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New Aspects of Lipids in Strength and Elastic Activity of Human Hair

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ABSTRACT

Although concentration of lipids is below 5% (w/w) of the hair, the lipids play an important role in keeping hair healthy, such as shining and texture. The goal of this study is to elucidate the effect of lipids in hair on exposure to surfactant and to clarify how much their loss impacts hair strength. The experimental approach was to obtain physical properties of the hair lost lipids or the hair conserved lipids; dual modification was treated to hair in washing. The results show hair in which lipids are conserved over time by washing, maintains their physical properties. It was confirmed that hair with lost lipids decreases its strength in structure and elasticity.

Keywords: Hair, Structure, Lipid, DSC

INTRODUCTION

According to the mechanism of lipid loss in our previous study, lipids are clearly classified into two groups [1]. The first group consists of highly hydrophobic lipids that are removed from the inside of hair by direct emulsification. The second group, on the other hand, comprises relatively less hydrophobic lipids that diffuse to the outermost layer of hair and are lost by a roll-up process. The lipids in the first group are prevented by filling inside hair with amine-coupling materials in carbodiimide chemistry [2] named internal modification, and the lipids in the second group are prevented by coating polar film, named surface modification. Gas chromatography/mass spectrometry (GC/MS) study proved that the dual modification consists of internal and surface modification perfectively prevents lipid loss against surfactant in wash.

This study handles the change of physical property upon alteration of lipid in hair. The lipid decomposition studies have led to the development of a simple method for the extraction and analysis of lipids from tissues. The entire procedure can be carried out in approximately a few days; it is efficient, reproducible and free from deleterious manipulations. Lipid-based residue reports require correct understanding of both the total amount of lipid decomposition and their role. Today, the first demand is well-established by the study in detail [3-5] but the second is, however, more questionable. Numerous studies have shown that very complicated methods currently used in their research provide lipid extraction under complicated process. The lab considered it to be advantageous if the chloroform solvent is used in multiple times. Further, exploration of the roles of the lipid in hair may provide clues for understanding the mechanism of hair conditioning.

In this paper, we report the change of physical property for the hair from human hair conserved lipids because of dual mechanisms, greatly facilitates the measurement of increased amounts of labile lipid components, such as fatty acids, squalene, cholesterol and wax esters. These experiments use differential scanning calorimetry (DSC), bending tester, tensile strength tester and GC/MS to determine physical property by conserved lipids. The results from these evaluations have been confirmed based on determining the quantities of lipids. We used hair as a representative model of tissue and systematically demonstrated how lipids in tissues are lost by surfactant use. It has been demonstrated that the mechanism by which physical properties are enhanced from lipids depends on the type of shampoo.

MATERIALS AND METHODS

DSC

Dry-DSC experiments were performed with a DSC-400 (Perkin Elmer, US). Each sample was subjected to heating and cooling treatments at a scanning rate of 10°C/min under

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nitrogen atmosphere in order to prevent oxidation. A test sample of 3.5 mg was placed in an aluminum pan with two tiny pinholes and tested over a temperature range of 30°C-300°C. Two types of hair were used. A total of 5 hair tresses which are healthy and 4 shampooed samples were used in this experiment.

Pendulum test

The vibrational mechanical tests based on pendulum motion were performed with a home-built system analyzer (Hanagiyeon, Korea). Test specimens were taken from the middle section of the start point bar and were vibrated up to a side height position with a support vibration of 30 mm. The length of hair tress was 150 mm. Measurements were conducted over a temperature range of 25°C with 30 cycles under a constant frequency of 75.0Hz.

Tensile strength

Experiments were performed by preparing and testing the properties of 20 individual hair fibers per each sample. The properties were evaluated to convenient method using a Diastron (UK) testing machine model MTT175.

Bending rigidity

The bending rigidity of hairs was measured with KES-FB instruments (Kato Tech, Japan). Testing samples were cut into 30 × 50 mm^2 in size.

Analysis of lipid concentrations

Hair samples were analyzed on an Agilent (7890A GC System, US) gas chromatograph coupled to an Agilent detector (5975C MSD System, US). The mass spectrometer was operated in the electron impact mode at ionization voltage of 70 eV. Mass spectra in the full scan mode were recorded in the mass range of 50-500 amu. Selected ion monitoring (SIM) was carried out by monitoring m/z 228 for myristic acid, m/z 256 for palmitic acid, m/z 69 for oleic acid, m/z 284 for stearic acid, m/z 85 for docosane, m/z 85 for tetracosane, m/z 74 for 18-MEA, m/z 121 for squalene, m/z 386 for cholesterol and m/z 257 for myristyl palmitate, palmityl palmitate and stearyl palmitate. Peak identification was based on comparison with standards for retention times and mass spectra fragmentation. M/z 230 for o-Terphenyl as the internal standard was added to the lipid solution. 100 mg of each reference substance was dissolved in 10 mL of the 2:1 mixture of chloroform and methanol. The concentration of all mixture of reference substances was 1000 mg/L. 10μL of the internal standard, o-Terphenyl (2000 mg/L) was added to 1 mL of the extractable lipids.

