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Effect of coconut oil on prevention of hair damage. Part I

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Synopsis

Beneficial effects of coconut oil on prevention of combing damage on different types of hair have been established by protein loss and water retention measurements. *In vivo,* salon-based, half-head tests confirm these beneficial effects. Beneficial effects were also observed on chemically (bleached) and thermally (treated with boiling water) damaged hair. In addition to providing lubricating film, it is hypothesized that coconut oil used as a prewash penetrates endocuticular material in the intercuticular region and reduces its swelling propensity. The penetration of water into the intercuticular region is prevented by hydrophobic oil film at the edge of the cuticle. Both these effects prevent the lifting of the surface cuticle and its breaking by the force exerted by the comb.

INTRODUCTION

Hair fibers consist of three distinct morphological components, namely, the cuticle, the cortex, and the medulla. Layers of cuticle cells form the outer sheath of the fiber and are mainly responsible for the cosmetic properties of hair. Mechanical properties, on the other hand, are attributed to the cortex, which forms the bulk of the fiber.

Because of extensive cross-linking, cuticle cells tend to be brittle and, therefore, are susceptible to damage by grooming procedures, especially wet combing (1). The loss of cuticle cells by gradual chipping impairs the structural integrity of hair, leading ultimately to split ends and fracture. This limits the length and the cosmetic qualities of hair such as smoothness and shine. Grooming methods involving abrasive procedures are known to damage hair and its appearance.

Historically, coconut oil has been used as a hair dressing in the developing countries in the tropical regions of the globe where coconut is cultivated extensively. Prolonged use of coconut oil has been known to lead to healthy-looking long hair, suggesting that it may prevent damage to the cuticle in grooming procedures involving abrasion. Obvious is the lubricating effect of oil on fiber friction, which reduces abrasive damage, especially in combing.

This investigation is aimed at presenting alternative mechanisms for the beneficial effect of coconut oil in preventing hair damage when used as a preconditioner. Although several methods involving scanning electron microscopy (SEM) and measurement of combing forces and tensile mechanical properties have been used earlier to characterize hair damage, we have used protein loss and water uptake methods for this purpose (3). We have also used consumer-perceived attributes of hair quality as additional measures of hair damage and its alleviation. Furthermore, these methods have been extended to study the beneficial effects of coconut oil on chemically treated (bleached) hair and hair treated with boiling water for 2 hr. There is a large amount of work showing this effect. It is well known that bleached hair, because of its high degree of swelling, is more prone to grooming damage, especially in the wet condition (2).

MATERIALS AND METHODS

MATERIALS

Samples of straight, curly, and wavy hair of Indian origin were used in this work along with a sample of untreated dark brown hair from DeMeo Brothers, New York. The lengths of the Indian and DeMeo hair strands were 25 and 15 cm, respectively. The reagents for protein estimation were obtained from Sigma Chemicals Co. (St. Louis, MO). All other reagents were of analytical grade.

Sample Preparation. Hair tresses of 3 ± 0.5 g (or 2 ± 0.2 g for DeMeo hair) were prepared for this investigation. They were cleaned by soaking in 0.01% (w/v) of polysorbate 80 (30 min at 28°C), de-ionized water at room temperature (several rinses), and 0.01% (w/v) acetic acid (15 min at 28°C), in that order. Finally, they were extensively rinsed in water and blow-dried.

Bleached hair was prepared by using a bleaching kit containing 30 vol. hydrogen peroxide and ammonia solution to adjust the pH to ~10. Five milliliters of this solution was employed per tress, and the treatment time was 120 min. With this treatment the tresses became light brown with a red tone.

The boiling water treatment was carried out for 120 min. After bleaching or boiling in water, some of the tresses were treated with 0.2 ml of coconut oil, spread uniformly throughout the tress by a brush. The tresses were stored at room temperature for 48 hr before use.

The entire study involved samples with the following treatments on four types of hair, i.e., DeMeo and Indian (straight, curly, and wavy): (a) undamaged control; (b) undamaged/coconut oil; (c) bleached; (d) coconut oil/bleached*; (e) bleached/coconut oil*; (f) boiling water; (g) coconut oil/boiling water*; and (h) boiling water/coconut oil*. Twenty-five replicate tresses were used for each treatment.

METHODS

The tresses were wet under running tap water (28°C) and were washed with a 20%

* Sequential treatments.

solution of sodium laureth (3 moles of EO) sulfate (SLES). One milliliter of the solution was applied per tress and the tresses were worked between fingers to produce a lather. Following this, they were extensively rinsed to remove all the SLES residues. After this treatment the tresses were subjected to the following investigations.

Combing damage. The protein-loss method of Sandhu and Robbins (3) was used in the following manner: Each of the wet tresses was combed with a fine-toothed nylon comb (20–22 teeth/inch) 50 times, rather vigorously, along the entire length of the tress on both sides. After every five strokes the comb was dipped in 50 ml of water contained in a beaker to dislodge the debris. The entire tress was dipped in water after every ten strokes to collect the damaged and dislodged cuticle cells. The water suspension was tested for protein content using the Lowry method. This method involves the formation of a copper-protein complex in alkaline solution that in turn reacts with phosphomolybdic-phosphotungstate reagent (Folin-Ciocaltaeu phenol reagent) to yield an intense blue-colored solution, which is analyzed spectrophotometrically.

