A Novel Biomimetic Approach Focused on Branched Alkyl Chains

“A new hair care approach that moisturizes hair internally while protecting it from external humidity”

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A Functional Trade-off in Hair Care Development

People all over the world suffer from **dry hair** and **frizz** **caused by humidity.**

Major Challenge ： Solving both dryness and frizz at the same time

Moisture Retention

We need
Hydrophilic Ingredients
to keep moisture inside.

But they also absorb
moisture from the air.

This can cause **frizz** and **swelling**.

Trade Off

Balancing these two properties in one formula was our big challenge.

Humidity Resistance

We need
Hydrophobic Ingredients
to block humidity.

But they alone cannot
retain moisture inside the hair.

This can lead to hair **dryness**.

Too much oil can make hair feel
greasy and **flat**.

Inspiration from Nature: The Wisdom of Waterfowl (Biomimetic Approach)

To solve this problem, we looked to nature.

Waterfowl coat their feathers with a special oil from the uropygial gland. This oil maintains feather flexibility and high water repellency, even in harsh watery environments.

Focusing on Multiply Branched Alkyl Oils

It is well-known that this secretion contains "Multiply Branched Alkyl Oils". Based on this knowledge, we hypothesized that this specific structure is the key to providing both healthy shine and strong water resistance.

The start of this research

Our research started with the idea that applying this structure to cosmetics could resolve this trade-off.

Materials & Methods｜Preparation 1

Preparation of hair samples for testing

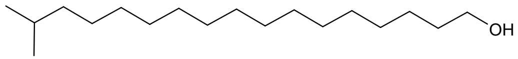
We used Asian black hair. We bleached and permed the hair to create a damaged hair model with a hydrophilic surface.

Preparation of Branched Alkyl Compounds with Different Branching Levels

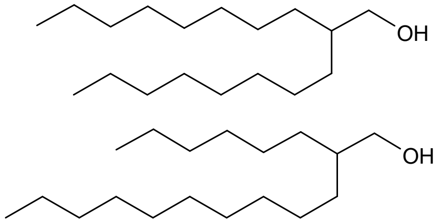
To compare the effect of "branching structures" clearly, we used fatty alcohols with 18 carbons. We used linear "Stearyl Alcohol (SA)" as a control. We also prepared four types of "Isostearyl Alcohol (iso-SA)" with different branching levels.

On the slide, the numbers 1 to 4 show the levels. Level 1 is mono-branched, and level 4 is multiply-branched.

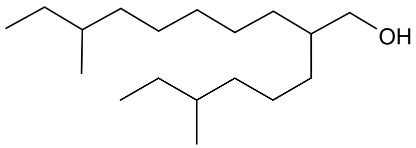
Stearyl Alcohol（**SA**）



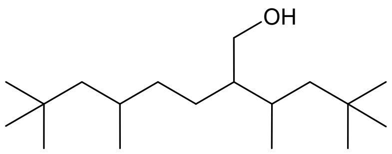
Isostearyl Alcohol ①（**iso-SA**①）



Isostearyl Alcohol ②（**iso-SA**②）



Isostearyl Alcohol ③（**iso-SA**③）



Isostearyl Alcohol ④（**iso-SA**④）

Linear Alkyl Chain

Multiply Branched Alkyl Chain

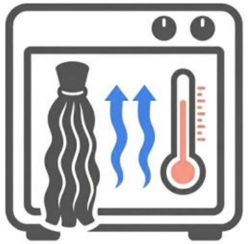
Materials & Methods | Preparation 2

Treatments formulated with these alcohols were used for evaluation.
Formulation A (control) contained 7 wt% SA without iso-SA.
Each iso-SA (2 wt%) was added to a base with 5 wt% SA to prepare Formulations B–E.

*Concentration shown as weight percent (%)

Ingredient	**Formulation A**	**Formulation B**	**Formulation C**	**Formulation D**	**Formulation E**
SA	**7**	5	5	5	5
iso-SA①	—	**2**	—	—	—
iso-SA②	—	—	**2**	—	—
iso-SA③	—	—	—	**2**	—
iso-SA④	—	—	—	—	**2**
Stearamidopropyl Dimethylamine	2	2	2	2	2
Lactic acid	0.75	0.75	0.75	0.75	0.75
pH	3.5	3.5	3.5	3.5	3.5
Viscosity (mPa・s)	10,590	14,470	8,470	13,480	11,770

Materials & Methods｜Measurement



1. Measurement of Water Content of Hair

Treated hair was dried, kept at 75% RH for 24 h, then heated at 180° C.
Total water loss was defined as hair water content.