Hair shampooing

We used commercial shampoo, named as P and C. The washing section involved rubbing the hair by hand. To wash hair with SLES, a 1 g hair swatch was pre-wetted with 1 mL of water and then covered evenly with 0.1 mL of the surfactant. The surfactant was lathered well by hand for 15 s. Subsequently, the hair was gently rubbed for the shampoo ingredients to be absorbed into each hair shaft for 45 s and the hair swatch was rinsed with water for 2 min. The tap water used in the foaming for washing and rinsing flowed at a speed of 40 mL/s from a faucet. After removing excess water, the hair swatch was gently dried with a paper towel. These steps, with exception of the pre-wetting step, were repeated several times for experiments. After the rubbing wash, the samples were thoroughly blow-dried.

RESULTS AND DISCUSSION

The behavior of surfactant is very complicated due to its amphiphilic structure [6]. The washing mechanism is not simple and the activity of surfactant exhibits that lipids are lost over time by washing, exposure to the surfactant. However, it was shown that prevention of these lipids is possible by dual modification for surface and internal hair [1]. Dual modification produces an increase in the lipid concentration **(Figure 1)**. The percentage change in the lipid concentration of the hair is defined as:

100 × (Lipid concentration from virgin - Lipid concentration after washing) / Lipid concentration from virgin

The lipid level reaches a maximum of 90% after 10 times of washing by the modification. The hair washing without the modification decreases the lipid concentration, and most of this decrease is accounted by a penetration of surfactant inside hair or roll up mechanism at the hair surface. On the assumption that the lipids influence physical properties in hair, further experiments for the physical properties were carried out.

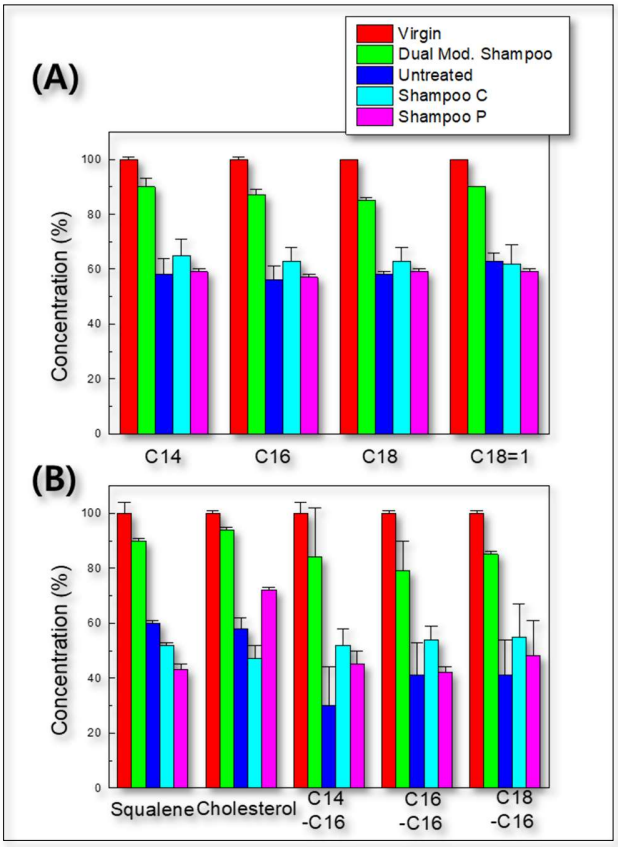

Figure 1. The concentrations of the remaining lipids from the virgin hair, hair with general shampoo as control and the hair by the dual modified shampoo in rubbing 10 times. Untreated indicates lipids from hair washing with only surfactant. Shampoo C and P have conditioning cellulose polymer and oils to cover hair surface for development of texture. The normalized concentration was calculated based on the average concentration of the control. (A) Amphipathic lipids (B) hydrophobic lipids.