Water-retention index (WRI). The SLES-washed tress was weighed and then soaked in a 0.01% solution of polysorbate 80 for 30 min. Following this procedure, the tress was centrifuged to remove capillary water and then weighed. In the next step, the dry weight of the hair was determined by drying the tress in a vacuum oven at 50°C for 90 min and then weighing it again. The water retention index (WRI) is given by:

$$WRI = (W_{wet} - W_{dry})\ 100/W_{dry}$$

Evaluation of cosmetic attributes. These evaluations were made on normal untreated and bleached hair, with and without coconut oil. For each treatment three tresses were treated with 0.2 ml of coconut oil and the other three were used as untreated controls. The attributes evaluated in this study were ease of combing (wet and dry), smoothness, bounce, setting, luster, and flyaway. All the attributes were rated on a scale of 1–5 (1 is poor and 5 is excellent). Three judges did the ranking.

Half-head tests. Each half-head test involved 20 clients, each with normal and bleached hair. The hair was parted in the middle, and half the head was treated with coconut oil and the other half was left without treatment. Then the hair was washed with warm water (28°C, 200 ppm hardness) using 20% SLES and rinsed well to remove any residue. To avoid inherent differences in damage from left to right side, application of the treatment was randomized. Panelists with an odd number were treated on the left side, while those with an even number were treated on the right side.

After shampooing and rinsing, the hair was combed with a fine-toothed comb (separate comb for each side). After each of the ten combing strokes, both the hair and the comb were dipped in 200 ml of water to recover broken cuticle debris. A total of 100 strokes (50 on each side) was applied. The suspension with cuticle debris was used for protein estimation.

The entire study was carried out according to a completely randomized block design approach, and the outcome of these experiments was analyzed statistically (taking into account the mean standard deviation of the number of replicates) for the significance of the treatment effects within the confidence limits.

RESULTS AND DISCUSSION

PROTEIN LOSS

This is the most important measurement relevant to hair damage. It is well known that wet combing is accompanied by the breaking of the surface cuticle cell because of its brittleness. Histologically, the major component of the cuticle cell consists of the exocuticle and the endocuticle as shown in Figure 1. The exocuticle, being highly cross-linked, is not swollen by water. The endocuticle and the cell membrane complex, on the other hand, are less crosslinked and are more vulnerable to damage. This leads to the lifting of the surface cuticle via bending. Such cuticle cells can be broken in the process of combing or teasing. The protein loss observed in these measurements results mostly from the cuticular region. Because of the short time involved in the combing and brief immersion of the comb tress in water, it is unlikely that proteins from the bulk of the fiber are involved in this measurement.

The data for protein-loss measurement for undamaged hair are shown in Figure 2.

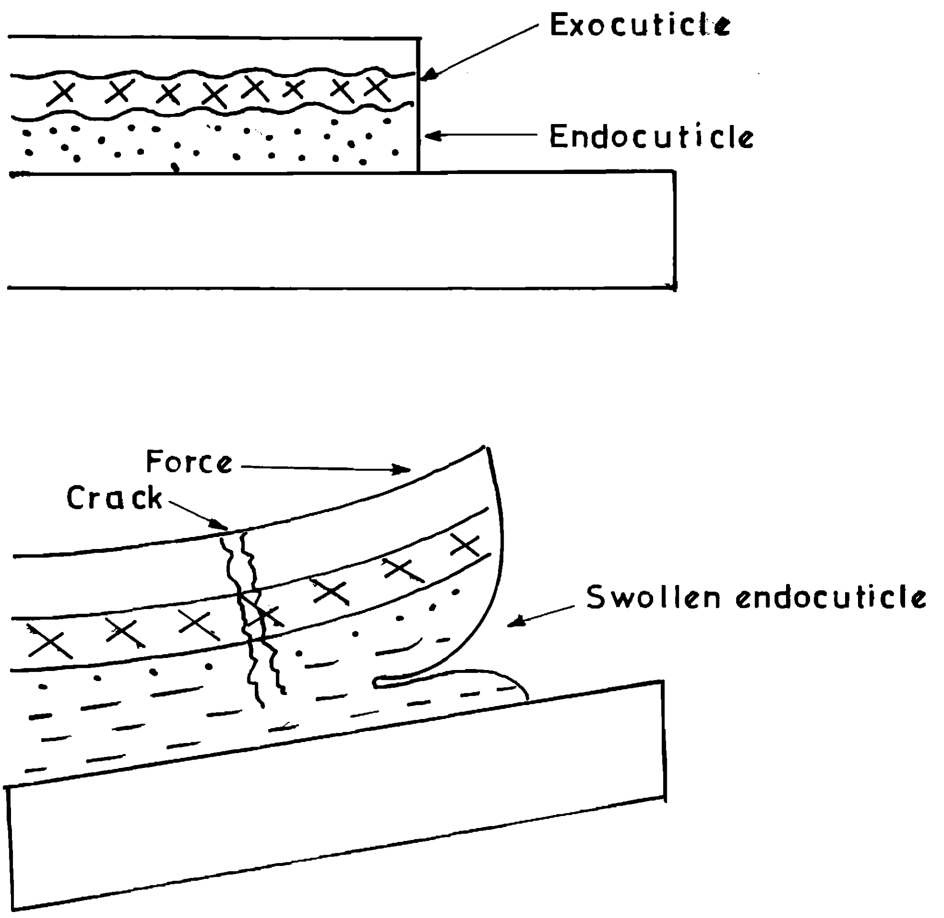

Figure 1. Schematic diagram of the possible mechanism of chipping of surface cuticle cells in wet combing.

