News Release

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Mandom Corporation

Kyoto University

Mandom and Kyoto University develop a new hair-styling technology that forms moisture-proof bonding inside hair to keep naturally finished hairstyles

Mandom Corporation (Head Office: Osaka City, Japan; President Executive Officer & Director: Motonobu Nishimura; hereinafter called Mandom) and Kyoto University (Kyoto, Japan; President: Juichi Yamagiwa; joint researchers: Associate Professor Hikaru Takaya and Assistant Professor Katsuhiro Isozaki; hereinafter called Kyoto University) have been working together since 2014 to develop hair-styling technology to meet the demand for naturally finished hairstyles.

In conventional hair-styling approaches, styling ingredients are usually applied or attached onto the outside of every hair to hold some hairs in bundles or to glue hairs to each other to keep the hairstyle. However, hair with heavy styling ingredients often looks solid and has a heavy finish, in contrast to the current demand for hair-styling products to simultaneously provide natural finish and hold, which have been incompatible so far.

Against this background, Mandom started research into potential hair-styling ingredients that can act inside hair, assuming that the formation of strong bonds inside each hair could provide a strong holding power under high humidity conditions.

As a result, α-ketoglutarate, which has been used in moisturizers, was found to be a potential to achieve both natural finish and strong hold at the same time through penetration and bond-forming action inside hairs.

This technology enabled us to develop new styling products with which users can keep their desired hairstyle with a natural finish.

The results of this study will be reported at the 30th International Federation of Societies of Cosmetic Chemists (IFSCC) Conference held in Milan, Italy, from September 30th to October 2nd, 2019.

1. Young men's need for compatibility between natural finish and keeping hairstyle

As described above, conventional hair-styling technology involves the application of hair-styling ingredients such as set polymers or wax on the outer surface of hairs, which act to solidify or glue hairs to each other to keep the hairstyle (**Fig. 1**). Consequently, while applying a larger volume of hair-styling ingredients to external hairs provides stronger fixing of hairs together, the finish becomes solid and heavy.

Hair appearance　Hair cross-section　Hair appearance　Hair cross-section

Set polymer　Wax

Figure 1: Conventional hair-styling technology (acting on hair externally)

While this solid, heavy finish has been favorably accepted by many consumers, the number preferring

naturally finished hairstyles has been on the rise lately, particularly among young men. This trend has created demand for new styling products that can preserve hairstyles with a natural finish (**Fig. 2**).

Existing externally acting hair-styling technology has been inadequate for natural finishes because the stronger the holding power, the larger the volume of hair-styling ingredients required for coating the hair. The development of new technology to satisfy the demand for hold with a natural finish is therefore required.

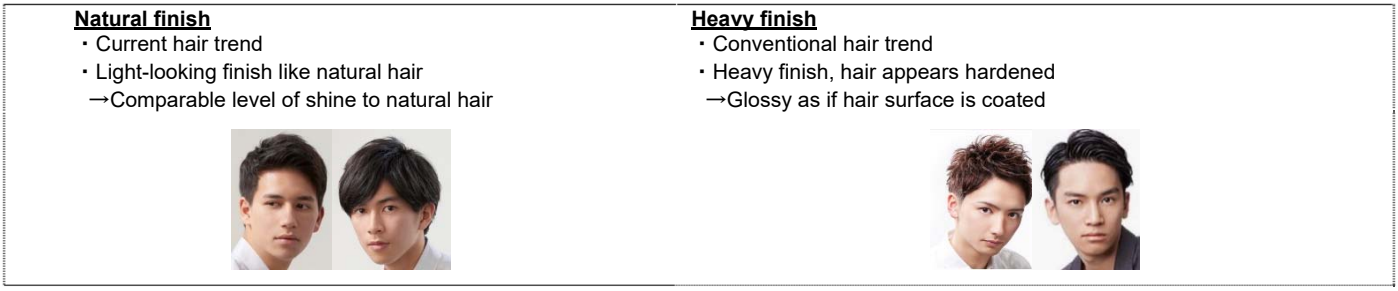


Figure 2: Two major types of finish with hair-styling products

2. Search for hair-styling ingredients that penetrate into and act on the inside of hair

Humidity is the main cause of the loss of hairstyle shape. Hair is composed of proteins, most of which form hydrogen bonds to provide each hair a shape. These hydrogen bonds are highly vulnerable to water; once exposed to moisture, the hydrogen bonds are cleaved , changing the hair shape. This is one of the reasons humidity can disarrange hairstyles (**Fig. 3**).

