

Mandom elucidates the hair repair mechanism of levulinic acid

—Heat damage care achieved with levulinic acid—

Mandom Corporation (Head office: Osaka, President Executive Officer & Director: Ken Nishimura, hereinafter “Mandom”) pursues “creation of new value” as a human-oriented company to delight, excite, and bring joy to consumers. We aim to solve everyday hair care concerns for consumers and are working to develop hair care products that provide a better care experience.

It was discovered that heat from hair styling irons and other devices changes the internal structure of hair, reducing its breaking strength. levulinic acid, formulated in hair care products such as acid heat treatments to address such issues and improve hair quality and repair hair, is known as an ingredient that achieves a manageable finish. We conducted an evaluation to elucidate the changes occurring inside the hair that achieve this finish. The results showed that levulinic acid affects the internal structure of hair, increasing hair breaking strength and effectively reducing heat damage caused by using a high-temperature hair styling iron.

In addition, it was found that by using an ionic liquid (a complex salt consisting of oleic acid and tromethamine)^{*1}, which is expected to have the effect of helping levulinic acid penetrate into hair, the amount of levulinic acid that penetrates and is adsorbed into the hair can be further increased.

These research results were presented at the Society of Fiber Science and Technology’s Autumn Meeting held on October 27–28, 2025.

■ Research background

Hair styling irons have become a widely used item in daily hair care and hair styling^{*2}.

However, because hair styling irons come into contact with hair at high temperatures, it is believed that using them on a daily basis can lead to hair damage such as breakage. For this reason, consumers are seeking hair care products that contain ingredients that are highly effective in reducing heat damage.

Levulinic acid is used in hair care products as an ingredient for improving hair quality and repairing hair and has been shown to have a significant effect on improving texture, but its mechanism of action had not been clarified. Therefore, we conducted an evaluation to elucidate the effect of levulinic acid on hair when using heated tools such as a hair styling iron. Furthermore, we investigated the use of an ionic liquid in combination with levulinic acid to further enhance its penetration and absorption into the hair.

1. Using a hair styling iron can cause heat damage to the inside of the hair, making hair break easily.

We examined the hair breaking strength and changes in the internal structure of black hair with no history of chemical treatment when a hair styling iron was used and when it was not.

First, we checked the breaking strength of the hair and found that hair that had been treated with a hair styling iron had a significantly lower breaking strength than hair that had not been treated with a hair styling iron (Figure 1).

Next, the DSC (differential scanning calorimetry) measurement^{*3} was used to determine the temperature range in which the internal hair structure is altered/disrupted (denaturation temperature) and found that the denaturation temperature was lower in hair that had been treated with a hair styling iron



(Figure 2). This decrease in denaturation temperature in DSC measurements suggests that the crosslinking density inside the hair is decreased.

Therefore, it is thought that using a hair styling iron (heat treatment) lowers the denaturation temperature, which means that the crosslinking density⁴ inside the hair decreases, loosening the internal structure, resulting in a decrease in the hair's breaking strength and making the hair more prone to breakage.

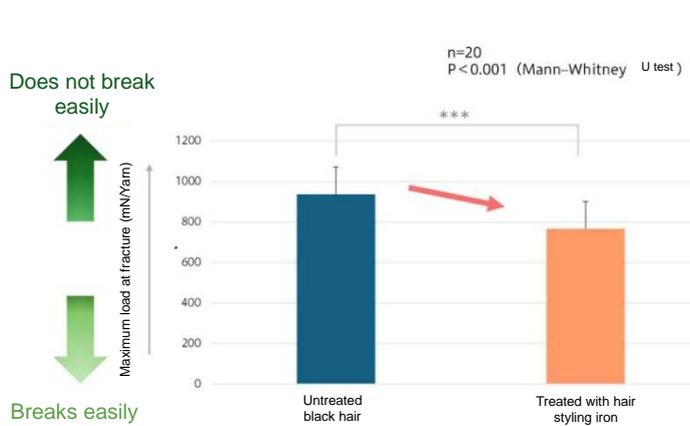


Figure 1. Hair breaking strength measurement (measurement in wet state, black hair)