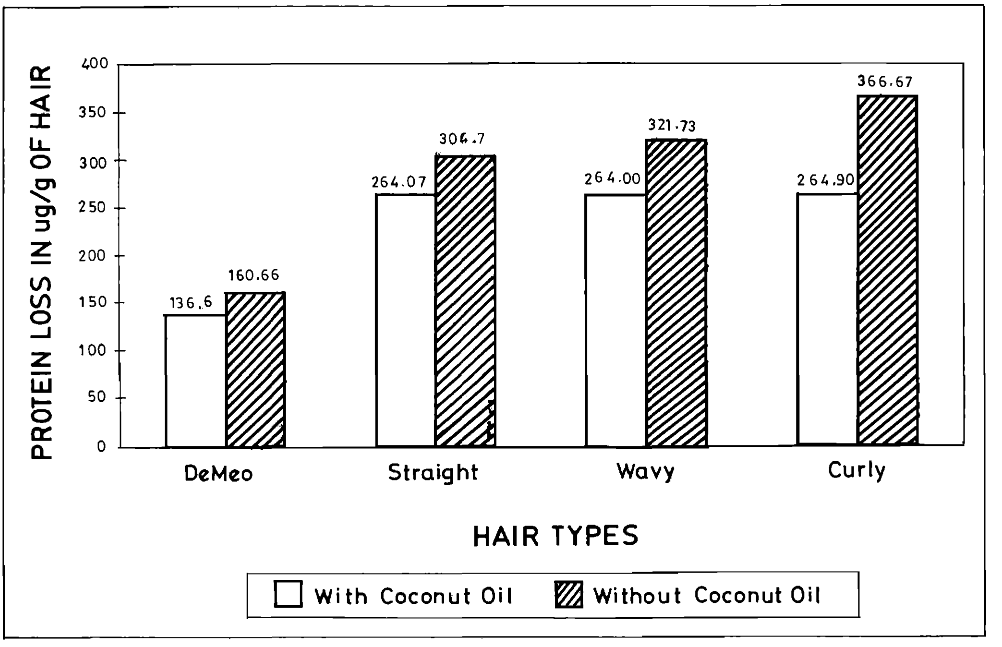

Figure 2. Comparison of protein loss in wet combing for undamaged hair.

Clearly, the protein loss is significantly reduced by the application of coconut oil as a prewash conditioner (coconut oil applied before SLES wash). The same trend is also observed in the case of bleached hair and hair treated with boiling water (Figures 3,4).

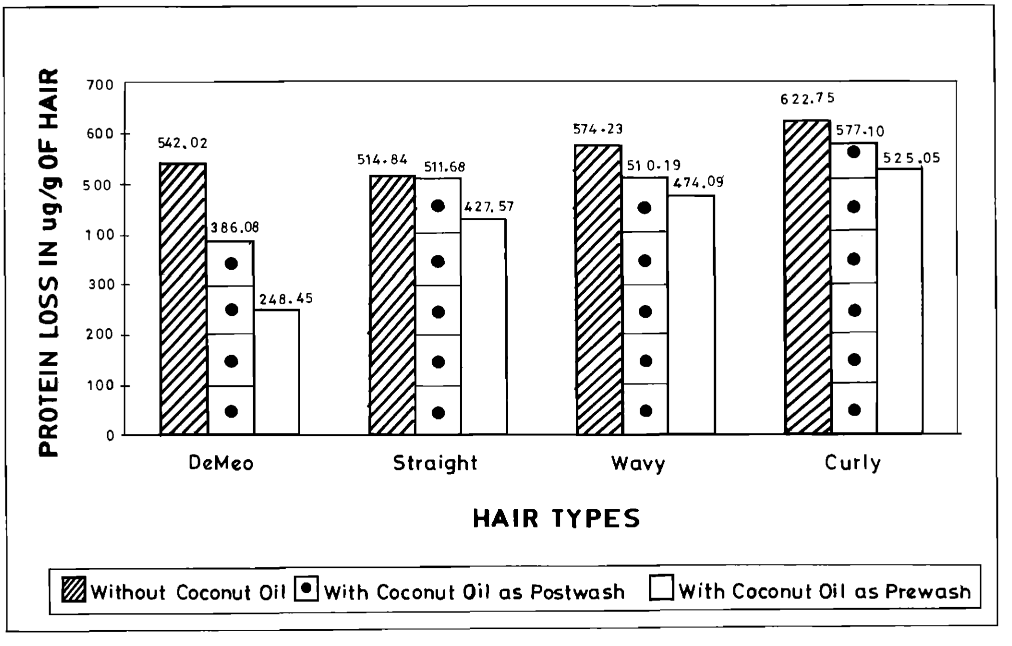

Figure 3. Protein loss in wet combing of bleached hair with coconut oil as pre- and postwash conditioner.

