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RESEARCH ARTICLE

EFFECTS OF TREATMENTS WITH CURLING IRON ON HUMAN HAIR FIBERS

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ABSTRACT

Thermal treatments for hair styling are becoming increasingly popular with consumers both at home and in hair salons. The aim of the present study was to reports an investigation into the effects of this treatment by flat iron on Tunisian hairs. Untreated hair (not chemically treated) was obtained from a volunteer woman who have 34 years old. Individual hair fibers were mounted in parallel arrangement and subjected to 20, 40, 60 and 80 cycles of curling with the flat iron. Each cycle consisted of fifteen seconds of heating at a temperature of 180°C and fifteen second of cooling. In the other hand, the same hair fibers were bleached using H2O2 and subject to the same thermal treatment as virgin hair. The resulting damage to the fibers has been investigated and quantified by tensile measurement and surface characterization. Tensile properties were performed using a Miniature Tensile Tester Model 675 of Dia-Stron and surface characterization was examined using the SEM. After the cited treatment, the cuticle which is the outer covering surrounding and protecting the cortex was destroyed and a cracking of the cuticule cells and a scale lifting was observed for both virgin and bleached hair. It has also contributed to a progressive decrease in the tensile properties of the hair. The elastic modulus and the break stress have respectively decreased of 12.4 % and 18.18% for virgin hair. However, bleached hair loosed 35.7% and 50% respectively of the elastic modulus and the break stress at 100 % RH.

In conclusion, the thermal treatment has conducted to the hair surface modification and cuticle damage. In addition, there was a significant reduction in tensile properties after treatment as a function of exposure time especially bleached hair which was affected by the curling more than virgin hair.

INTRODUCTION

Human hair can undergo different treatments which can influence its properties (Rageliené *et al*, 2009; Signori and Lewis, 1997; Kon, 1998; Wolfram *et al*, 1970; Robbins, 1969). Among this treatment, the study of heat effects on keratin fibers has both fundamental and applied interest. In literatures, there are many experimental studies about the effects of chemical treatments on human hair, such as permanent-waving, bleaching, relaxing, or oxidative dyeing (Robbins, 1994). Also, physical changes produced as a result of grooming operations have been thoroughly discussed (Garcia, 1976) In addition; the photodegradation of human hair has been of growing interest to scientists and has warranted considerable attention (Hoting and Zimmermann, 1996; Pande and Jachowicz, 1993). On the other hand, the literature reflects a limited amount of research focusing on the irreversible chemical or physicochemical changes occurring in hair as a result of thermal treatments applied to hair in conjunction with the use of flat irons or hairdryers (Crawford, 1981; Humphries, 1972; Rebenfeld, 1966).

Ethnicity is an important factor to consider when evaluating the behavior of hair, which may potentially impact the hair's response to treatments and processes. Although same researches were interested to the effect of thermal treatment on human hair (Crawford, 1981; Humphries, 1972; Rebenfeld, 1966; Mcmullenand Jachowicz, 1998; Ruetsch and Kamath, 2004), no studies have examined the behavior of Tunisian hair after treatment with flat iron. The aim of this study is to investigate the effect of the thermal treatment on Tunisian hair. The changes in hair properties were characterized by several techniques including dry and wet tensile properties and scanning electron microscopic (SEM) examination.

MATERIALS AND METHODS

Untreated hair (not chemically treated) was obtained from volunteer Tunisian women (who has 34 years old). Hair was cut near the end of the hair shaft (10 cm long). Individual hair

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fibers were mounted in parallel arrangement as shown in figure 1 and subjected to 20, 40, 60 and 80 cycles of heating with the flat iron. Each cycle consisted of fifteen second of thermal treatment and fifteen second of cooling. We have used a Braun satin flat iron and the temperature of treatment was fixed at 180°C. In this case, individually treated fibers will be much more affected by the hot metal surface than a hair fiber assembly, which tends to absorb and distribute the heat and moderate temperature within the hair strand.