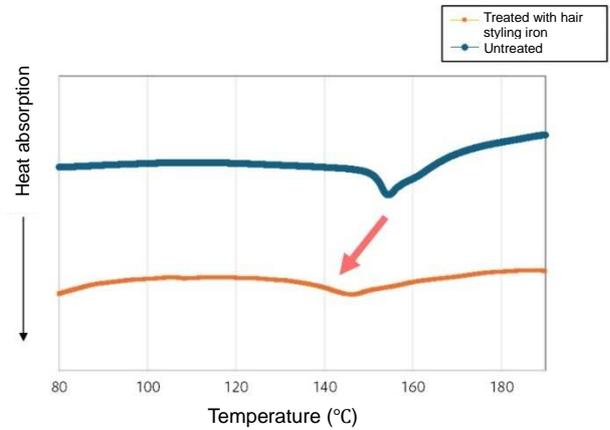


Figure 2. Comparison of denaturation temperatures in DSC measurements (measurement in wet state, black hair)

2. levulinic acid penetrates deep into the hair and improves the thermal stability of the hair's internal structure.

To elucidate the effect of levulinic acid on hair, we first checked how levulinic acid penetrated into the hair. Bleached hair was treated with deuterium-tagged levulinic acid, and the TOF-SIMS measurement⁵ taken confirmed that the levulinic acid had penetrated throughout the hair shaft (Figure 3).

Next, DSC measurement was taken on both hair treated with levulinic acid and untreated hair. It was confirmed that the denaturation temperature was higher in hair treated with levulinic acid (Figure 4). This is thought to be because levulinic acid penetrates into the hair, increasing the crosslinking density, improving the adhesion between the tissues inside the hair, and changing it into a state that is resistant to heat.

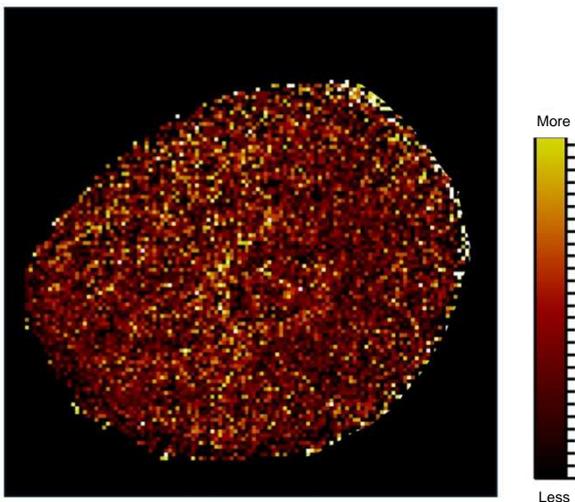


Figure 3. TOF-SIMS image of levulinic acid penetration into hair (detection of levulinic acid by D/¹H ratio, bleached hair)

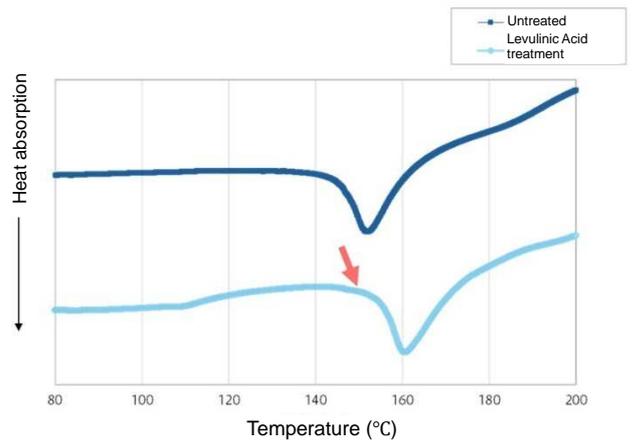


Figure 4. Comparison of denaturation temperatures in DSC measurements (measurement in wet state, bleached hair)

Furthermore, we compared the breaking strength of “bleached hair treated with a hair styling iron” and that of “bleached hair treated with levulinic acid and then with a hair styling iron” (Figure 5). It was found that “bleached hair treated with levulinic acid and then with a hair styling iron” had higher breaking strength than “bleached hair treated with a hair styling iron.”