STEP 01		STEP 02		STEP 03		STEP 04		
We rinsed the hair after the treatment.	→	Drying	→	75% RH / 24 h	→	heated at 180° C	=	Total water loss was defined as **Water Content**

2. Measurement of Moisture Absorption of Hair

After drying, hair was placed at 75% RH for 24 h.
The weight increase was defined as moisture absorption.

STEP 04		STEP 05		
heated at 180° C	→	75% RH / 24 h	=	Weight increase was defined as **Moisture Absorption**

Materials & Methods | Quantification & Surface Observation

3. Quantification of Residual Treatment Ingredients on Hair

After treatment and rinsing, the hair tresses were immersed in hexane to extract the residual oils. Then, the extracted samples were analyzed by gas chromatography–mass spectrometry (GC-MS).

STEP 01
We rinsed the hair after the treatment

→

STEP 02
Drying

→

STEP 03
Immersion of hair tresses in hexane

→

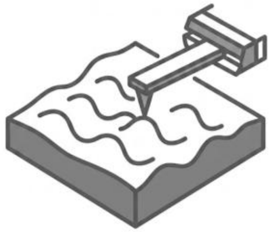
STEP 04
Analysis by GC-MS

=

This method allowed us to quantify the remaining amounts of **SA** and **iso-SA** on the hair surface after rinsing.

4. Measurement of Surface Properties of Adsorbed Layer on Mica

The mica sheets were treated with the formulations, rinsed with running water, and dried. Then, the surfaces were observed by atomic force microscopy (AFM) under ambient conditions.



