureth sulfate solution in tap water. Afterwards, the hair swatches were rinsed with tap water for 30 sec, dried with a paper towel, combed and dried overnight in a climate room at 20°C and 60% rel. humidity.

The following colouration products bought in a Swiss supermarket were used:

Brown/Auburn Colour Shades
- Garnier. Nutrisse Creme, "Mittelblond" 70. INCI (Coloration creme color components only): 2, 4-diaminophenoxyethanol HCl, m-aminophenol, toluene-2, 5-diamine, N, N-bis(2-hydroxyethyl)-p-phenylenediamine sulfate, resorcinol.
- Excellence Creme, "Mahagoni Kupfer" 6. 54. INCI (Coloration creme color components only): 4-amino-2-hydroxytoluene, p-aminophenol, toluene-2, 5-diamine, 2-methyl-5-hydroxyethylaminophenol.
- Garnier Nutrisse Creme, "Kastanie" 5. 15. INCI (Coloration creme, color components only): p-aminophenol, m-aminophenol, 4-amino-2-hydroxytoluene toluene-2, 5-diamine, p-methylaminophenol sulfate, 2-methyl-5-hydroxyethylaminophenol.

Red Colour Shades
- Schwarzkopf. Brillance Intensiv Color Crème, "Kaschmirrot" 842. INCI (Coloration creme, color components only): 1-hydroxyethyl 4, 5-diamino pyrazole sulfate, 3-amino-2, 4-dichlorophenol HCl, 4-amino-2-hydroxytoluene.
- Garnier. Nutrisse Farbsensation, "Intensivrot" 6. 60. INCI (Coloration creme, color components only): 1-hydroxyethyl 4, 5-diamino pyrazole sulfate, 4-amino-2-hydroxytoluene, 5-amino-6-chloro-o-cresol, p-aminophenol, toluene-2, 5-diamine.
- L'Oreal Preference. "Ultra-Violett" 3. 66. INCI (Coloration creme, color components only): 1-hydroxyethyl 4, 5-diamino pyrazole sulfate, 4-amino-2-hydroxytoluene, 5-amino-6-chloro-o-cresol, hydroxypropyl bis(N-hydroxyethyl-p-phenylenediamine) HCl, toluene-2, 5-diamine.

Colour analysis method: L*a*b*-values of the coloured hair swatches were measured on three points per hair swatch using a Minolta CM-3600d spectrophotometer. For each data point, we have collected the L*a*b – values from 3 hair swatches and used the respected mean values for L*a*b. Based on that, dE was calculated according to the following equation (11):

$$dE_{1,2} = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

For UV irradiation, the Atlas Suntester XLS+ was used (UV filter cut-off 290nm and full sunlight spectrum with continuous spectrum of wavelengths). Hair swatches were fixed on both ends on a rotating platform and irradiated with an intensity of 500 W/m^2 for 40hr. This corresponds to ~29hr of sun radiance power for Mid-Europe summertime with a clear sky.

One damage cycle consists of 5x hand-washing or 15 minutes of ultrasound bath washing, followed by combing, drying, conditioning in climate chamber and 40hr of irradiation, if appropriate. This cycle is representative for one week of consumer behaviour. For every experiment three hair swatches were used.

RESULTS AND DISCUSSIONS

We analysed the susceptibility of different permanent colorations to physical and chemical factors. Tests were performed with the natural/auburn and red tones from different leading colour brands that are currently most fashionable. In particular we compared colour fading of coloured hair tresses either under the influence of washing only or with a combination of washing and UV irradiation. In the methodology we also compare the hand washing procedure versus processing in an ultrasound bath. The results of the investigation with colorations in different brown shades are summarized in Figure 1. One damage cycle consisted of either five hand washes without irradiation or five hand washes with irradiation. L*a*b measurements were done at the end of each damage cycle, i. e. either after five hand washings OR after five washings and one UV irradiation cycle. Looking at the dE values for the swatches after washing only, a slow increase in fading was detectable which reached a maximum dE after four wash cycles, equal to twenty hair washes. After this the impact of washing on colour fading was small for the brown shades tested. When hair washes were combined with UV/VIS irradiation after every five washes, the increase in dE was greater, reaching a level of above ten after four cycles. For brown/auburn colour shades the combination of washing and UV irradiation led to greater colour fading than washing only. These differences in colour fading were easy to spot by visual assessment.