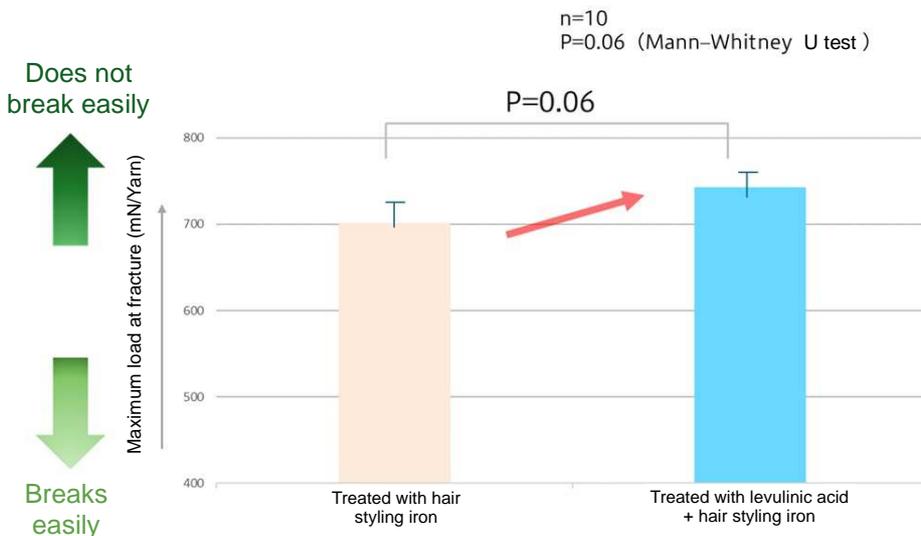


Figure 5. Hair breaking strength measurement (measurement in wet state, bleached hair)

From these results, it is thought that levulinic acid penetrates into damaged hair and increases the crosslinking density of the internal structure, thereby transforming the hair into a heat-resistant state. This is expected to prevent hair breakage due to heat damage (Figure 6).

