BRONTIDE™

NATURAL BUTYLENE GLYCOL

Personal Care
User Guide

Contents

What is Brontide™ natural butylene glycol?

Brontide is a sustainable, naturally sourced alternative to petroleum-derived polyols and solvents. This effective and sustainable functional ingredient is increasingly becoming formulators' choice in beauty, personal care and fragrance applications. Brontide™ natural butylene glycol is versatile in delivering active ingredients and enhancing their properties to make stable formulations — with the added benefits of elevating natural origin content, superior humectancy, viscosity control and achieving a premium skin feel without irritation.

Key characteristics

Chemical structure

Brontide™ natural butylene glycol is an organic compound, a linear alcohol with two hydroxyl groups, with the molecular formula $C_4H_{10}O_2$.

Biodegradability

It's readily biodegradable according to Organisation for Economic Co-Operation and Development (OECD) criteria, minimizing its impact on [2]ecosystems.

No build-up effect

It is not known to leave residue on the skin over time. The ingredient is non-comedogenic and non-irritant, making it suitable for acne-prone or sensitive skin.

Low molecular weight

Its low molecular weight (90.12 g/mol) allows it to penetrate the skin easily, effectively delivering other active ingredients into the skin[1].

Hygroscopic nature

It's hygroscopic, meaning it can attract and retain moisture from the environment, helping to keep the skin and hair hydrated.

Solubility

It is highly soluble in both water and many organic solvents.

[1] Kis, Gunnarsson, Berkó, Sparr, "The effects of glycols on molecular mobility, structure, and permeability in stratum corneum", Journal of Controlled Release 343 (March 2022): 755-764.

[2] ECHA Registration Dossier (R)-(-)-butane-1,3-diol

Benefits and uses

Natural and sustainable product

It helps brands reach sustainability goals. Brontide™ natural butylene glycol reduces global warming potential by 50% compared to petroleum-based butylene glycol production processes.

Solvent

It can act as a solvent, helping to dissolve other substances and create homogeneous mixtures in cosmetics.

Hair care

In addition to skincare, natural butylene glycol can help maintain the moisture content of the scalp and hair.

Antimicrobial efficacy

Natural butylene glycol inherently prevents some microbial growth.

Viscosity and texture enhancer

It can improve the texture and feel of products by providing a smooth and lightweight consistency, improving shine, spreadability and after-feel while reducing tackiness and greasiness.

Moisturization

Its humectant properties help to retain moisture, keeping the skin hydrated and preventing dryness.

Enhanced skin penetration

Due to its low molecular weight, it aids in penetrating other active ingredients into the skin.

Transparent supply chain

Made in Europe from local feedstocks, designed in California, USA.

Humidity control

It can maintain the stability of a product by controlling its moisture content, thus preventing dry-off.

Prevent stickiness

Its lightweight and non-greasy texture can help prevent the sticky feeling sometimes associated with other humectants like glycerin.

Features

Sustainably produced: 50% less carbon emissions than petroleum-based butylene glycol with a minimal environmental footprint [3]

ISO 16128 Natural Ingredient, Natural Index of 1, Natural Origin Index of 1

USDA BioPreferred Program, 100% Biobased (ASTM D6866-16)

Naturally sourced from renewable feedstocks

No animal testing

No heavy metals detected

Vegan

[3] Pacheco, Huston, "Life Cycle Assessment (LCA) of Naturally-Sourced and Petroleum-Based Glycols Commonly Used in Personal Care Products", SOFW Journal (11/18) | Volume 144, Nov 15, 2018.

Applications

Skin care & sun care

Found in moisturizers, serums, creams and lotions to provide hydration and improve product texture.

Hair care

Used in shampoos, conditioners and hair masks to maintain moisture and enhance product spreadability.

Cosmetics

Included in various makeup products, such as foundations and primers, to improve application and wear.

Deodorants and antiperspirants

Anti-whitening, quick drying and reduced residue.

Cosmetic ingredients

Used as a carrier solvent with active ingredients.

Fragrance diluent

Improves organoleptic expression of fragrance ingredients while increasing natural content of formulations.

Discover new benefits in skin and hair care formulations with Brontide™ natural butylene glycol

When designing a personal care formulation, selecting each raw material is critical, but few ingredients influence as many attributes of a final product as the solvent. Solvents are critical for developing a formulation that meets consumer demand for mild products that are not irritating to the skin. Additionally, solvents dictate how a product is perceived by its users in terms of consistency (rheology), stability and how effectively it delivers its intended functionalities, such as moisture, emollience, low tackiness, conditioning and fragrance dispersion.