The tensile strength results of virgin, shampoo control and dual modified hair in wash were demonstrated and compared in **Figure 2**. These results show that the control composites' tensile properties were significantly lower when compared to the treated hairs by the dual modification. In all cases, the control composites of other general shampoos had worse tensile properties than the human hair reinforced composites (data not shown). It is proved that when the loading stuff increases for the dual modifications, physical property keeps due to the prevented lipid amounts. A comparison with the lipid contents indicates the lipids are responsible for the strength.

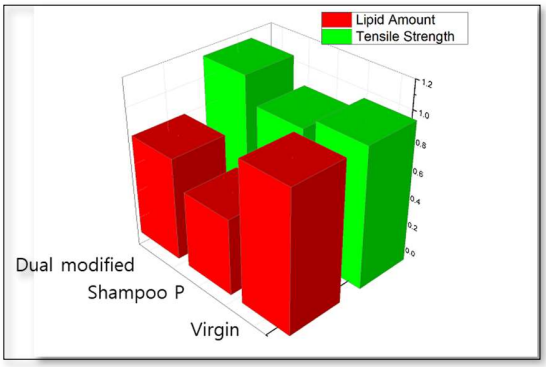

Figure 2. Tensile strength of hair washed by dual modification and general shampoo. The strength is normalized to the intensity of virgin hair.

Oscillating motion with hair tress makes movement of a mass for the tress. The elastic force of the hair tress is responsible for the oscillating motion. Although vibrations frequency does not depend on the movement distance in physics, hair elasticity reflects height of hair tress at the ending point as shown with arrows in **Figure 3**. The height from bottom reaches up to 2.7 cm and 3.4 cm, for the untreated hair lipid lost and the dual modified hair lipid conserved.

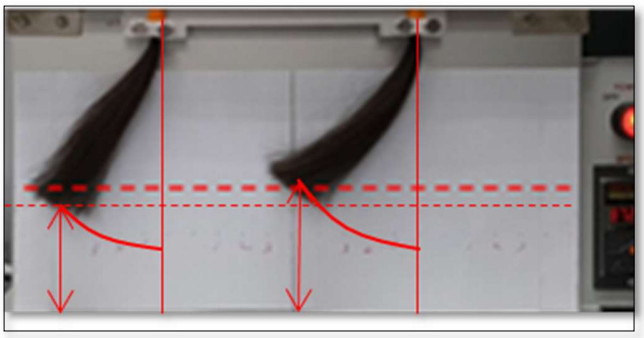

Figure 3. Pendulum motion test with movement of the hair tress. (Left) untreated hair, (right) the dual modified hair.

The bending strength results are demonstrated. The bending rigidity increases with the increase in the lipids content as shown in **Figure 4**. The bending rigidity values are reduced from 1.38 to 0.49 gf due to a defeat of lipid inside the hair. The bending rigidity of human hair reinforced composite increases up to almost value of virgin hair when the hair is treated by the dual modification. We have compared the bending rigidity of virgin and dual modified hair. No significant difference between them was observed.

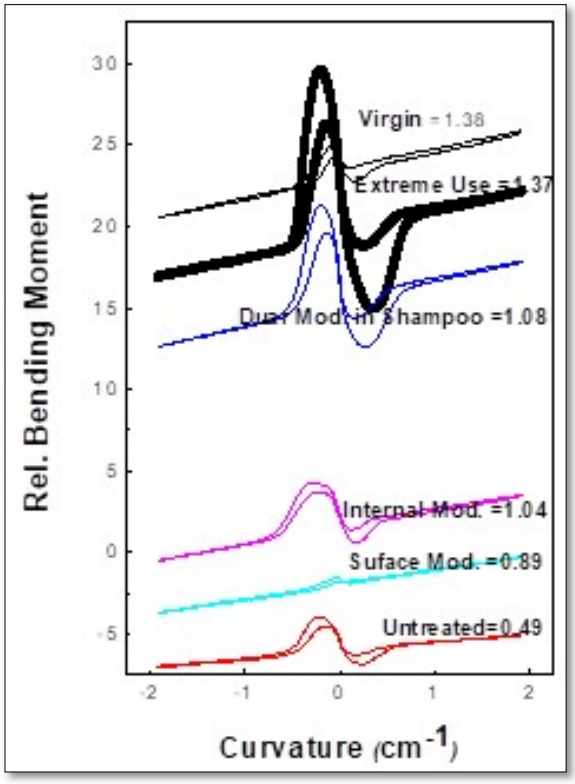

Figure 4. Comparison of experimental bending rigidity dependent lipid concentration with GC/MS.

