African hair: exploring the protective effects of natural oils and silicones

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ABSTRACT

Due to its curvature and ellipticity, African hair tends to suffer higher level of breakage than other hair types. Its structure becomes compromised due to constant exposure to a variety of stresses such as washing, combing and heat styling, which further increases its propensity for breakage.

OBJECTIVE: The objective of this study was to determine the protective effects of two natural oils and two silicone polymers on African hair. The tested materials were: Crambe Anyssinica (Anyssinian) seed oil (ASO), Orbignya Oleifera (Babacu) seed oil (BSO), Bis-Aminopopyl Dimethicone (BAD) and Silicone Quaternium-22 (SQ22). The above active ingredients were applied to hair tresses as pre-treatments to grooming cycles and solar radiation exposure, estimated to be the equivalent to one month of damage.

METHODS: The protective effects of the treatments were assessed using the following tests: tensile stress requited to extend a wet fibre by 10%, the changes in hair colour after exposure to a sun simulator, torsional modulus measurements and thermogravimetric analysis.

RESULTS: Wet tensile stress testing showed a reduction in tensile stress required for 10% extension in the case of silicone-treated hair, whilst the natural oils did not show a significant effect. There was a visually perceptible change to hair colour (expressed as ΔE value) before and after grooming in all tresses, indicating that none of the treatments were able to completely protect hair from solar damage; however, ASO and SQ22-treated hair was less discoloured. The TGA analysis determined that grooming and SR reduced the water content of the hair and the oil treatments did not have a protective effect. The dry torsional tests showed that ASO softened the hair cuticle. Overall, the results infer that the Anyssinian seed oil in particular offers some benefits to African hair, including maintaining cortex strength, mitigating the solar radiation-induced degradation of melanin, and increasing cuticle softness.

It is expected that over extended period of time, these effects would contribute to maintaining the fibre’s manageability and reduced breakage, which are critical for keeping African hair in good condition. The remaining three active materials were less effective.

Key words: African hair, treatment, protection, oils, silicones

Introduction

It is known that hair fibre shape and curvature are determined genetically and that they affect the physical characteristics of hair. Round to oval cross-sectional shapes form straight to wavy fibres, while oval and elliptical shapes give curly to frizzy hair. Comparisons between African, Caucasian and Asian hair identify African hair's cross sectional area as the most elliptical of the three, while it is in the middle between Asian (the largest) and Caucasian (the smallest) in size [1]. The distribution of para-, meso- and ortho-cortex cells within the fibre cortex has been associated with the degree of hair curliness, with African hair having paracortex, no mesocortex and a higher proportion of orthocortex cells compared to Caucasian hair [2]. Despite these structural differences, the protein composition of different racial types of hair do not differ. However, the differences in the external lipids [3] and Cell Membrane Complex (CMC) lipids have been reported [4].

Due to its curvature, African hair is characterised by low manageability; even the hair with no history of braiding, chemical treatments and heat styling has been observed to have high incidence of knots, longitudinal cracks, splits and occurrence of broken hair [5]. Hair breakage due to combing loads has been investigated in Caucasian hair, with the conclusion that snag formation during combing causes strong impact loads of fibres over other fibres; such high loads over small area are more likely to cause hair to break [6]. This conclusion is equally applicable to the African hair, as due to its high curvature, combing or styling impact loads are likely to occur and cause breakage. The pattern of breakage under slow stress (1 mm/minute) of dry undamaged African hair has been shown to follow several stages: cuticles separation, cracks appearing at the cuticle-cortex interface, and cracks propagating towards the surface [7]. Although this experiment is not directly related to consumer's handling of hair, it illustrates the role of CMC in maintaining fibre integrity. In addition to being prone to breakage, the African hair has been found to sustain damage to the cuticle from UV radiation, with scaling and lifting of the cuticles after 24 h of exposure [8]. Cyclical hair blow-drying has been shown to cause longitudinal cracks in the cuticle of Caucasian hair, starting from the inner cuticle layers and propagating towards the surface [9], whist using hot styling appliances causes chemical decomposition of the amino acid tryptophan and an increase in combing work [10]. These studies were conducted on Caucasian hair only, but the impact of heat on African hair in similar conditions (repeated rapid blow-drying and intermittent styling at temperatures of 180^{0}C or higher) is expected to be considerable. Overall, these studies point that African hair is very likely to accumulate grooming damage, which manifests in lower manageability and tendency for breakage. It is therefore important to actively protect African hair in order to reduce the probability of breakage. Silicone polymers have been used in haircare formulations for a couple of decades for the purpose of mitigating hair grooming damage, whilst plant-derived oils for hair care were the traditional treatment over centuries, gaining back their popularity in recent years.