STEP 01
Application of treatment to a mica sheet

→

STEP 02
Rinsed under running water

→

STEP 03
Drying

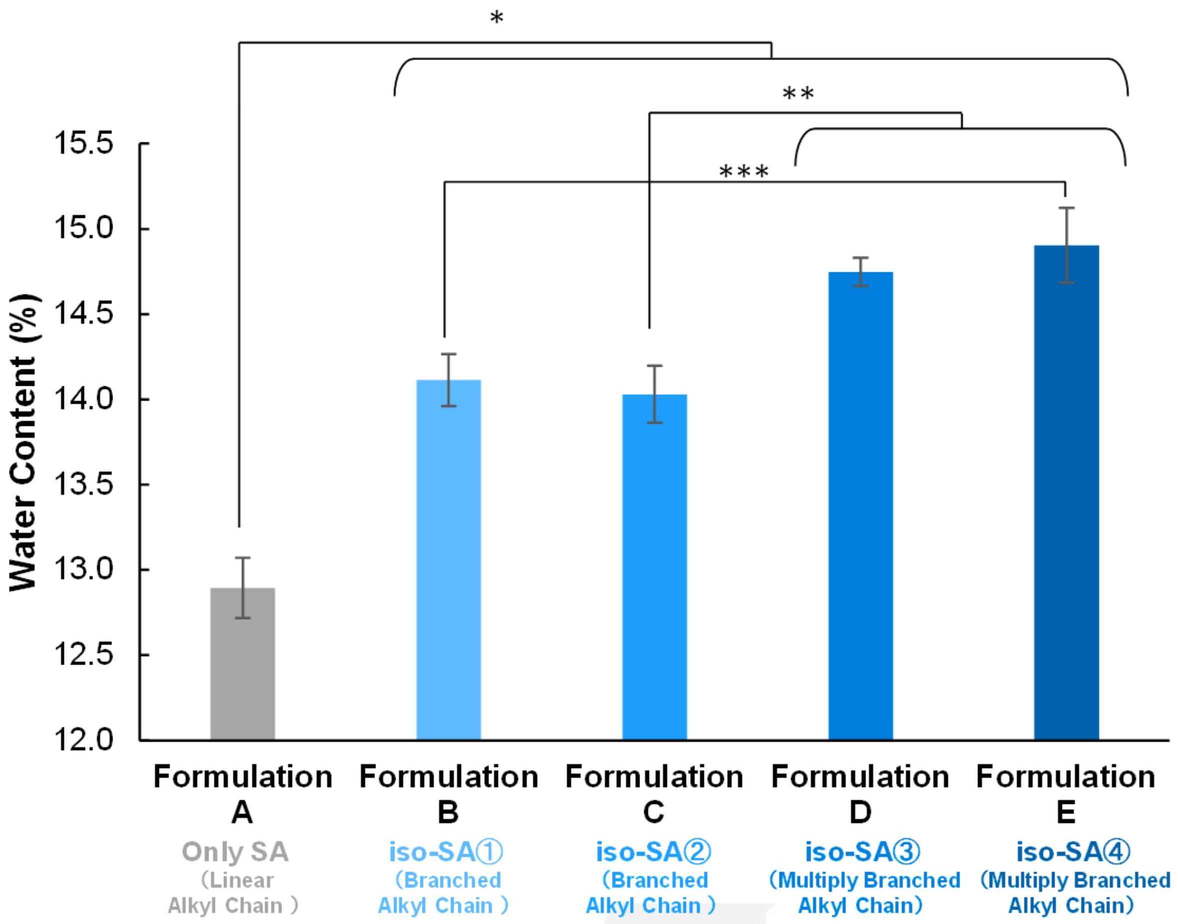
→

STEP 04
AFM observation

=

This observation allowed us to visualize the morphology of the **barrier film** and understand how it was formed after rinsing.

Results 1 ｜ Measurement of Water Content of Hair



Key Finding **01**

Branched structures enhance moisture retention

Formulations B–E (branched iso-SA) achieved significantly higher moisture retention than Formulation A (linear SA).

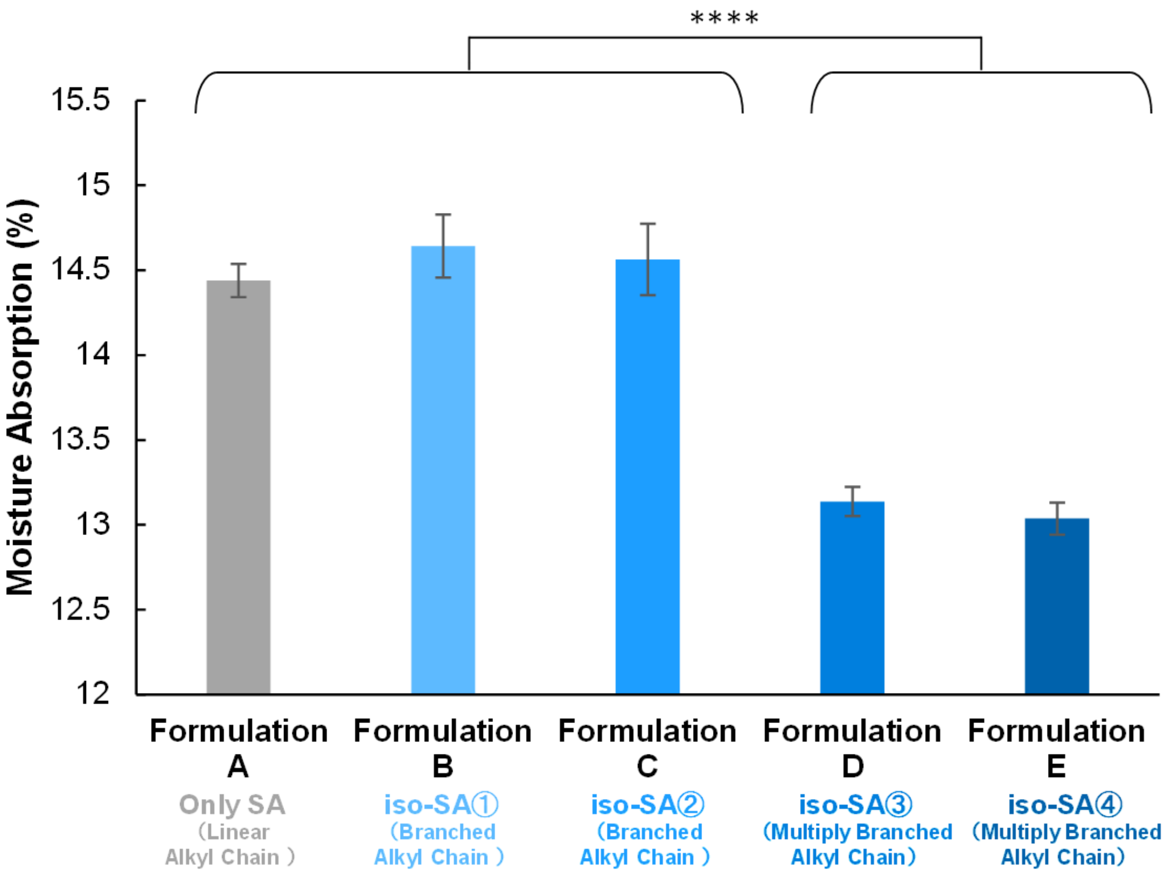
Key Finding **02**

Moisture retention correlates with branching level

Multiply branched iso-SA (Formulations D and E) exhibited the highest moisture retention

※Asterisks indicate statistically significant differences ($p < 0.05$). The number of asterisks (*, **, ***) is used to distinguish between comparison groups and does not represent the degree of statistical significance.