Brontide offers benefits across a wide variety of products. It can be used in oil-in-water (O/W) emulsion systems (hand and body creams) to generate higher viscoelasticity behavior, which results in a smoother skin feel with no stickiness. The ingredient can also be added to single-phase aqueous formulations like shampoos and conditioners to enhance the formulation's stability, ensuring long-term stability and product uniformity. Using *Brontide* can reduce the need for, or even replace, select actives responsible for a smooth sensorial experience, viscosity and product after-feel, increasing performance or lowering overall formulation costs.

How to formulate with *Brontide* natural butylene glycol

Brontide works well in a variety of emulsion systems:

- In O/W (oil in water), *Brontide* can help create lightweight, hydrating products like lotions and serums.
- In W/O (water in oil), it can contribute to improved texture and moisture retention in products like water-resistant sunscreens.
- In complex systems like W/O/W and O/W/O, Brontide's solvency and humectancy properties can aid in encapsulating and delivering both water- and oil-soluble actives.

The choice of emulsion system and the use of Brontide™ natural butylene glycol depend on factors such as the desired product texture, targeted skin benefits, stability requirements and compatibility with other ingredients.

Cold process emulsification

Brontide™ natural butylene glycol is versatile and suitable for both cold and hot process emulsification in cosmetic formulations. Its stability at room temperature makes it particularly effective for cold process emulsions, allowing the creation of stable formulations without heat. Its relatively low boiling point is also advantageous when used in hot process emulsions, provided that heat-sensitive ingredients are considered.

Formulations featuring natural and sustainable ingredients is a strong trend in cosmetic emulsions. These emulsions often incorporate innovative textures, customization options and advanced delivery systems. The rise of smart emulsions, multi-functional products and transparent ingredient information is also notable. These trends impact ingredient selection by prioritizing natural, sustainable, and skin-friendly options, aligning well with the use of ingredients like natural butylene glycol to support clean and environmentally conscious formulations.

Basics for oil-in-water (O/W) systems

Creating O/W emulsion systems involves dispersing oil droplets within a continuous water phase. Butylene glycol is typically added to the water phase with water-soluble ingredients like other humectants, botanical extracts and preservatives. The water phase provides moisture, hydration and solubilization for water-soluble ingredients.

Preparing complicated emulsion systems, such as hand creams and body butters, requires a multistep process. The first step may involve the dissolution of the rheology modifier and butylene glycol in the aqueous phase with consistent mixing at an ambient temperature until the aqueous system becomes homogeneous. The levels of natural butylene glycol used in these formulation types typically range from 2-6% overall.

Natural thickeners offer the benefit of being biobased and sourced from renewable feedstocks, but they can often be difficult when formulating a product. Natural thickeners such as cellulosics should be added to cold water while very slowly dispersing the fine powder into the vortex created by an overhead mixer. Other thickeners, such as xanthan gum, can be dispersed in a water-miscible solvent like Brontide before adding them to the bulk water and agitating them for about 10-15 minutes (before other ingredients are added).

The oil phase consists of oils or oil-soluble ingredients. This stage provides emollience, nourishment and lipid-based benefits to the formulation. The oil phase also contains lipophilic emulsifiers that help stabilize the emulsion by surrounding oil droplets.

> Advice from Dr. Brew[1], Geno technical advisor: Another way to use Brontide natural butylene glycol is to clear a stable but hazy formulation while increasing the cloud point. This can replace the use of an amphoteric surfactant (hydrotrope). To create a smooth but very low viscosity solution that is clear yet rich, Brontide can be employed at levels from 2-6%.

[1] Dr. Henry Brew is the CEO of Here2Grow Cosmetics and Homecare Labs UK, winner of the 2021 Cosmetics Development Specialist of the Year – UK.

After this phase, the collection of the oil-phase components (humectants, emollients and natural oils) are thoroughly mixed together in a separate beaker, utilizing moderate-to-high mechanical agitation until uniform. Depending upon the specific ingredients, gentle heating (40-50 degrees Celsius) may be required to pour these components and add them into the oil phase. At this point, the aqueous and oil phases are combined with a high-shear mixer to form the O/W emulsion. The final stage incorporates additives such as extracts, preservatives and fragrances to round out the formulation. This step will likely include a fairly rigorous mixing after the temperature of the batch falls below 35°C.