The aim of this study was to explore the effects of two natural oils and two synthetic polymers on African hair subjected to moderate daily grooming cycles.

Materials and methods

Hair tresses

Curl type VI African hair tresses weight=3g, length (average, when fully stretched) =15cm (single donor, the hair had not been treated chemically), were cleansed with 20% Sodium Lauryl Ether Sulfate (SLES). Three tresses were allocated to each group of treatment.

Protective treatments and grooming damage

Protective treatments: The silicone treatments were prepared as 3% dilutions in cyclomethicone following suppliers' recommendations. Diluting the oils in a cyclomethicone carrier was considered too, however there were no recommended concentration levels, unlike the available information for the silicone polymers. As a result, the oil treatments comprised of neat oil. Each tress was treated with 1.0 ml of 'active treatment' (Table I) per 1.0 g of hair, which was then massaged with gloved fingers into the tress and rested for 10 minutes. Three tresses were allocated to each treatment. These quantities were chosen to ensure that uniform coverage of the whole tresses by the treatment can be achieved, accounting for the extremely curly shape of the fibres and for the fact that each treatment was applied to dry hair.

Grooming damage cycle: following the application of the protective treatment, the tresses were washed thoroughly with 3 ml SLES, blow-dried for 2 minutes and combed with 55 strokes; this was repeated 3 times, followed by 25-30 seconds thermal straightening at 215 ^{0}C.

Complete grooming process: Three repetitions of protective treatments and grooming cycles were carried out on each tress, followed by a single 6-hour exposure to solar radiation (SR) 300-800nm at 250W/m2 using Suntest CPS (Atlas, Germany). Between treatments, cycles and tests the tresses were stored in a controlled humidity chamber at 65% relative humidity (RH) and the temperature between 22–25^{o}C. Figure 1 illustrates the treatment and test sequence. Three tresses were used in each treatment group.

TABLE I. ACTIVE TREATMENTS

Figure 1. A flow chart of the sequence of the complete grooming process and testing

Hair fibre tests - tensile stress

Wet fibres were extended for 10% of their initial length using TA.XT Plus (Stable Micro Systems, UK). Prior to the test, the tresses were kept at 65% RH for 12 hours. Just before the extension test, each fibre diameter was measured using a Digimatic Micrometer (Mitutyo, UK) in three places and averaged, then the fibre was submerged in a petri-dish filled with distilled water and left to soak for 5minutes. The fibre was then swiftly mounted on a card (50mm test length) and extended at a rate of 5mm/s; the force required to reach 10% extension was recorded. The results were then normalised by dividing the force by the cross-sectional area of the fibre. All treatment groups were tested untreated, then subjected to the respective assigned grooming process, and tested again. 24 fibres were tested for each group, they were randomly selected from the assigned three tresses (however, the tresses with diameter <40 microns were not included in the tensile stress test, as such fibres are deemed very fine) from which the mean values were calculated.

Hair tress colour test

Colour was measured using the L* (white/black scale), a* (red/green scale) and b* (yellow/blue scale) colour space with the CM-2600D Spectrophotometer, at illuminator D65, specular light excluded and a viewing angle of 10 degrees (Konica Minolta, UK). The hair colour was measured in both control and treatment groups at pre- and after-grooming time points. Three colour measurements per tress were taken at each time point and the mean values for *L, a* and *b* were calculated. ΔE, signifying the difference in tress colour between pre- and after-complete grooming process, was calculated next. A mean ΔE for each treatment group was calculated.

Thermogravimetric analysis

The experiment was conducted using Discovery TGA (TA Instruments, USA) whereby the water loss of hair snippets heated in increments of 10^oC/min until 180^oC was recorded. The top of the temperature range was selected to match the temperature commonly reached by heated styling appliances. The following groups were tested: control undamaged, control damaged, ASO and BSO treatments. All tests were conducted in triplicate. The hair samples used had been conditioned at 65% RH for 12 hours before the experiments.