Results 2｜ Measurement of Moisture Absorption of Hair



Key Finding **03**

Multiply branched iso-SA enhances humidity resistance

Hair treated with multiply branched iso-SA (Formulations D and E) showed significantly lower moisture absorption from the external environment than hair treated with linear SA or less-branched iso-SA.

※Asterisks indicate statistically significant differences ($p < 0.05$). The number of asterisks (****) is used to distinguish between comparison groups and does not represent the degree of statistical significance.

Results 3 | Quantification of Residual Treatment Ingredients on Hair

Formulation	Target residue	Concentration (ppm)	Target residue	Concentration (ppm)
Formulation A	SA	14※1	SA	31※2
Formulation B	Iso-SA①	6	SA	62
Formulation C	Iso-SA②	6	SA	71
Formulation D	Iso-SA③	—(Not detected)	SA	67
Formulation E	Iso-SA④	—(Not detected)	SA	60

Ingredient	Formulation A	Formulation B	Formulation C	Formulation D	Formulation E
SA	7	5	5	5	5
iso-SA①	—	2	—	—	—
iso-SA②	—	—	2	—	—
iso-SA③	—	—	—	2	—
iso-SA④	—	—	—	—	2
Stearamidopropyl Dimethylamine	2	2	2	2	2
Lactic acid	0.75	0.75	0.75	0.75	0.75
pH	3.5	3.5	3.5	3.5	3.5
Viscosity (mPa・s)	10,590	14,470	8,470	13,480	11,770

Key Finding 04

Iso-SA promotes the deposition of linear SA on the hair

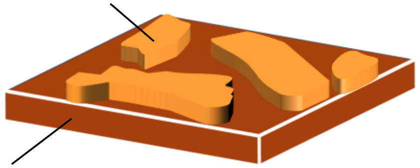
- iso-SA showed little retention on the hair.
- The amount of linear SA remaining on the hair in Formulations B–E increased to approximately twice that of Formulation A.