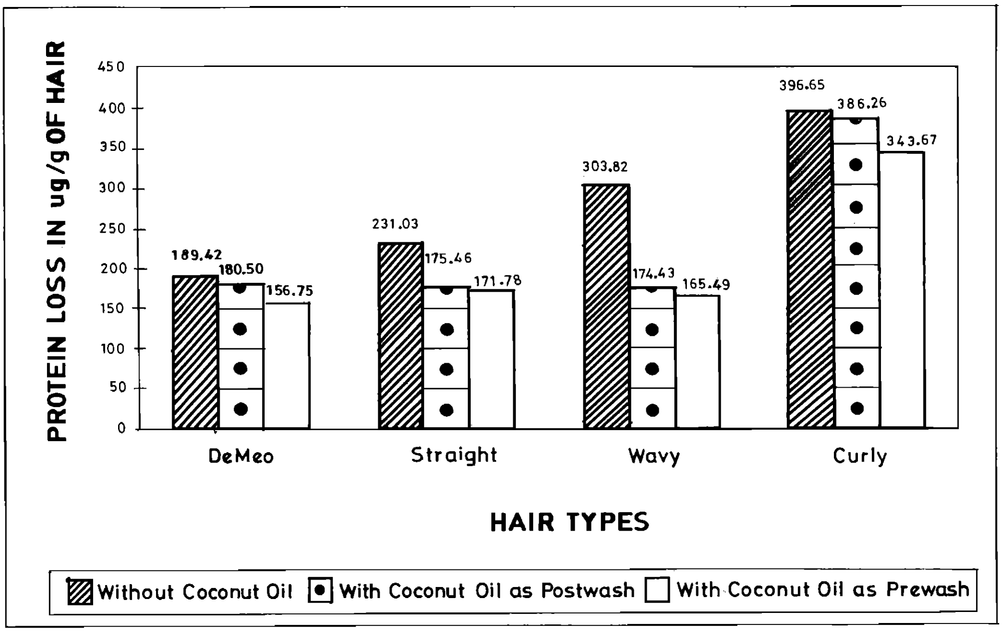

Figure 4. Protein loss from hair treated with boiling water and the effect of coconut oil as a conditioner.

With these two damaged samples, coconut oil was also used as a postwash conditioner (coconut oil after SLES wash) in addition to use as a prewash treatment. The difference between the results of the prewash and postwash treatments reflects the relative importance of fiber lubrication on cuticle loss. From the point of view of combing damage, limiting the swelling of the fiber appears to be more beneficial than just lubricating the swollen fiber.

As in the laboratory test, the beneficial effect of coconut oil was also observed in a salon test. A significant difference in protein loss was observed with (13.1 µg/g) and without (203.02 µg/g) coconut oil for normal hair. For bleached hair, the corresponding values were 304.8 and 466.0 µg/g, respectively, for treatments with and without coconut oil.

The beneficial effect of coconut oil in preventing cuticle damage in the laboratory test was established statistically by analysis of variance (ANOVA). The outcome of the analysis is shown in Table I. F-values clearly indicate that damaged as well as undamaged hair benefit from application of coconut oil as a prewash conditioner. The effects of coconut oil were also positive in the salon test, as can be seen from the data in Table II. In both normal and bleached hair, treatment effects in reducing protein loss are significant.

This is also seen in pair-wise comparison using the t-test. The data is shown in Table III. In this table, there are four outcomes that are not statistically significant. They are comparisons of hair treated with boiling water for 2 hr (without any treatment) with hair treated with coconut oil after treating with boiling water for 2 hr. This clearly shows that the cuticle damage has occurred in the hair treated with boiling water for 2 hr before the application of coconut oil.

Table I
Analysis of Variance for Treatment Effects

Hair type	Source of variance	Degrees of freedom*	Sum of squares	Mean square	F-Value
DeMeo	Between treatments	7	3545687.30	506526.76	156.76
	Experimental error	192	620411.57	3231.31	
Straight	Between treatments	7	35050625.20	500723.60	37.80
	Experimental error	192	2543128.50	13245.46	
Wavy	Between treatments	7	3071240.99	438748.71	28.39
	Experimental error	192	2967233.28	15454.34	
Curly	Between treatments	7	2729734.30	389962.04	21.839
	Experimental error	192	3429503.00	17861.99	

* F theoretical for degrees of freedom (7,192) at 95% confidence level = 2.01.

Table II
Analysis of Variance for Half-Head Treatments and Their Significance

Hair type	Source of variance	Degrees of freedom*	Sum of squares	Mean square	F-Value
Normal	Between treatments	1	51724.87	51724.87	413.70
	Experimental error	38	4751.07	125.03	
Bleached	Between treatments	1	259854.40	259854.40	654.89
	Experimental error	38	15077.94	396.79	

* F theoretical for degrees of freedom (1,38) at 95% confidence level = 4.08.