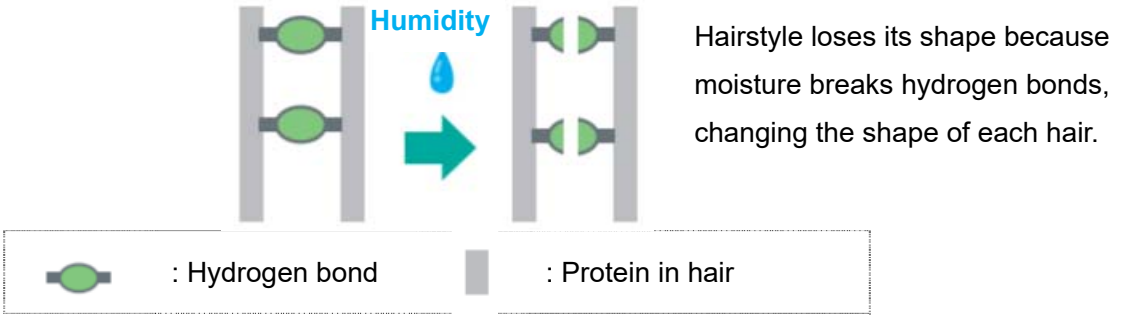


Figure 3: Schematic of hair proteins held together with hydrogen bonds

Mandom hypothesized that resistance to moisture could be improved by infusing active ingredients into hair through formation of ionic bonds between hair proteins. Ionic bonds provide stronger association than hydrogen bonds (**Fig. 4**).

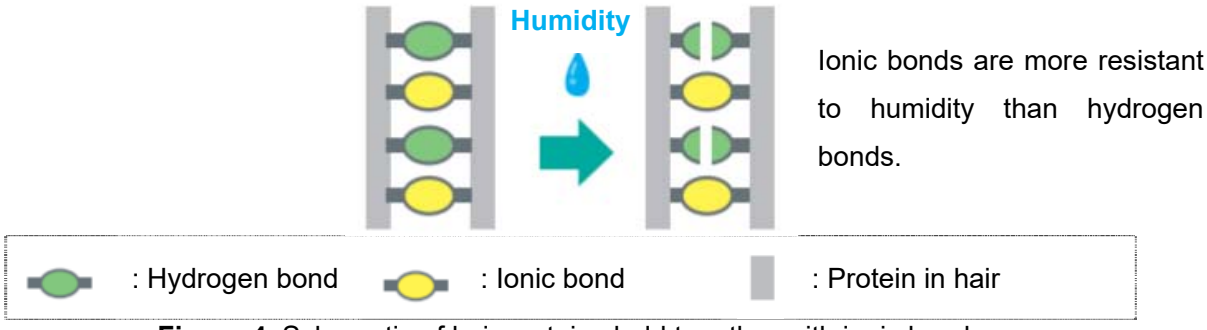
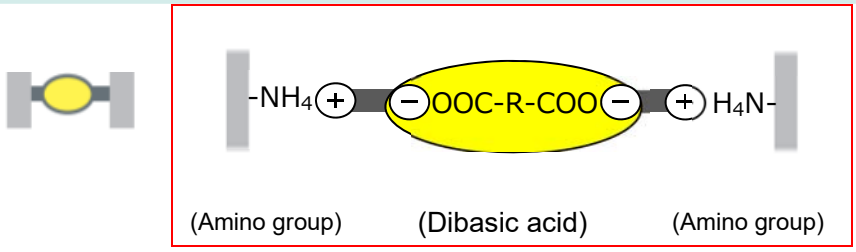


Figure 4: Schematic of hair proteins held together with ionic bonds

Proteins in hair have positively charged sites. If they interact with a molecule with negatively charged acid groups at each end, bridges between individual hair proteins are expected to form through ionic bonds (**Fig. 5**).



Dibasic acids can easily form ionic bonds with amino groups through the charged sites at both ends

Figure 5: Schematic of ionic bonds between dibasic acid and hair proteins

After investigating a series of dibasic acids, Mandom found that α-ketoglutarate, which is used as a moisturizing ingredient, could penetrate into hair efficiently and improve moisture resistance. It was also confirmed that hair treated with α-ketoglutarate had a similar finish to native hair. We concluded that application of α-ketoglutarate could provide a natural finish and hairstyle holding power in one hair-styling product.