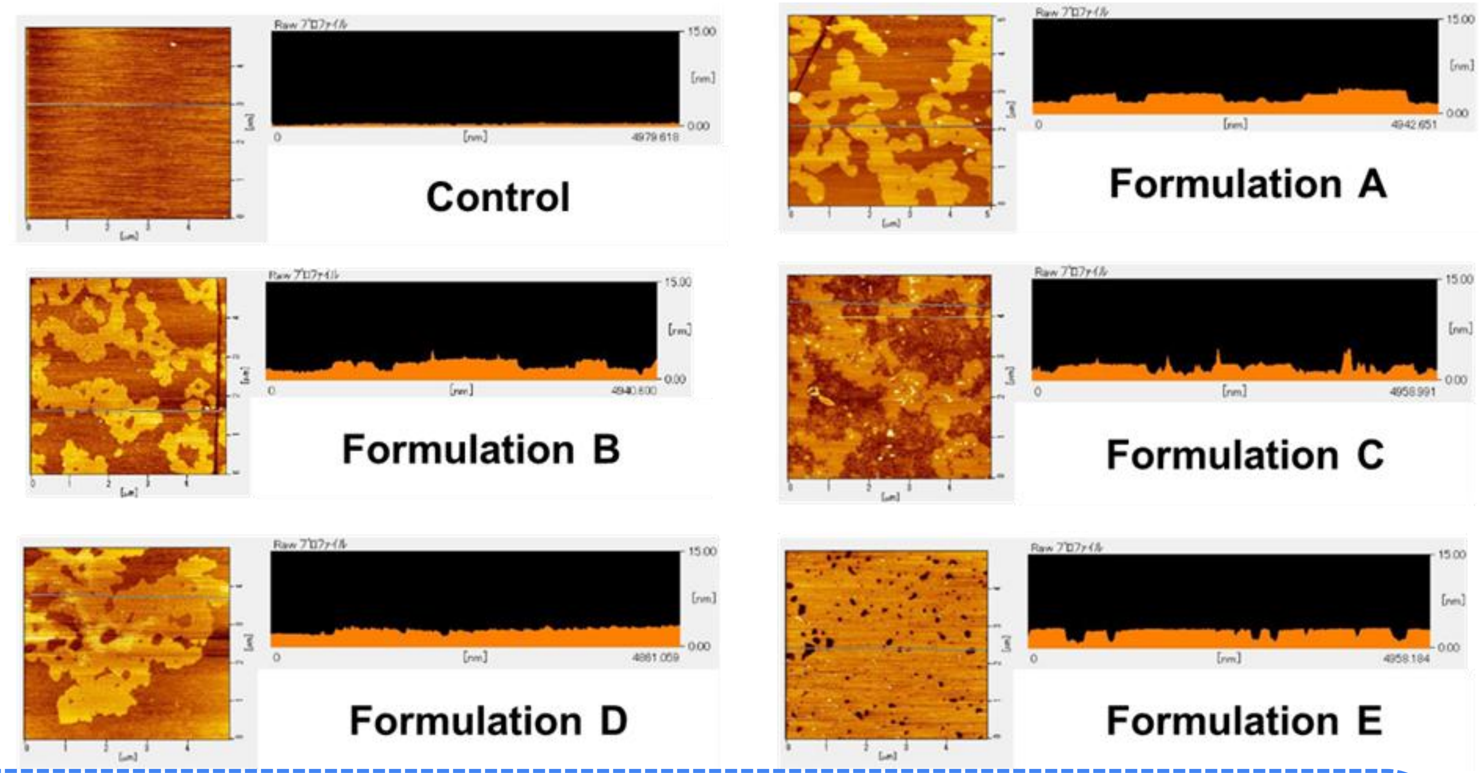
Key Finding 05

The presence of branching is key for deposition support

- The ability to support linear SA deposition depended mainly on the presence of branching.
- No significant difference was observed between less-branched and multiply branched iso-SA.

Results 4｜ Measurement of Surface Properties of Adsorbed Layer on Mica





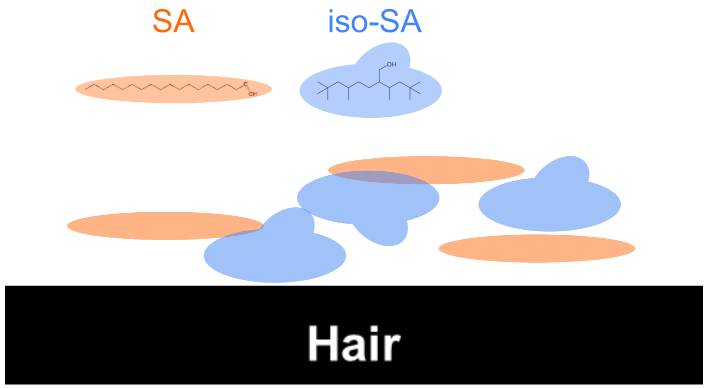
Key Finding 06

Branching level affects adsorbed layer formation

- As the degree of alkyl chain branching increased, the area of the adsorbed layer expanded.
- On formulation-treated mica, multiply branched iso-SA formed a more uniform film that covered a larger area of the substrate.

Discussion | Proposed Dynamic Mechanism of Multiply Branched iso-SA

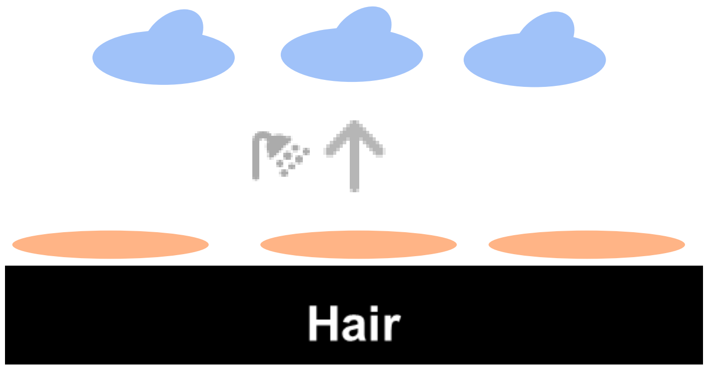
STEP 1
Application and Uniform Spreading



Functional Matrix

Multiply branched iso-SA has a bulky structure and **helps the oily components spread uniformly** over the hair surface.