Table III
Pair-Wise Comparison of Treatment Effects*

Treatment	DeMeo	Straight	Wavy	Curly
Undamaged: with and without coconut oil	6.55	1.73	8.26	5.26
Undamaged: without coconut oil and bleached	17.55	2.35	26.24	9.63
Undamaged: without coconut oil and boiled	5.21	4.59	32.99	1.83
Bleached and treated with boiling water	16.02	7.43	2.26	10.00
Coconut oil-treated; bleached and coconut oil-treated; treated with boiling water	32.07	13.16	4.93	16.88
Bleached; coconut oil-treated and treated with boiling water; coconut oil-treated	10.28	8.85	17.04	7.04
Treated with boiling water and coconut oil-treated; treated with boiling water	6.33	0.06	0.91	0.81
Treated with boiling water and treated with boiling water; coconut oil-treated	1.51	1.91	1.70	1.26
Bleached and coconut oil-treated; bleached	6.91	3.85	7.29	1.82
Bleached and bleached; coconut oil-treated	13.22	3.91	8.63	3.47

* Student's t-test theoretical for 48 degrees of freedom at 95% confidence level = 1.645.

Protein-loss measurements were also used to highlight the beneficial effect of coconut oil as a prewash conditioner for different commercial shampoos (instead of 20% SLES). Seven different brands were used in this study involving Indian curly and straight hair. Protein-loss data in Figures 5 and 6 once again show that combing damage is alleviated by coconut oil used as a conditioner. Curly hair shows a greater trend towards protein

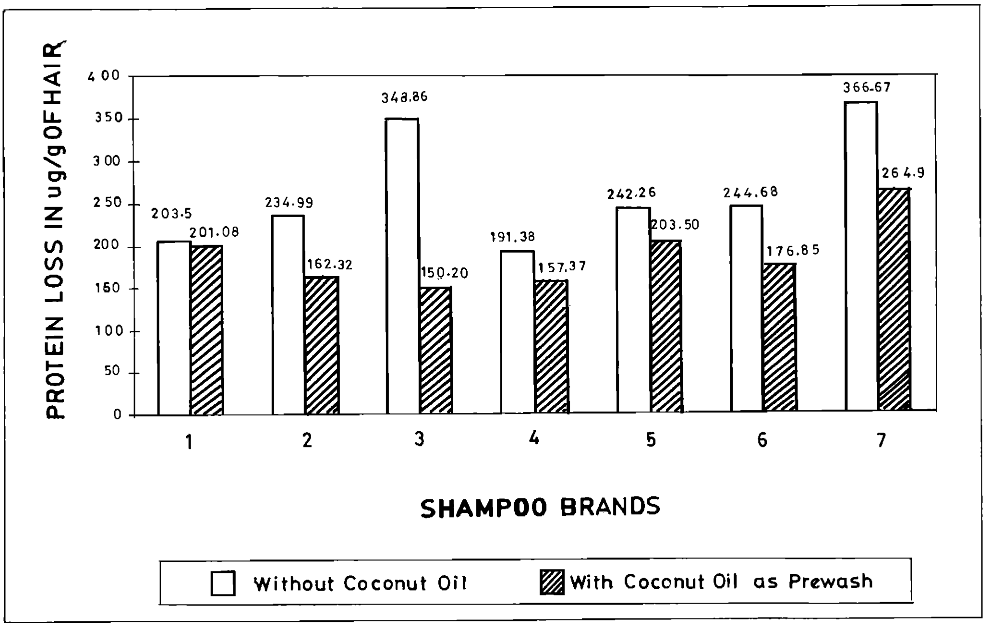

Figure 5. Reduction of protein loss by prewash treatment with coconut oil on curly hair washed with various commercial shampoos.

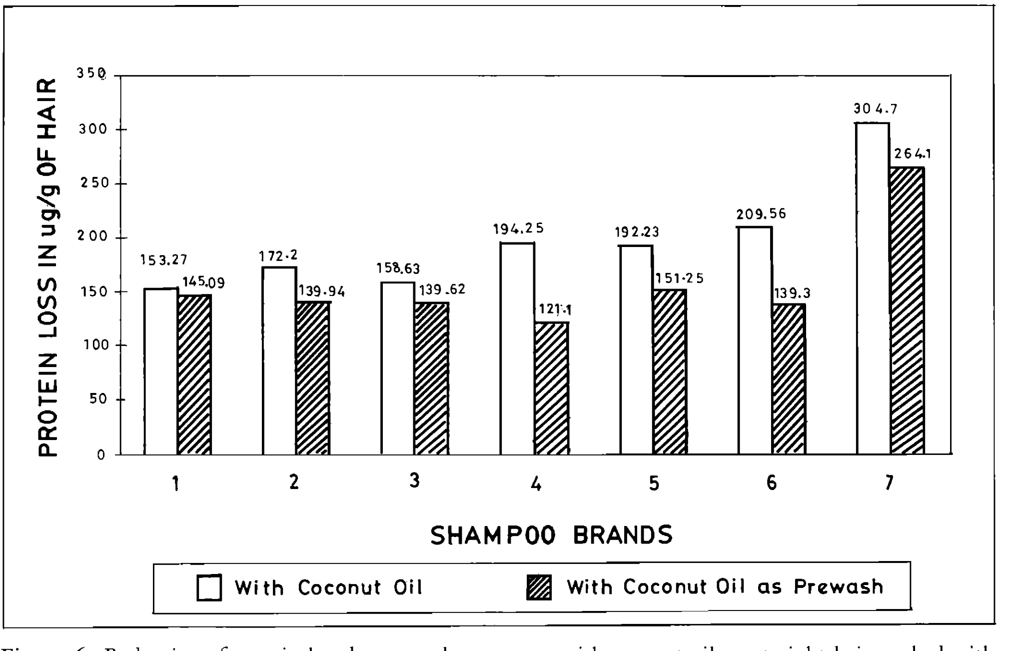

Figure 6. Reduction of protein loss by prewash treatment with coconut oil on straight hair washed with various commercial shampoos.

loss as compared to straight hair. This is mainly due to greater comb–hair interactions of a frictional nature in curly hair as compared to straight hair.