Permeability:

Hair immersed in an α-ketoglutarate solution was cut and the distribution of α-ketoglutarate on the cut surface was analyzed by Raman spectroscopy. The results showed α-ketoglutarate permeating into the core of the hair fiber (**Fig. 6**).

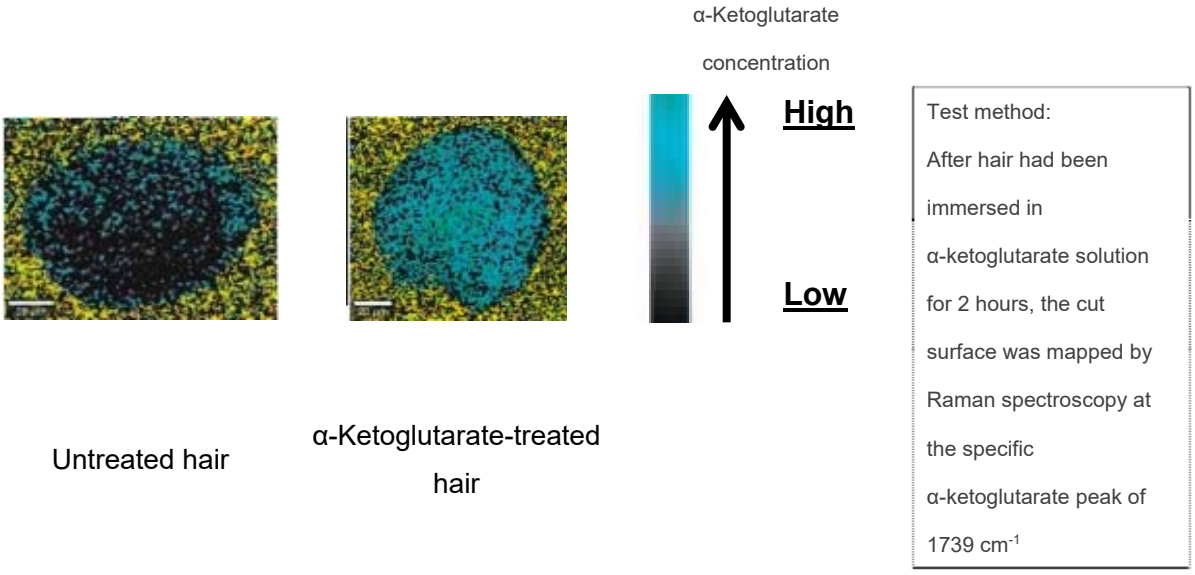


Figure 6: Permeation of α-ketoglutarate into hair

Bonding with hair protein:

To confirm whether the penetrated α-ketoglutarate binds to hair-protein, small-angle X-ray scattering (SAXS), which allows micron-scale structural analysis, was performed at Kyoto University.

SAXS provides a X-ray scattering pattern, in which sequential length and structural regularity of hair proteins are identified by the angle and intensity of scatterings. Higher scattering intensity suggests that the hair has a more regular shape and structure (**Fig. 7**).