The DSC characterizations of all the samples were subjected to one heating process. The results from the heating are displayed and taken into consideration in **Figure 5**. Typical DSC peak in water stands a peak of around 160°C responsible for α-helix [7]. The keratin fiber loses their ordered regions at this heating region.

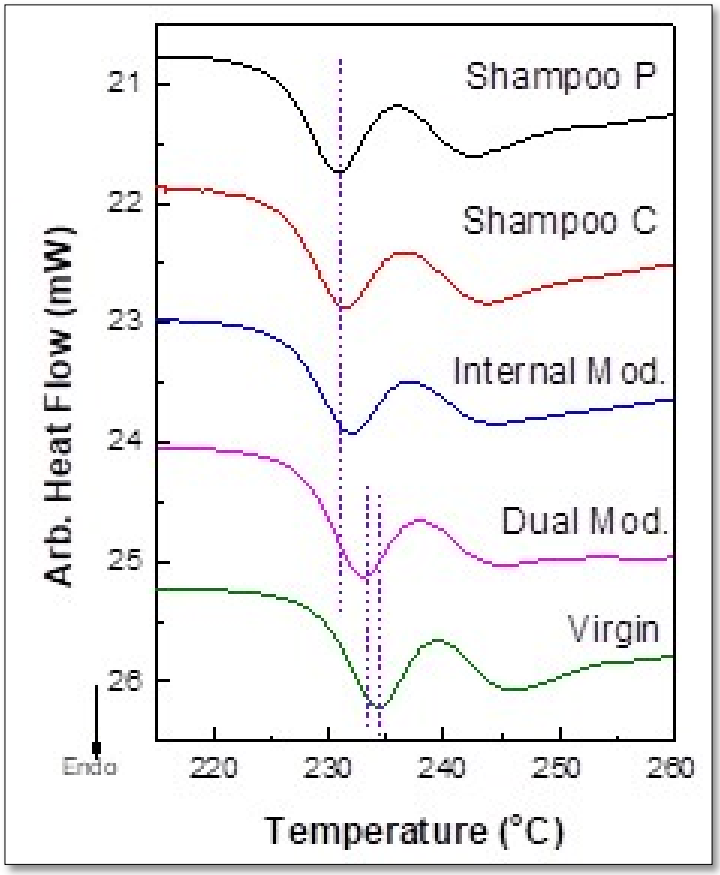

Figure 5. DSC curves recorded for the hairs treated with various shampoos. Peak of the temperature reflects structural strength for the folding-unfolding of α-helix.

Dry-DSC thermo grams show the presence of two peaks for all scans of the composites. The origins of the peaks are under debate [8]. The lower one indicates α-helix structural distribution [9]. The second temperature appears to be due to cysteine decomposition [10]. The first one ranges from 230°C to 234.5°C. The peak for the curve was consistent, independent of hair origin in a three times repeated measurement. Using a combined approach of lipid concentration and lipid loss for hairs treated with various shampoos, DSC thermo grams show that the presence of structural degradation under lipid loss. The lipid loss has significant effect on the first temperature of the α-helix.

The ΔH is an important parameter since its magnitude is directly proportional to the overall level of structural rigidity for releasement of the α-helix. The ΔH of hairs was estimated around 4.5 J/g; these values were similar in all samples. However, the temperature of the maximum peak for the α-helix was decreased down to 230°C. This shift of the peaking temperature indicates that the structure for the α-helix was weakening due to a loss of lipids.

A cell membrane complex (CMC) is filled with lipids [11]. The membrane may be unstable as the lipids lost after washing with surfactant. This may cause destruction of the entire structure of hair. Our interpretation is not sufficient to explain the enhancement of hair strength, thus, in order to understand a structural analysis, it is necessary first to distinguish several levels of description about strength level and to place these levels within a lipid concentration perspective in future.

CONCLUSION

On the basis of the evidence presented above, we suggest that the hair lipids support strength which is responsible for most physical properties in hair. Human tissues such as skin and hair have the potential to accumulate lipids, such as glycerides that contain fatty acids important for high value fatty acids. Although lipid extraction methods for the human hair are well established, there is currently no explanation for the role of lipids, especially in hair. This has caused a few problems in lipid research due to absent goal of the prevention of lipids for hair in entire lipid study and industry. This experimental study presents the effects of human hair lipids in compressive strength of conserved lipids. This study conserved lipids against washing with surfactants, as the experimental group and lost lipids as

standard group being the control groups. Finally, all results prove that the lipids greatly increase the strength of the hair. Conserving lipids improve the health of the hair.

COMPETING INTERESTS

All authors are employed by LG Household & Health Care Ltd.

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