WATER-RETENTION INDEX

The water-retention index of undamaged hair is shown in Figure 7. From the data it can be seen that coconut oil reduces the WRI by 2–5%. Since coconut oil was used as a prewash conditioner, it would be reasonable to conclude that the effect may be due to oil residues left in the hair.

The data for the bleached and boiling-water-damaged hair are shown in Figures 8 and 9, respectively. For these damaged samples, the WRI is much higher than that for the undamaged hair. This is mostly due to chemical degradation of proteins, generating hydrophilic groups. Both cleavage and oxidation of disulfide bonds, as well as hydrolysis of the peptide linkage, occur, although the contribution of the latter is probably minor. All samples show a reduction in the WRI as a result of the application of coconut oil. Assuming that most of the water is absorbed by the fiber, the WRI reflects the swelling propensity of hair. Since repeated swelling and contraction damage the cuticle, reduction in the WRI can be considered as beneficial in reducing hair damage.

The data in Figures 8 and 9 show that the sequence of application (whether pre- or postwash) is important. Postwash application is less effective in reducing the WRI as compared to prewash application. The difference seems to be in the location of the oil residues. In postwash application the oil film is on the surface, with no penetration into the fiber. In prewash application, because the fiber is swollen after the application of the

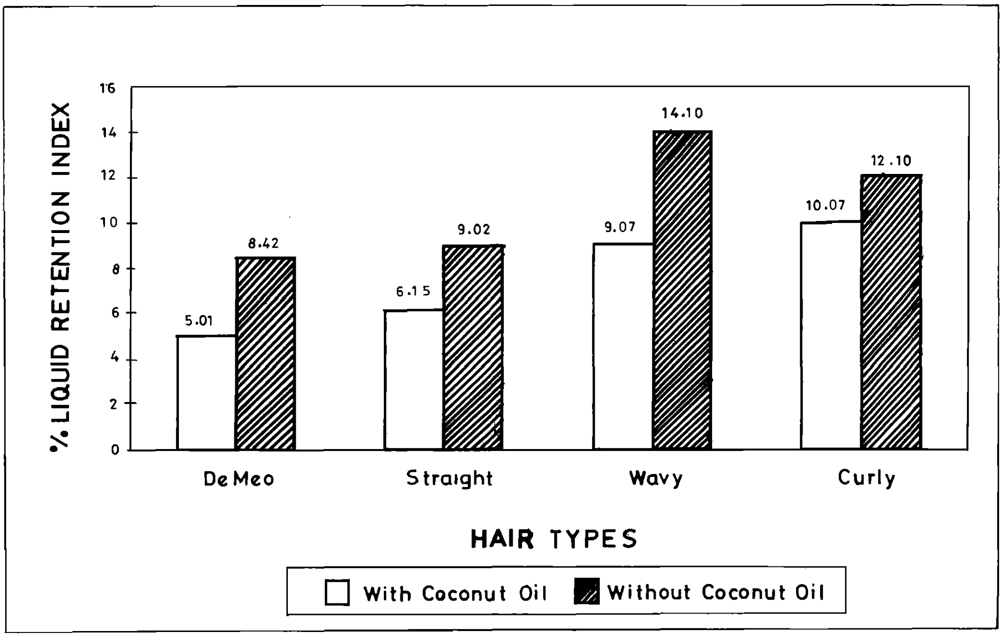

Figure 7. WRI of various hair types: Effect of coconut oil as a prewash conditioner.