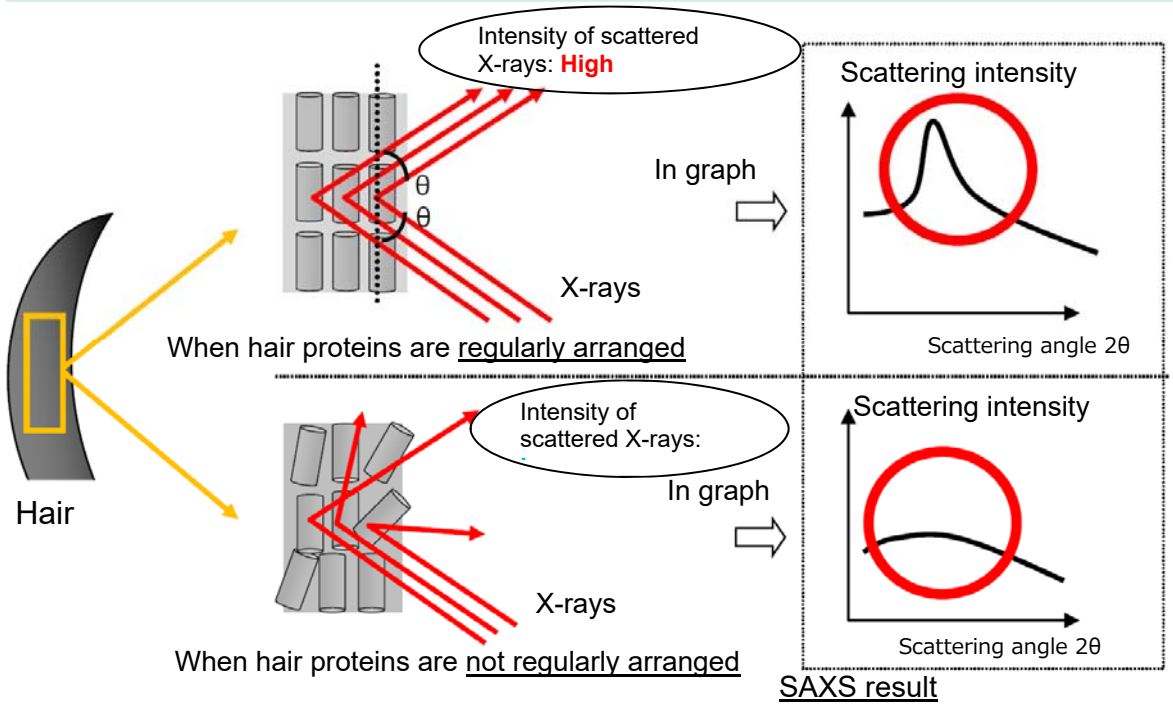


Figure 7: Schematic of SAXS study

There was a remarkable difference in SAXS intensity at the region of matrix protein between hair treated with α-ketoglutarate and with purified water (**Fig. 8**). The matrix protein structure was broken in normal hair when it was stored under humid conditions, whereas the matrix protein structure of hair soaked in α-ketoglutarate formed a regular arrangement that was maintained irrespective of humidity.

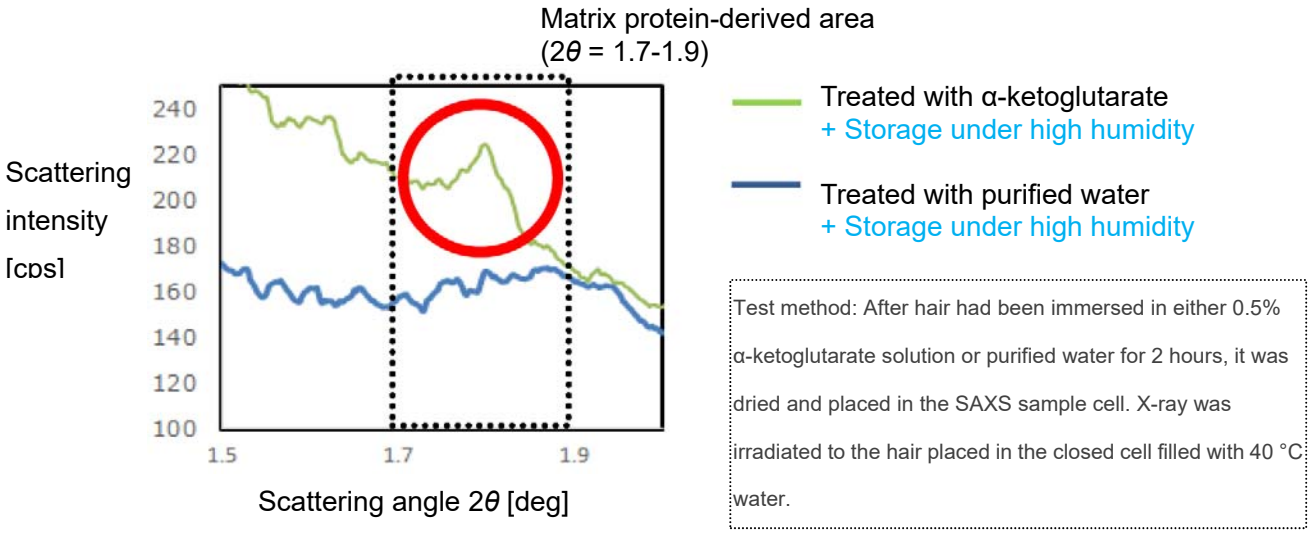


Figure 8: SAXS patterns of treated hairs after storage under high humidity

This is evidence of the effect of α-ketoglutarate on hair matrix protein. α-Ketoglutarate binded to hair protein and formed a robust, regularly arranged structure that was not affected by humidity (**Fig. 9**).