In order to maintain uniformity of the experimental conditions and to assure reproducibility of the obtained data, the treatment was administered in the same position.

After the treatment, the fibers were conditioned for at least 24 h at 65% +/- 4 RH and 21°C +/- 2 °C. Specimens from the same treated fibers were used to examine the effects of “repeated cyclical short-time heating/cooling” on the mechanical properties of hair.

The tensile measurements were performed using a Miniature Tensile Tester Model 675 (MTT675) and a Fiber Dimensional Analysis Unit Model 765 (FDAS765) of Dia-Stron, UK. About 50 single fibers were tested for each sample at a stretching rate of 20 mm/min and a gauge force of 1.5 gmf, as initial condition. The measurements were performed in wet conditions. Prior to loading in the circular cassette, the samples were immersed in distilled water for 120 min to allow them wetting. During the measurements the cassettes were also filled with distilled water to ensure the 100% humidity content during the measurement. Mechanical properties were also measured in dry conditions at 65% +/- 4 RH and 21°C +/- 2 °C. To show the effect of thermal treatment in hair surface, we have exanimate the fiber surface using the SEM. We have used a SEM S360 (Zeiss NTS GmbH, Oberkochen).

Concerning the bleached hair, the bleaching was induced for 30 mn by an oxidative treatment with commercial bleaching products (IGORA VARIO BLOND PLUS bleaching powder and IGORA ROYAL 30 vol 9% H_2O_2 bleaching lotion). The oxidative procedure followed the instructions of use. The fibers were cleaned with 1% Lauryl ether sulphate (LES) and rinsed with distilled water after the treatment.

RESULTS AND DISCUSSION

Effect of thermal treatment on virgin hair

Keratin fibers present a complex surface morphology, the most apparent of which are the cuticle scales that surround each fiber. It is a protective coating made of overlapping scales, produce a characteristic pattern.

The typical topography of virgin hair fiber without thermal treatment is shown in figure 2. The untreated controls show good differentiation of the cuticle cell. There may be some debris on the scale faces and jagged scale edges, which is normal and indicative of chipping damage from standard grooming practices.

Figure 1 hair fibers mounted in parallel arrangement for thermal treatment

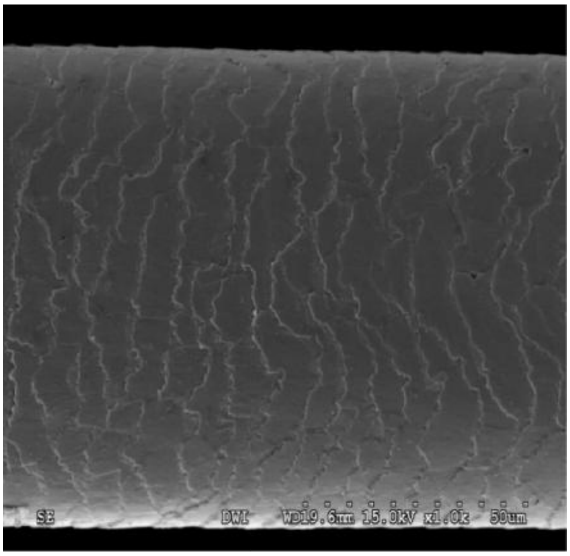
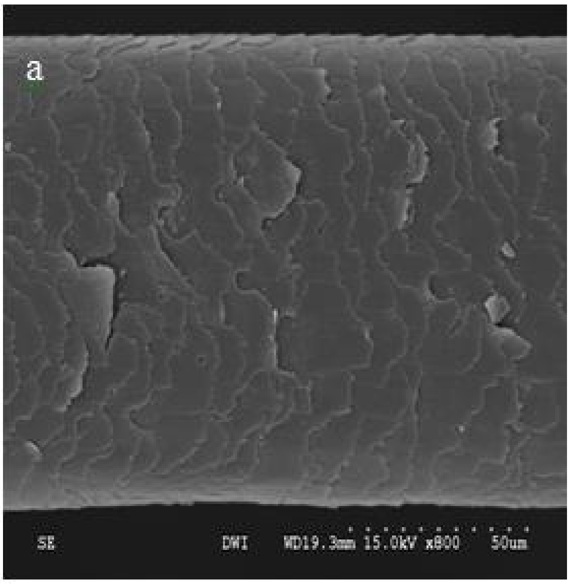