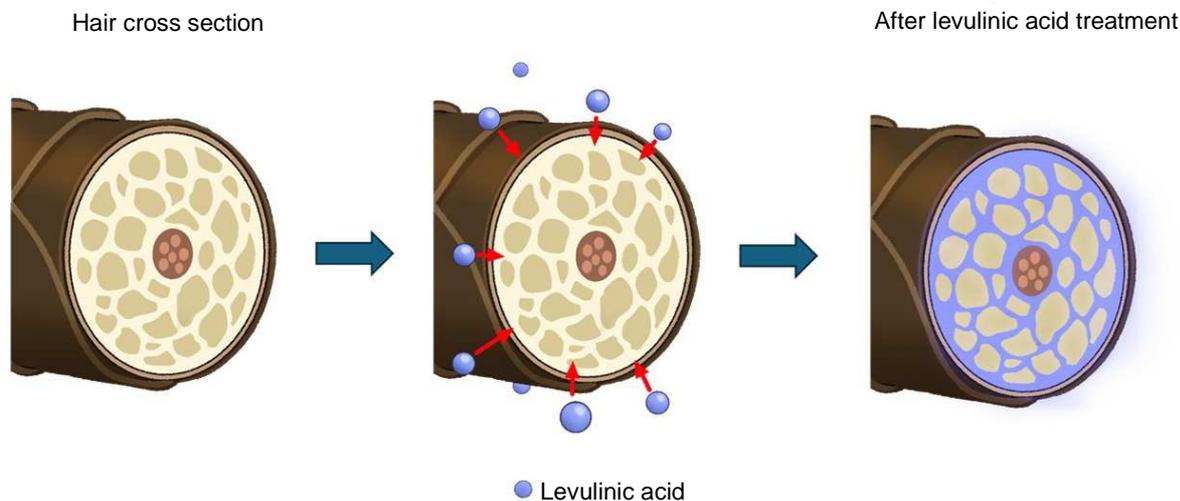


Figure 6. Image of levulinic acid repairing the hair shaft

3. The addition of ionic liquid promotes penetration and absorption of levulinic acid into hair.

While regular salts (such as sodium chloride) are solid, ionic liquids are organic salts made up of organic anion salts and organic cation salts and are liquid even at room temperature. They are compatible with hair and, unlike water, do not evaporate easily, so we thought they are more likely to penetrate deep into the hair. Furthermore, we hoped that since this ionic liquid can easily dissolve levulinic acid, an organic

acid, it would help transport the levulinic acid deeper into the hair.

In this study, bleached hair swatches were immersed for 15 minutes in either solution A, which consisted of levulinic acid dissolved in ethanol, or solution B, which consisted of levulinic acid and an ionic liquid (a complex salt of oleic acid and tromethamine) dissolved in ethanol, and then they were rinsed with water and air-dried. The hair swatches were chopped up, and levulinic acid was extracted using ultrasound and quantitatively measured using HPLC^{*6}.

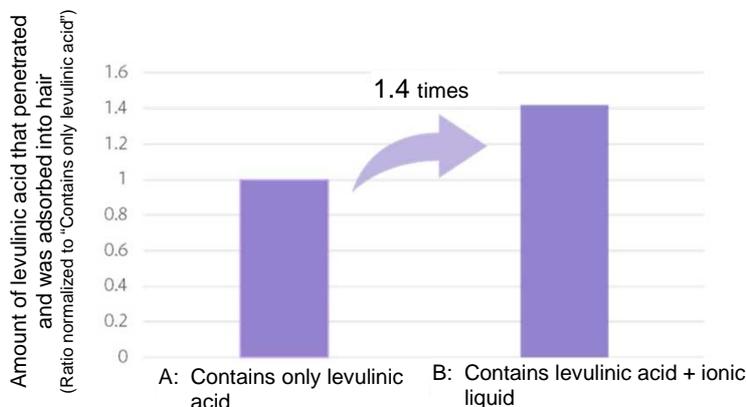


Figure 7. Comparison of the amount of levulinic acid that penetrated and was adsorbed into hair

The results confirmed that when ionic liquid was used in combination, the amount of levulinic acid that penetrated and was adsorbed into the hair increased by 1.4 times compared to levulinic acid alone (Figure 7). This demonstrated the adsorption- and penetration-promoting effect of this ionic liquid.

Mandom will continue to promote research with the aim of creating better products that meet the needs of consumers.

Notes and Glossary

- *1 We used LIQUBELLE 2C, an ionic liquid-based substance manufactured by Miyoshi Oil & Fat Co., Ltd.
- *2 Survey on frequency of hair styling iron use
"Mandom survey, November 2022, 4,193 women in their 20s; 61% use it daily, 90% use it at least once a week"
- *3 A method in which a constant amount of heat is applied to an inert reference and a measurement sample, the temperatures of the reference and the sample are measured, the sample's thermal properties are assessed based on the temperature differences, and endothermic and exothermic reactions due to changes in the state of the sample are measured.
Measured at a temperature rise rate of 10°C/min. The vertical axis in Figures 2 and 4 is amount of heat.
- *4 An index that indicates the number and density of "crosslinks" that connect molecules in high molecular weight materials (such as polymers). The higher the density, the stronger the bond, resulting in improved hardness and durability.
- *5 A surface analysis method in which secondary ions emitted by irradiating a sample surface with an ion beam are mass-separated based on the time of flight.
- *6 High-performance liquid chromatography