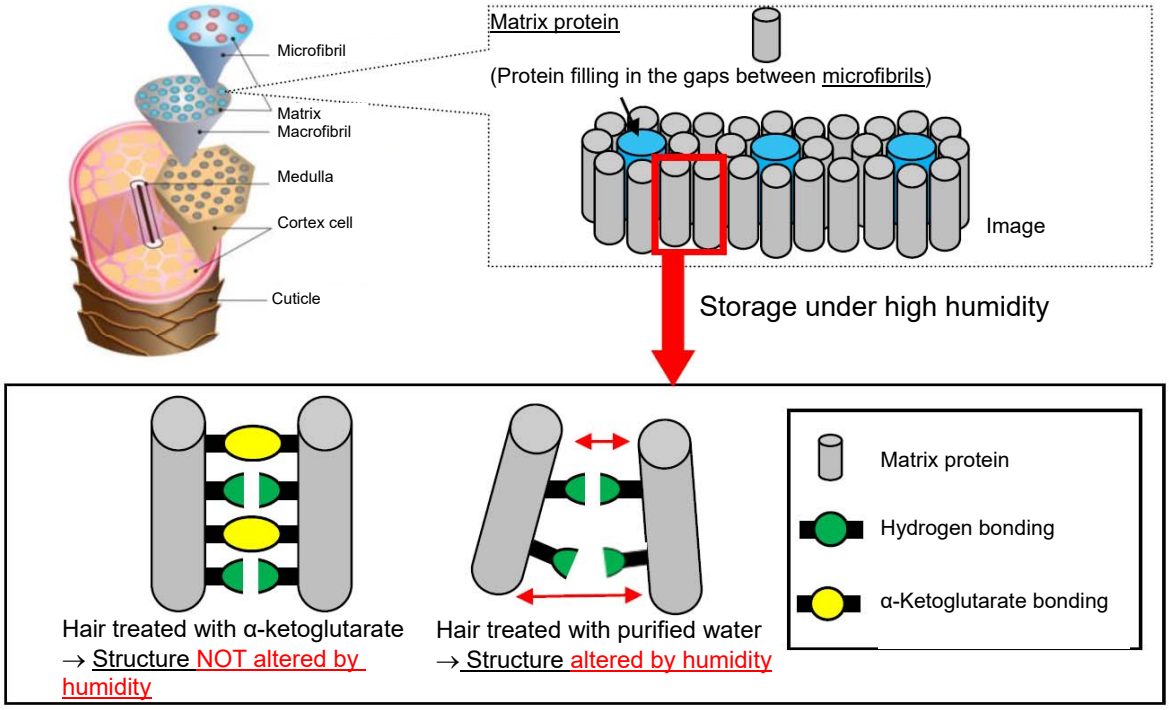


Figure 9: Regular structure of matrix protein under high humidity

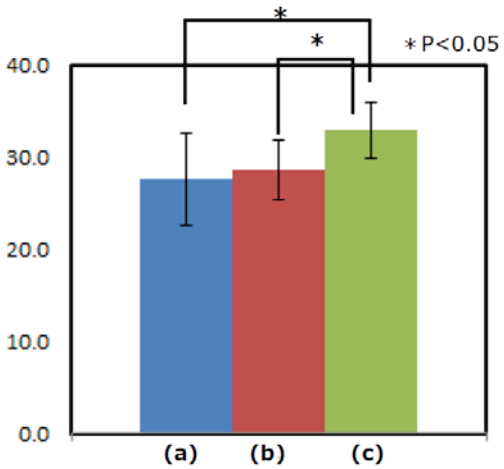
(Based on the results in **Fig. 8**)

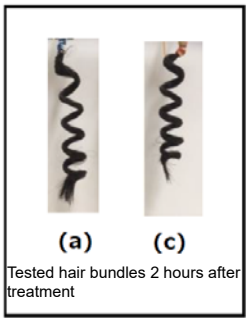
Moisture resistance:

A bundle of hair treated with α-ketoglutarate was curled around a rod, dried, and left for 2 hours under high-humidity conditions of 25 °C and 80% relative humidity (RH) to measure the endurance of the hair curls. When hair absorbs moisture, internal hydrogen bonds are usually cleaved and it uncurls. In this test, hair treated with α-ketoglutarate was compared to hair treated with other dibasic acid and purified water to identify the extent to which α-ketoglutarate could maximize the curl retention under high humidity.