Torsional test

30 randomly selected fibres from each treatment group were mounted at a 30mm gauge length and stored across a 15-slot cassette. The dimensions of all fibres were first measured via laser scanning, using Dia-Stron FDAS770 (Dia Stron Ltd, UK). The fibres were then tested using Dia-Stron FTT950 (Dia Stron Ltd, UK) using linear extension rate of 10mm/min followed by rotation to 90^o angle, at a speed of 5^o per second. Dimensional and torsional tests were performed at temperature of 20+/-2 ^{o}C and relative humidity of 20+/-2% with fibres being equilibrated for 3 hours prior to testing. The following groups were tested: control undamaged, control damaged and ASO treatment. Due to breakage in one group the number of valid results were 27. A torsional analysis tool calculates the sheer modulus G; additionally, elastic modulus E is also generated via this test.

Statistical analysis

The 10% tensile extension data and the *L*-values for hair colour were statistically analysed in the following manner: Shapiro-Wilk's test for normality, followed by One-way ANOVA in order to identify differences within groups (pre- and after- complete grooming process) and between treatment groups. Where appropriate, Tuckey HSD test was performed to identify which pairs of treatment groups showed statistically significant differences. Student t-tests (paired) was also performed within each treatment group to assess the pre- and after-grooming differences.

Elastic and torsional moduli data was analysed using Shapiro-Wilks normality tests, followed by Levene test for homogeneity of variance, and by Student t-test (unpaired) between treatments.

In all cases, $p < 0.05$ was used as a threshold of statistical difference.

Results

Tensile properties

The results, shown in Fig. 2, have revealed that the pre-treatment groups did not significantly differ. After the complete grooming process, statistically significant differences were detected between the following groups: BAD vs. control and BAD vs. both oils, and for SQ22 vs. control and SQ22 vs. ASO. In summary, the silicone-based treatments recorded lower tensile stress needed for 10% extension than the control and the oil-treated hair, after grooming and solar damage.

Statistically significant difference was also found within the silicone groups in the pre- and post-complete grooming process measurements, with BAD reducing the tensile force by 19% and SQ22 by 17%. There were no such differences for the control and oils treatment groups (Fig. 2).

Figure 2: Impact of different pre-treatments on African hair. Grey bars show the tensile stress needed for 10% extension of the fibres when undamaged, while black bars show the tensile stress after the respective complete grooming process. Statistically significant difference is denoted by asterisk (*).

Colour retention

Following the SR, all hair groups displayed ΔE values between 4.0–6.0 (Table II) with ASO and SQ22 eliciting the smallest colour change values. The colour change direction (Fig 3) suggests that the notable impact on the colour was via the L (white to black axis) and *b* (yellow to blue axis) values, but not so much in the *a* (red to green axis) value. The statistical analysis of the *L*-values of all tresses before SR exposure showed no difference, but for each treatment group, a difference in the *L*-values before and after grooming and SR was found. The BSO treated hair was significantly lighter that all others.

TABLE II. *L*-VALUES OF PRETREATMENT TRESSES, ΔE VALUES CALCULATED FROM L,*a,b* VALUES TAKEN PRE-TREATMENT AND AFTER THE RELEVANT TREATMENT, GROOMING CYCLES AND SOLAR RADIATION

Figure 3: Impact of different pre-treatments on the direction of colour change in African hair. Each Δ value is calculated by subtracting the respective mean values for the group before any grooming from the mean value measured on the same tresses after the grooming (and protective treatment where applicable).

Thermogravimetric test

Only control and oil treated hair was tested, as they exhibited better tensile properties than the silicon-treated groups. The results (Fig. 4) indicate that untreated hair had the highest water loss. This is attributed to having more loosely bound water in the first place due to its undamaged structure in comparison with the groomed hair.

Figure 4: Thermogravimetric analysis of African hair measured as weight loss. UNT - control group without any grooming damage; CONT- control group after grooming damage; ASO and BSO treatment groups after grooming damage.

Torsional Test

Only ASO-treated hair and controls were tested, as out of the two oils ASO elicited a better outcome for the hair in the previous tests. The torsional modulus G for the ASO-treated hair group was lower than the undamaged and damaged values for the control group (Table III). The torsional modulus reflects the state of the cuticle, whereby lower values mean softer cuticle. At the same time, the estimated elastic modulus (calculated by the software) showed no statistically significant differences between the tested groups.