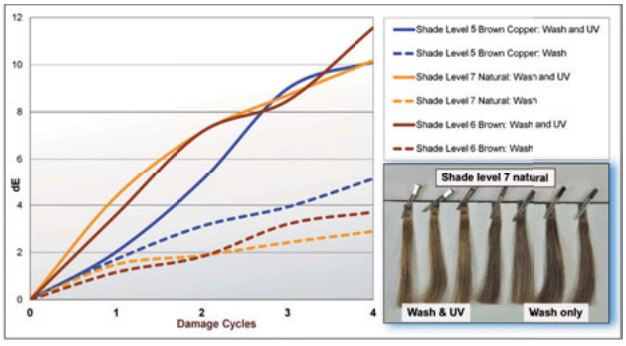

Figure 1. Colour fading curve for natural / auburn colourations under the influence of hand-washing and/or UV irradiation. One damage cycle: 5x hand-washing, drying, conditioning in climate chamber, with or without UV irradiation.

The same tests were applied to two different red tones. As can be seen in Figure 2, the detected dE value of the colour loss for the washing experiments was 6–8 after four damage cycles. Including irradiation after every cycle of five washes did not increase the colour fading in the same way as was observed with the brown/auburn colour tones. The difference between irradiated and non-irradiated swatches was more than two dE only for colour shade eight, and even this was hard to detect by visual assessment. The main impact on colour fading of red shades is due to the washing steps. Compared to the brown shades (Figure 1), washing the red shades had double the impact on dE values.

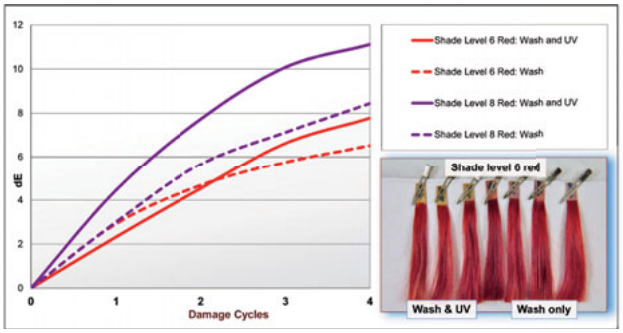

Figure 2. Colour fading curve for red colourations under the influence of hand-washing and/or UV irradiation. One damage cycle: 5x hand-washing, drying, conditioning in climate chamber, with or without UV irradiation.

From these experiments it can be concluded that red colours are more prone to washing out while brown colour fading is mainly caused by sunlight. To further demonstrate the influences of these two factors we conducted a more detailed investigation, including L*a*b measurement and dE calculation of the coloured hair swatches after each washing cycle or UV irradiation cycle. dE values were calculated based on the starting points of the respective treatment. Furthermore, the washing procedure was changed from hand washing to an ultrasound bath method in order to increase reproducibility and make the results independent of the person doing the testing.
A 15-minute ultrasound bath in a 3% sodium laureth sulfate solution was taken to replace 6 hand washing treatments. Although we found that ultrasound leads to greater colour fading, we have demonstrated much better reproducibility of

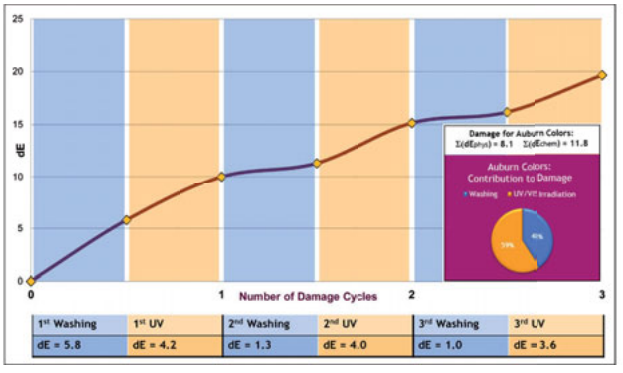

Figure 3. Colour fading curve for shade level 5 auburn colour. Washing with ultrasonic bath and UV irradiation.