The results showed that α-ketoglutarate treatment had higher curl retention with improved holding power than water and glutarate treatment (**Fig. 10**).

$$\left\{ \text{Curl retention [\%]} = (*A_{\text{after 2 hours}}/A_{\text{baseline}}) \times 100 \right\}$$





(a) Purified water (b) Glutarate (c) α-Ketoglutarate

Test method:
30-cm long hair bundles were immersed in 0.5% aqueous solutions containing each treatment ingredient (or pure water for untreated hair) for 2 hours, then curled around a rod and dried for a day at a room temperature of 25 °C and 60% RH. After removing the rods, the hair bundles were left for 2 hours at a room temperature of 25 °C and 80% RH, and hair length was measured over time.
* A=B: Length of the hair bundle before treatment (cm) - C: Length of the hair bundle at different measurement time points (cm)

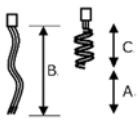


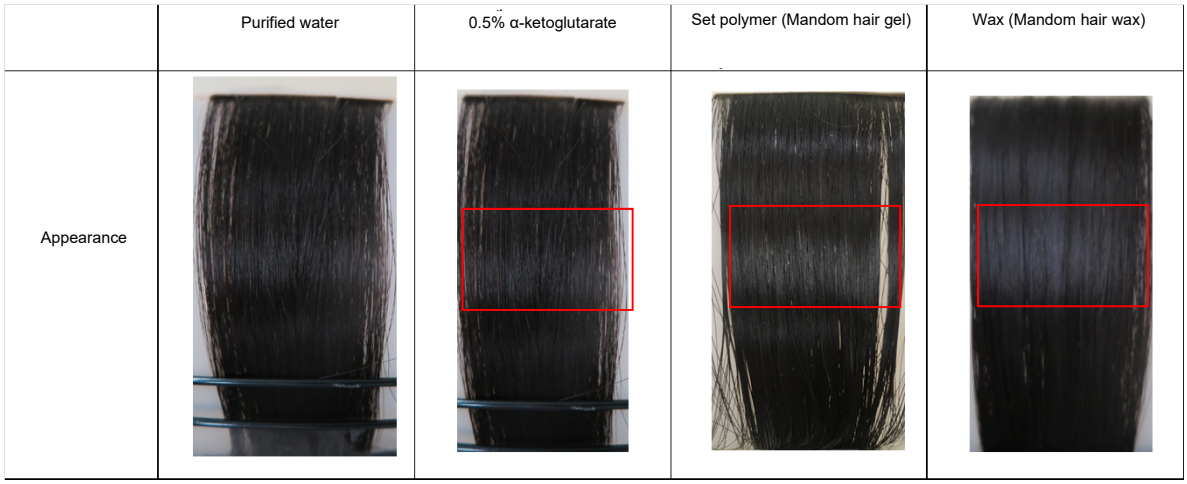
Figure 10: Curl retention results of curled hair stored under high humidity

Natural finish:

α-Ketoglutarate was applied to hair bundles to evaluate whether α-ketoglutarate could provide a natural texture by observation of shine on the dry hair surface. For comparators, other hair bundles treated with

purified water, set polymer (Mandom hair gel as a traditional hair-styling ingredient), and wax (Mandom hair wax) were also prepared.

Hair bundles treated with the set polymer and wax were glossier than that treated with purified water, while the hair bundle treated with α-ketoglutarate had a similar amount of gloss to that treated with purified water (natural finish) (**Fig. 11**).



Test method:
Hair appearance was observed after 0.4 g of each sample was applied and soaked into the 20-cm long flat hair bundles and naturally air-dried.

Figure 11: Evaluation of shine in hair bundles coated with samples

In summary, Mandom succeeded in developing a hair-styling technology with α-ketoglutarate that can take effect from the inside of hair fibers and ensure the hairstyle could be preserved all day under humid conditions.

Mandom intends to apply this technology in our hair-styling products to provide both natural finish and holding power.

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