Figure 2 Topography of untreated hair (x 1000)

Surface examination using the SEM was used in many studies to observe the effect of some treatment on hair surface (Ruetsch and Kamath, 2004; Garcia, 1998; Robinson, 1976). After the treatment of hair with the flat iron, about ten fibers of these were examined in the SEM. Damage phenomena or special features observed in the hair specimens are described as "typical" or "representative" in this discussion. The thermally induced damage phenomena are shown in Figure 3 which represents the damage after 80 cycles of treatments.



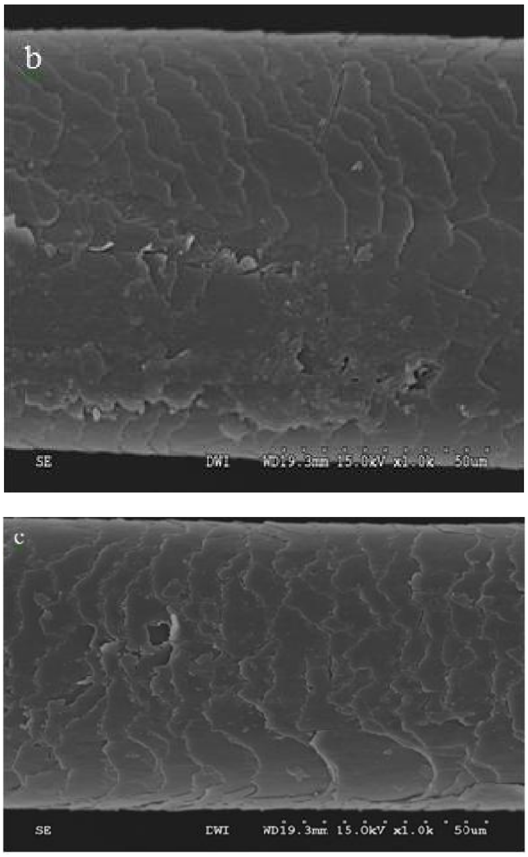


Figure 3 (a-c) thermally induced damage phenomena commonly observed on virgin hair exposed to 80 thermal cycles of treatments with the flat iron

The above figures seem to suggest that the contact time of 80 thermal cycles for individual hair fibers with the heated metal surface of the flat iron has produced a severe damage in hair surface. We showed a fusion of the scales edges (figure 3b) and a scale lifting and fracturing has occurred in the cuticle (figure 3a and 3c).The thermal treatment can induce failure in the endocuticle or the cell membrane complex, the weakest structures of the cuticle, resulting in the separation of the surface scales from the underlying layers producing an uplifting of scales.

Ruetsch and Kamath (2004) have exanimate the hair surface of European hair after different cycles of thermal treatment using a curling iron with a temperature ranged from 110°C to 120°C , they have observed an increase in various types of surface damage as a function of progressive thermal exposure. They have showed a radial cuticular cracking, fine axial cracking of the exposed surface cuticle cell has become a frequent damage phenomenon and fusion of the scale edges after 200 cycles of ten seconds of treatment.

Effect of thermal treatment on the tensile properties of virgin hair

Specimens from the same tress of Tunisian woman hair were used to examine the effects of "repeated cyclical heating/cooling" on the mechanical properties of the hair.

Figure 4 shows data concerning the tensile properties of hair after thermal treatment. At 65 % RH and 21 °C, we observed in the figure 4b a significant reduction in extension at break.