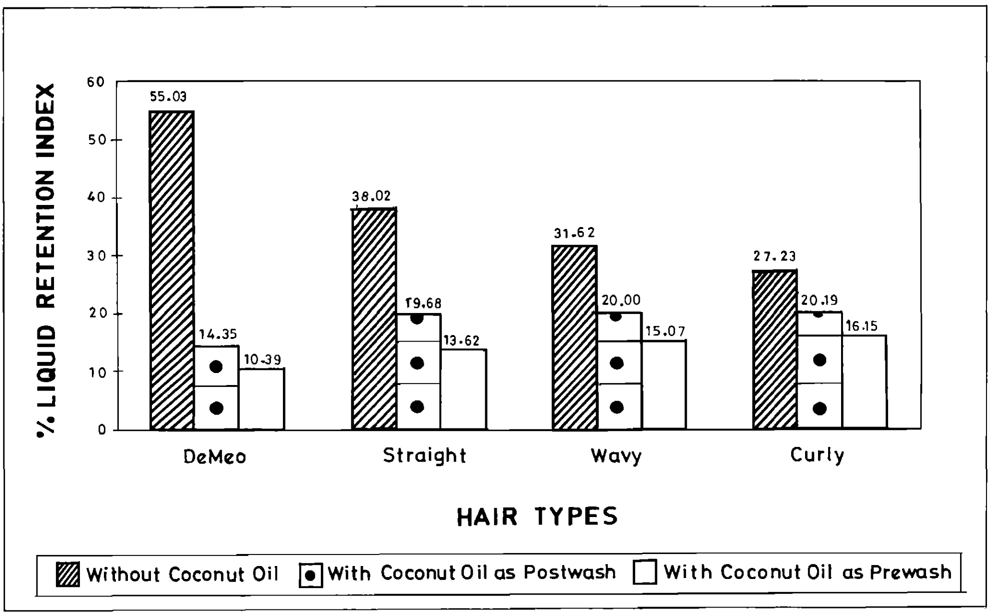

Figure 8. WRI of bleached hair with coconut oil as a pre- and postwash conditioner.

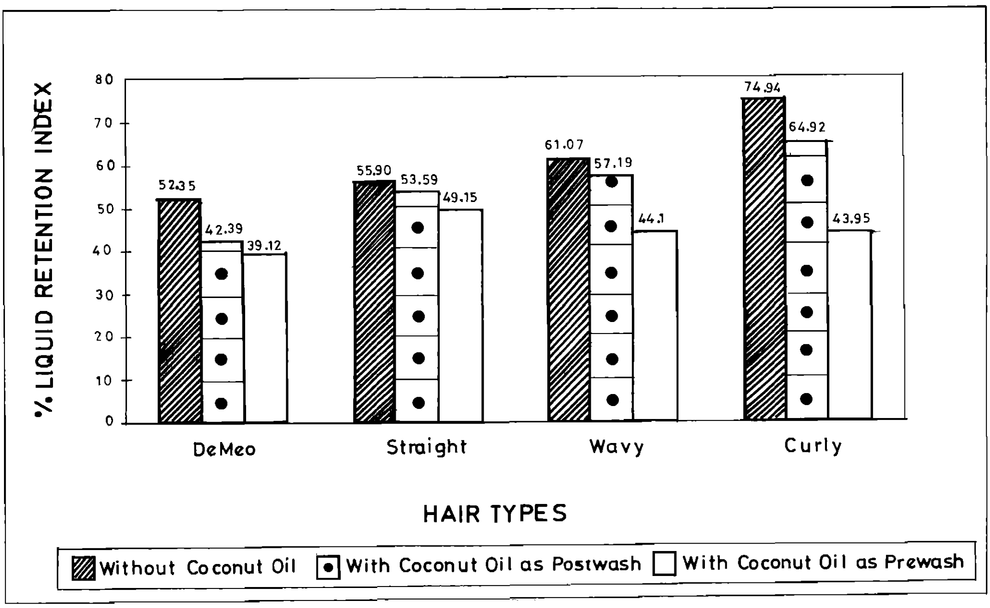

Figure 9. WRI of boiling-water-damaged hair with coconut oil as a pre- and postwash conditioner.

oil, it is possible that the molecules of the oil penetrate into the cuticle and probably even the cortex. This may also be the case with undamaged hair, although the effect is small. The reduction in the WRI must be due to the introduction of the hydrophobic triglyceride into the keratin structure.

BENEFITS ON COSMETIC ATTRIBUTES

This study was conducted *in vitro* on undamaged and bleached hair using coconut oil as a prewash conditioner. Three judges ranked the cosmetic attributes, which have been listed earlier. The rankings are shown in Figures 10 and 11, respectively, for undamaged and bleached hair. The beneficial effects of coconut oil are seen for most of the cosmetic attributes of hair.

MECHANISM OF PROTECTION BY COCONUT OIL

The histology of a cuticle cell and the mechanism of damage in wet combing proposed by Swift (4,5) is shown in Figure 1. Because of cross-linking, the exocuticle is brittle and does not swell. The endocuticle and the cell membrane complex have less cross-linking and therefore swell significantly. This effect produces the tendency for the surface cuticle cells to curve upward and break when pressure is applied with a comb.

Recent studies of Ruetsch and Weigmann (6) confirm that the endocuticle and the cell membrane complex (CMC) are the foci of weakness and that fracture occurs when the fiber is extended. Chemical methods weaken the adhesion of the cell membrane complex between the cuticle cells. The degree of swelling of the cuticular layers is increased by disulfide cleavage and oxidation. This enhances the combing damage and protein loss, especially in wet combing, as observed in this study.

Coconut oil is mostly a triglyceride of lauric acid and hydrophobic. Application of coconut oil as a prewash conditioner coats the hair and inhibits the penetration of water into the hair. A small part of it is also absorbed into the hair during the wash when the