TABLE III. TORSIONAL MODULUS AND CALCULATED ELASTIC MODULUS FOR THE DIFFERENTLY TREATED TRESSES OF AFRICAN HAIR

Discussion

Treatment doses

Lower quantities of treatments were pre-tested (0.5h per 1g of hair), however the application of oils on dry hair was visibly uneven. Hence, higher treatment doses were chosen, which created visible appearance of even coating, but without excessive oil being present on the tray used to rest the hair. The silicone treatments were prepared using recommended dilution levels and were more easily spread throughout the tresses also living the appearance of slight hair coating. Hence, higher doses of oils, in comparison with the silicones, were present on the hair for this experiment. After each washing and drying, the treatment materials were no longer visibly noticeable. However, the researchers observed changes to small visual characteristics of the hair such as curl definition and slight tress elongation as well as softening of the dry tresses. Whilst these observations were made for all tresses but they could not be quantified due to the lack of suitably trained sensory assessors.

Instrumental tests

The test measuring the 10% extension of wet hair fibre was chosen because it covers the elastic region and partly the plateau area of the Hookean curve of the hair fibre's tensile properties. In the wet state, this area of the curve is dependent on the structure of the cortex. The grooming damage applied in this study was chosen as moderate, hence it is reasonable to conclude that it caused negligible structural changes to the cortex of the control hair sample. The same result was returned by the oil treatments. However, the results of the silicone treatments infer that at the tested concentration level, they were causing plasticisation in the hair (Fig. 1). These results require further investigation, specifically precise measurements of the wet fibres' dimensions to control better for the fibre swelling. The discolouration caused by the SR to all treatment groups demonstrates that the nature of the donated hair was partly responsible for the significant lightning of the hair. Whilst the treatments were not expected to function as UV absorbers, it was noted that ASO and SQ22 treated hair showed colour changes of somewhat smaller magnitudes (Fig. 3). As the hair came from a single donor, this result can be attributed to possible radiation absorbance from these actives. The colour direction and *L*-value analysis suggest that further investigations in the factors causing changes to the *L* and *b* values, for example separating thermal from SR effects, will be beneficial.

It was also anticipated that heat and SR would affect the lipids in the CMC as well as some protein structures thus altering the amounts of water content of dry hair. The control untreated hair lost less water than the control damaged hair. This is attributed to having lower water content in the first place. In a separate experiment (not reported in this papers) Caucasian hair was tested untreated and after the same regime of grooming damage. The water loss in the undamaged and groomed Caucasian hair (3.647mg and 2.067 respectively) were higher than those for African hair (1.763mg and 1.590mg respectively) confirming that higher water levels were present in undamaged hair and that African hair holds less water than Caucasian hair. For African hair, the oils treatments did not facilitate a recovery of water content in dry hair, with BSO values being lower that damaged control.

The combination of tensile data, the colour tests suggested that ASO was relatively effective in preserving hair hence the additional testing of dry torsional and elastic modules. In line with the other tensile data, the E values were not significant, suggesting that the level of damage was moderate and did not reach the cortex. The torsional modulus for ASO being lower, infers that this oil had the effect of softening the cuticle of the African hair.

Conclusion

The purpose of this project was to identify to what extent the pre-treatment of African hair would contribute to maintaining it in good condition, when hair is subjected to daily damaging grooming processes. The moderate level of washing, combing and heat styling were applied in combination with solar radiation in order to simulate consumer's handling of hair for a period of one month. The results obtained from the range of tests suggested that the ASO oil (rich in C22 unsaturated fatty acid triglycerides) offered some concrete benefits to African hair, including: maintaining its cortex strength; some protection from the solar radiation induced degradation of melanin and increased cuticle softness. It is suggested that over extended period of time, these effects would contribute to maintaining fibre's mechanical strength (reduced breakage) and manageability (less stiff hair will be easier to handle), which are critical for keeping African hair in good condition. Based on the colour and TGA tests, the BSO oil was less effective. The tested silicones were also somewhat less effective under the test conditions. As their dosing was lower than that of the oils, effects may increase in treatment regimens including higher concentrations. Further studies are needed to investigate the sensory attributes of pre-treated African hair in comparison with hair subjected to the same grooming and solar exposure without any pre-treatment. Such sensory studies will complement the torsional and colour measurements and will facilitate the appropriate dosing of hydrophobic ingredients such as plant oils and silicones.

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