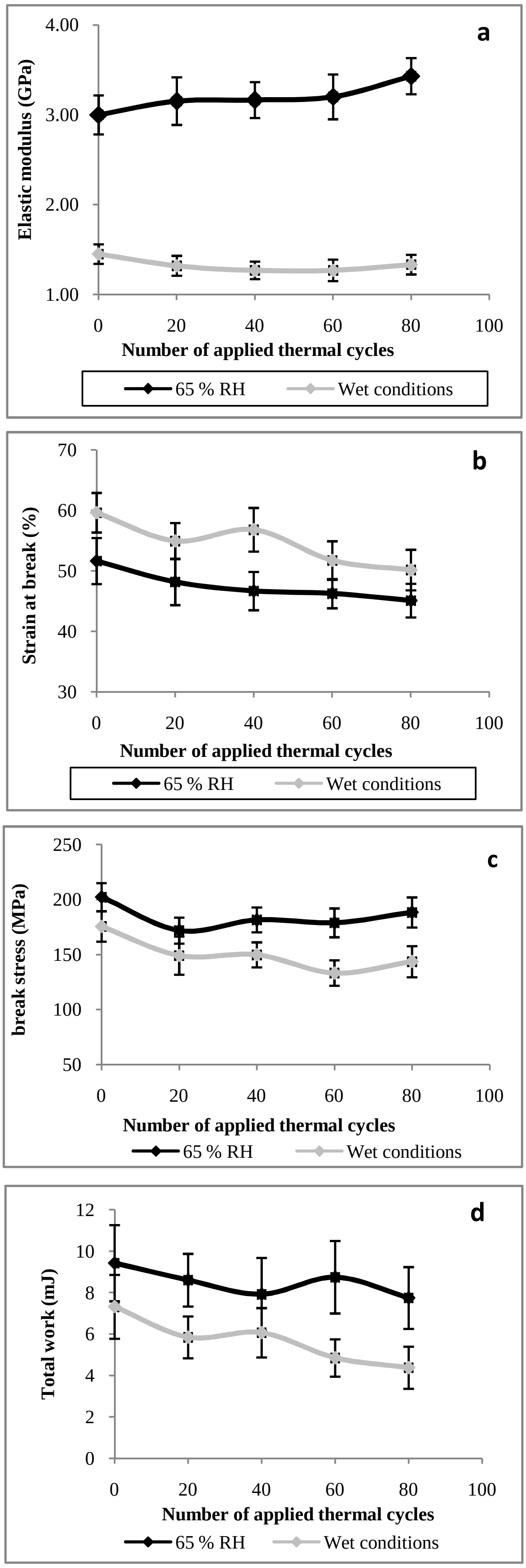


Figure 4 Tensile properties as a function of time of thermal treatment of virgin hair: (a) elastic modulus, (b) Strain at break, (c) break stress, (d) total work

Thermal treatment induces a decrease of the strain to break with increasing the time of treatment. This can be due to the rupture of hydrogen bonds and the introduction of new crosslinks by dehydration reactions at a higher temperature (Anne, 2013). When the fiber is heated, the water content on the fiber decreased as a result a reduction in extension to break. In fact, the literature shows that the study of the mechanical behavior of keratins fibers at wet conditions has demonstrated that keratin fibers are more extensible on the presence of water (Popescu and Höcker, 2007; Feughelman, 1997).

Hair dried with heat and equilibrated at room temperature at a moderate relative humidity will have lower moisture content than room temperature dried hair. After heat drying, hair absorbs moisture but does not return to the room temperature dried water level until it is rewet or conditioned at a higher relative humidity and dried at room temperature (Crawford, 1981). However, we note an increase of the elastic modulus as time of treatment increased, suggests rigidification of the fiber structure. One of the physical transformations in hair structure, occurring as a result of annealing between 70 °C and 180 °C, is an increase in fiber crystallinity, demonstrated by Milczarek *et al* (1992). Ruetsch and Kamath (2004) have studied the effect of thermal treatment at a temperature of 110 °C (200 times for ten seconds each) on the mechanical properties of a dark brown European hair, they have found slight increases in breaking strength with no statistical significance, a negligible variation in the initial modulus and a reduction of 5 % in the extension at break. Their results show a slight damage compared to our data.