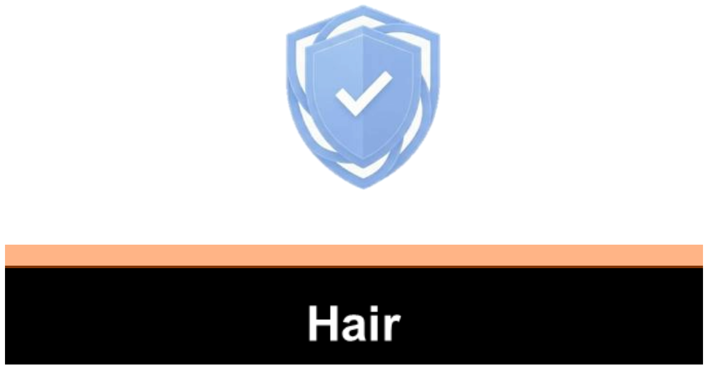
STEP 2
Rinsing and Selective Removal



Selective Retention Process

Damaged hair has a hydrophilic surface. During rinsing, the highly hydrophobic iso-SA is **selectively removed**, while the other oily component, SA in this study, remains and **becomes organized on the hair surface**.

STEP 3
Completion of a Continuous Film



Construction of a Barrier Film

As a result, **a continuous oil film without gaps is formed**. We consider that the key finding is not only the increased residual amount, but also the enhanced **spreading and distribution of the remaining oil components**.

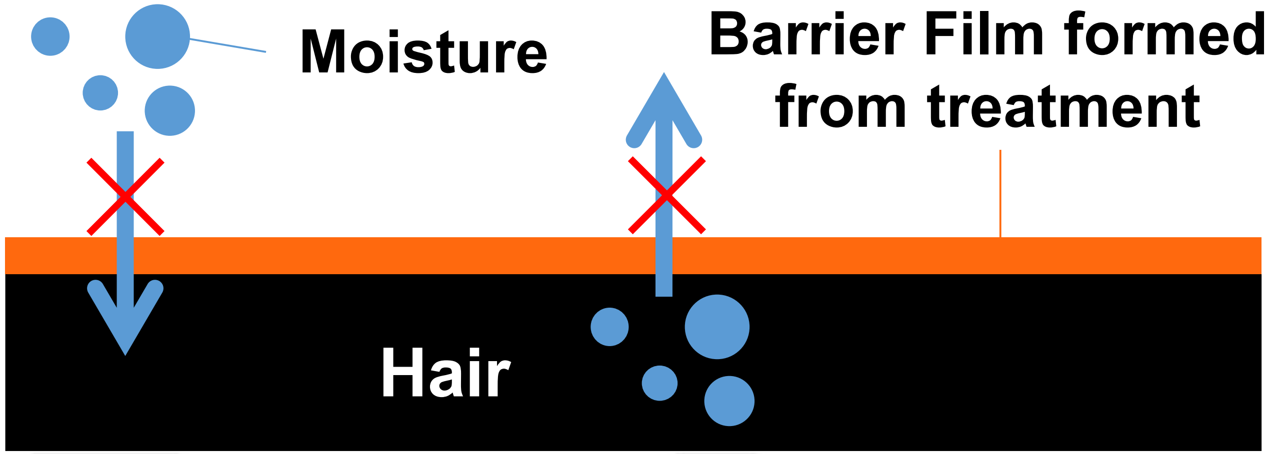
Discussion | Benefits: Why Hair Retains Moisture and Resists Humidity

Internal: Moisture-Sealing Shield

- The barrier film physically suppresses moisture evaporation from inside the hair.
- Even under dry conditions, it is thought to reduce dryness and maintain a smooth, moisturized feel.

External: Humidity-Resistant Barrier

- The barrier film is tightly packed without gaps, effectively blocking excessive moisture penetration from the outside.
- This is believed to suppress hair expansion and waviness caused by humidity.



Conclusion and Future Outlook

Biomimetic Application of “Waterfowl Wisdom”

- Focused on the protective mechanism of waterfowl feathers.
- Applied characteristic branched alkyl chains to cosmetic formulations.

Combining Two Opposing Benefits

- Achieved both internal moisture retention and external humidity resistance.
- Successfully overcame the conventional trade-off between these functions.

Sensory Benefits

- Selective desorption enabled a uniform barrier film with a very small amount of oil.
- Achieves both hair hydrophobicity and a light, non-greasy feel.

Potential Applications Across Multiple Fields

- Potential use in skin care, waterproofing, and next-generation material design.

Key Insight

- **Even when ingredients have the same INCI name or molecular formula, differences in their branched structure determine their performance.**
- **This underscores the vital importance of a structure-based approach in development.**