NOVEL PERMANENT HAIR COLORING SYSTEMS DELIVERING COLOR WITH REDUCED FIBER DAMAGE

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Background:

Use of permanent hair colorants is widespread and allows the consumer to either change their natural hair color and/or cover gray. However, there are trade-offs that the consumer has to make if she is using these products on a regular basis. One of the main trade-offs is the fiber damage that is sometimes seen over multiple uses. This can lead to the consumer experiencing poor hair feel, an increased incidence of split ends and generally hair that loses some of its healthy appearance and shine. Thus developing hair colorant systems that allow the consumer to color on a more regular basis yet maintain hair quality is highly desirable.

There are two key chemical processes that take place during the coloring process. The first is the oxidation of the melanin pigment and previously deposited dyes that lightens the underlying hair color and the second is the oxidation of the dye precursors to form the coloured chromophores. For both processes the oxidant is essential and in the majority of retail hair colorants the oxidant used is the combination of hydrogen peroxide with an ammonia alkalizer at a final pH of 10. Importantly, it is also the oxidant that is mainly responsible for the damage to the hair fiber which leads to the loss of the hair's strength and healthy appearance.

We have discovered that the uncontrolled production of free radicals during the coloring process can be a significant contributor to fiber damage. Free radicals are species that are characterised by their high reactivity with substrates and are well known to be formed by oxidants such as hydrogen peroxide.
There are two key strategies that we have utilised to control the reactivity of the radical species:

(1) Chelation of the redox metal

One important chemistry of hydrogen peroxide is its catalytic reactivity with redox metals such as copper and iron to form the highly reactive hydroxyl radical (OH*).

$$H_2O_2 + Cu^{+} \longrightarrow Cu^{2+} + HO^{-} + HO^{*}$$

We have demonstrated that the addition of a chelant to the hair colourant such as N,N'-ethylenediamine disuccinic acid (EDDS) can significantly reduce the formation of the hydroxyl radical by complexing with the low levels of copper in the hair. We have also shown that the choice of chelant is crucial. In particular, the chelant must have a high selectivity for complexing to copper, especially in relation to other metals such as calcium that are commonly found in hair.
The reduction of the formation of the hydroxyl radical has been shown to significantly decrease the fibre damage from hair colorants when used over multiple cycles. One measure of this damage reduction is via an assessment of the cuticle quality as measured by the Scanning Electron Microscope (SEM). Chart 1 below shows the benefit of the EDDS chelant vs a selection of other chelants and the correlation between this benefit and the ability of the chelant to complex copper in the presence of calcium.

Chart 1 - SEM Grading Data for range of chelants

Chelant (0.05M) added to retail colorant	Ratio of Cu to Ca Conditional Binding Constant	SEM Damage Index Score*
EDDS	4×10^{11}	6.8
DTPA	4.6×10^{7}	49.8
EDTA	1.6×10^{6}	68.6
HEDP	7.7×10^{3}	61.0

* SEM damage index score based on visual assessment of > 50 fibers. Fibers were graded on a 4 point scale - low, medium, high damage and stripped. SEM Damage Index = ((1 x med) + (3 x high) +(5 x stripped))/5

(2) Radical Scavengers

The purpose of an effective radical scavenger is not to prevent the radical formation but to trap a highly reactive radical rapidly converting it into a much less reactive species. This species has reduced potential to indiscriminately react with and destroy protein and other materials in the hair fiber. The less reactive radical species thus does much less damage to the fiber. We have demonstrated the effectiveness of adding a range of radical scavengers to hair colorants, particularly formulations based on the combination of ammonium carbonate and hydrogen peroxide. We have shown that when formulated to provide equivalent levels of bleaching (dL), the addition of a radical scavenger such as glycine, glutamine, glucosamine, arginine or proline can reduce the fiber damage significantly as measured by tensile strength as shown in Chart 2 below.

Chart 2 - Tensile Strength data for range of radical scavengers

Treatment	15% Extension Force (gmf)	Force To Break Fibre (gmf)	Lightening (dL)
Untreated virgin Hair	20.3	72.7	-
Reference composition (Ammonium Carbonate + Hydrogen Peroxide)	12.5 S	46.1 S	15
+ Sodium Glycinate	18.1 s	72.6	15
+ Glutamine	18.9	77.2	15
+ Arginine	17.0 s	67.8	15

s = significant versus untreated hair to 95% confidence, S = significant versus untreated hair to 99% confidence.

The suggested mechanism is the conversion of either the reactive hydroxyl or carbonate radical to the less reactive superoxide radical.