The measurements were also performed in wet conditions, considered to reflect best the changes at the level of intermediate filaments (Wortmann and De Jong, 1985; Schmidt and Wortmann; Wortmann and Zahn, 2004).

The effect of thermal treatment is more important on wet condition compared to its effect on mechanical properties at 65 % RH. In fact, we show a decrease of 15, 88 % against 12,63 % in the extension to break respectively at wet and dry conditions. The break stress was also reduced of 18.18 % and 10 % respectively at 100 % and 65 % RH.

The measurement of the mechanical characteristic at 65 % RH and 100 % RH of the thermally treated hair demonstrate that the damage occurred in hair after thermal treatment at 180 °C is irreversible.

Effect of thermal treatment on the tensile properties of bleached hair

Table I and II present the mechanical properties on wet and dry conditions of bleached hair after thermal treatment.

Table I Tensile properties on dry conditions of thermally treated bleached hair

		Number of applied thermal cycles		
	Bleached hair	40	60	80
Elastic modulus (GPa)	3,19 ± 0,29	3,15 ± 0,19	3,27 ± 0,22	3,44 ± 0,29
Stress at break (Mpa)	198 ± 13,3	163 ± 12,8	160 ± 13,3	156 ± 13
Extension at break (%)	50,05 ± 2,54	45,91 ± 3,89	45,07± 3,22	42,06 ± 4,1

Table I reveal a significant reduction on the mechanical properties of the bleached hair on dry conditions. Compared to the results obtained for virgin hair, we observed that the effect of the heating on the elastic modulus and the strain to break of bleached hair is similar to its effect on virgin hair. However, we noted that the reduction of the break stress is more important for bleached hair. In fact, break stress of bleached hair decrease of 21 % against 10% for virgin hair after 80 cycles of treatment.

Table II Tensile properties on wet conditions of thermally treated bleached hair

		Number of applied thermal cycles		
	Bleached hair	40	60	80
Elastic modulus (GPa)	1,37 ± 0,1	0,93 ± 0,1	1,01 ± 0,1	0,88 ± 0,15
Stress at break (Mpa)	173 ± 11,7	102 ± 11,8	105 ± 15,9	84,7 ± 13,1
Extension at break (%)	64,07 ± 3,51	51,46 ± 3,36	51,67 ± 4,47	47,86 ± 4,03

It's clear from this data that thermal treatment produces a severe damage of bleached hair mechanical properties especially when it was measured at 100 % RH. In fact, the elastic modulus decreases of 35.76%. The bleached hair loses also about 50% of it stress after 80 thermal cycles using flat iron at 180 °C.

Bleaching treatment affects the mechanical properties of hair. In fact, the bleaching reduces the cystine content of the hair which was through their high mechanical stability (Robinson, 1976). It also increases the porosity of the fiber (Syed and Ayoub, 2002). Thus, at a higher humidity the water uptake increase on the fiber, this was probably responsible for the loss of the physical strength on wet condition of the bleached hair after thermal treatment.

CONCLUSION

The thermal treatment of hair with the flat irons, at 180 °C was found to result in significant damage of hair fiber. The extent of damage was quantified in terms of (a) hair surface modification and cuticle damage determined by Scanning Electron Microscope (b) tensile mechanical properties determined by Diastron measurement. Both fiber surface and tensile properties were affected. Thermal treatment produces a fusion of the cuticle cells and a scale lifting. In addition, a significant reduction of the hair mechanical properties was detected especially at wet conditions. Thermal treatment affects the tensile properties of bleached hair more than the virgin hair.

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