data, and the variation of the calculated dE is less than 5%. Figure 3 shows the result of a repeated washing and irradiation procedure over 3 damage cycles taking the brown/auburn colour shade level 5 as an example. Overall colour loss was 18. 9 dE. After the first washing cycle the detected dE was 5. 8, a degree of colour fading which is visible when looking at the hair. For the second and third washings, with dEs of 1. 3 and 1. 0 respectively, the differences are so small that they are no longer visible. The impact of the UV irradiation, in contrast, is similar for each step. The first irradiation brought about a dE of 4. 2, the second 4. 0 and the third 3. 6. Overall, the results show an impact on fading of the brown/auburn shade 5 by washing of 41% and by UV/VIS irradiation of 59%.

In Figure 4, the result of a repeated washing and irradiation procedure over 3 damage cycles is shown using red colour shade level 3 as an example. The ultrasound bath method was used for the washing cycles. The resultant overall colour loss was 29. 8 dE. Here, the first step resulted in a huge colour fading of 11. 5 dE, while the difference after the second and third washing cycles was 5. 8 and 2. 7 respectively, a degree of fading that is still visible. As with the brown shades, the impact of UV irradiation is almost equal across all steps, but at a uniformly lower level, with dEs of 3. 3 in the first, 3. 8 in the second and 2. 7 in the third irradiation cycle. Overall, the results show an impact on red colour shade 3 by washing of 68% and by UV irradiation of 32%.

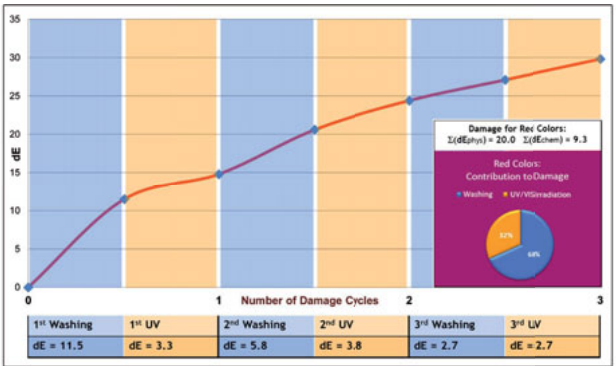

Figure 4. Colour fading curve for shade level 3 red colour. Washing with ultrasonic bath and UV irradiation.
Particularly noticeable in the two experiments illustrated in Figures 3 and 4 is that the colour fading impact caused by washing diminishes steadily, while the impact of light exposure remains roughly constant. This effect seems to be independent of colour tone.

CONCLUSION

Our studies revealed for the first time that colorations with brown and red shades are differently impacted by hair washes and sunlight. For both hair colour types fading is strongest in the first phase of washing, but the colour loss after further washings remains visibly detectable with red colour shades, while brown colour shades fade less over the course of several washings. This can be explained by differences in chemistry. The binuclear dyes present in red hair colours are readily water-soluble, have a relatively small molecular weight and easily diffuse out with shampooing. The polynuclear dyes present in brown/natural tones are less water-soluble due to their high molecular weight and undergo less diffusion out of the hair shaft with shampooing. Both colour types, red

and brown, are prone to sunlight damage. In the case of brown colours, the impact of fading by irradiation is greater compared to fading by washing. For red colour tones, the influence of washing is so great that it almost conceals the impact of fading due to UV/VIS irradiation, which is, however, still significant. Sunlight protection against colour fading is therefore necessary for both red and brown shades.
From the consumer's perspective it doesn't matter whether the fading is caused by washing with shampoo or by sunlight – the effect is the same and always undesirable.
In developing a new hair-colour product claiming colour protection and long-lastingness, both mechanisms need to be addressed and are essential to a reliable colour protection concept. This is especially true when these concepts follow a holistic approach and aim to be efficient for all types of colorations. Otherwise it leads to further market segmentation with products focusing on personalized hair colours based on different shades.

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