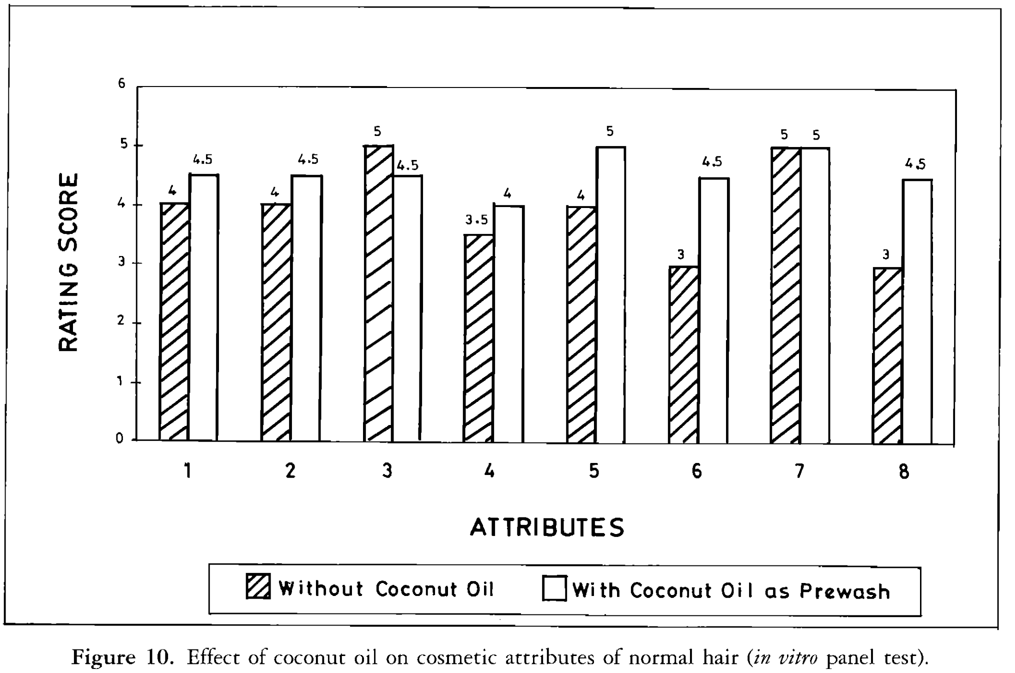

Figure 10. Effect of coconut oil on cosmetic attributes of normal hair (*in vitro* panel test).

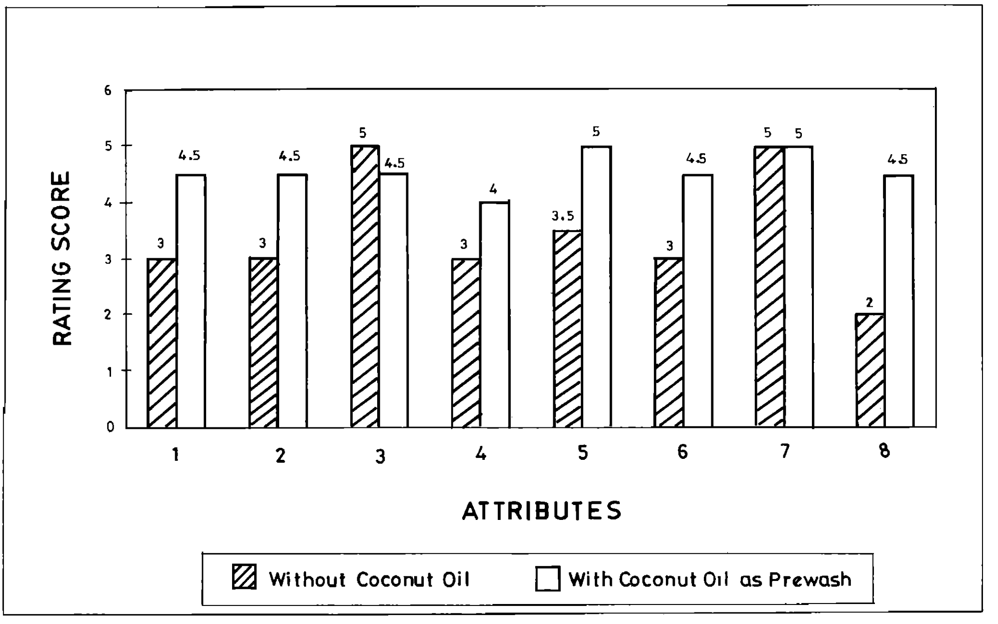

Figure 11. Effect of coconut oil on cosmetic attributes of bleached hair (*in vitro* panel test): Protective effect in improving appearance.

fiber is swollen. Introduction of this hydrophobic component reduces the swelling propensity of the cuticle, which limits the upward curving of the surface cuticle. This reduces the chipping away of the cuticle cells, which reduces protein loss, as observed in this work.

Because of its low molecular weight (~1000) the oil may also penetrate the cortex. Once again, because of the introduction of hydrophobic functionality into the fiber, the WRI is reduced. Reduction of water absorption and associated swelling seems to be the dominant mechanism of protection from the coconut oil. Lubrication provides an additional level of protection in grooming processes.

CONCLUSIONS

This study has firmly established the protective effect of coconut oil on hair damage in grooming processes when it is used as prewash conditioner. It also has a protective effect on chemically treated hair and hair treated with boiling water (i.e., hair in water at 100°C for 2 hr). The hydrophobicity of coconut oil seems to be responsible for this effect. Coated on the fiber surface, it can prevent or reduce the amount of water penetrating into the fiber and reduce the swelling. This in turn reduces the lifting of the surface cuticle and prevents it from being chipped away during wet combing. A reduction in the WRI is additional evidence for the decrease in water absorption. In addition to its protective effect, coconut oil seems to improve a number of cosmetic attributes of hair. Other benefits of this natural prewash hair conditioner are under investigation.

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