Example O/W emulsions formulations:

Natural day cream

Intensive lifting cream

Sunflower after bath body lotion

Basics for aqueous systems

Water-based systems require different formulation skills and techniques than O/W systems. Conventional facial cleansers and shampoos are commonly produced by a simple order of addition; namely water, a thickener (if required), a solvent like Brontide™ natural butylene glycol and surfactants, followed by extracts, additives, fragrances and preservatives. The Brontide levels used in this formulation type typically range from 2-12%.

> **Advice from Dr. Brew: In rare cases where the personal care matrix shows signs of phase separation after mixing is completed, a good first step for resolving this issueis to increase the level of butylene glycol to eliminate unwanted phase separation.**

The general procedure for single phase aqueous formulation devlelopment is typically as follows: First, weigh each ingredient's predefined amount. Then, start developing your mixture by adding deionized water into a beaker. Using an overhead mechanical mixer set at low speed for gentle mixing, slowly add the rheology modifier (if necessary), working diligently to achieve good dispersion and prevent polymer clumping. Next, add Brontide and any surfactants, adjusting to moderate shear and taking additional time to mix particularly viscous or dry surfactants. The remaining components (extracts, fragrances and preservatives) are typically in a solubilized liquid form and can be gradually introduced to complete the formulation. Consider ingredient compatibility when preparing mixtures and allow enough time for melting and dispersion.

Example single-phase aqueous formulations:

Bouncing legs after active gel

Sweat & tonic body wash

Glimmer and glow tinted moisturizer

Solvency and solubility

Solubility and the choice of solvents play a pivotal role in a personal care formulations' efficacy, stability and aesthetics. Navigating the intricate landscape of ingredient compatibility is both an art and a science, underlining the complexity inherent in creating effective and stable formulations and products. When using Brontide™ natural butylene glycol as the preferred or primary solvent system, there are some basic points to consider:

General compatibilities:

Water, alcohols, surfactants, natural emollients/ conditioners and fragrance oils.

No-go zones:

Extremely oily or polar environments and strong mineral acids.

Advice from Dr. Brew: Utilization of butylene glycol may reduce the concentration of solvent required to ensure phase stability and may allow for higher concentrations of active ingredient to be effectively coupled into the personal care formulation. As the carbon chain length increases, molecules have the tendency to become more hydrophobic. Comparing ethanol, propanol, butanol and pentanol, the incremental addition of one extra carbon produces an alcohol that is water-insoluble (pentanol) and one that has limited solubility (butanol). In contrast, in butylene glycol, the incorporation of a second alcohol group enhances water solubility, aiding coupling with longer chain hydrocarbons, including natural oils, most surfactants and fragrance oils when compared to propanediol and glycerin.

Brontide and surfactants

For conventional homogeneous, single-phase products (e.g., facial cleansers, shampoo, etc.), *Brontide* provides a means of coupling to or solubilizing minimally-soluble ingredients like surfactants. Brontide™ natural buytlene glycol can provide sufficient coupling to handle most solubility challenges and adjusting the concentration of natural butylene glycol can be a simple way of resolving these concerns. However, depending on the specific surfactants in question (e.g., cationics, amphoterics, etc.), there may be a need for a second solvent to facilitate the process. Fragrance oils may require the addition of a coupling solvent to ensure homogeneity and the stability of a formulation.

Natural solvency study:

In a recent study, solubility performance was quantified by measuring the refractive index (as a measure of solubility) of serial dilutions for 15 common natural extract ingredients in three polyols, Brontide™ natural butylene glycol, propanediol (PDO) and glycerin. In comparison, *Brontide* was proven in a study conducted by Geno[5] to to create solutions that are more consistent with the predicted/theoretical refractive index for each of the natural extracts tested.

Refractive indices of 10% weight dilutions of polyols plus an extract were measured to quantify solubility. The statistical residuals were then measured, comparing refractive indices to the predicted slope.

As an example, one of 15 charts showing reflective indices versus concentrations for an extract combined with *Brontide* is shown in Figure 1.

Extracts studied:

- oat
- aloe vera
- witch hazel
- marshmallow root
- bamboo
- camomile flower
- lavender flower
- pea (Pisum sativum)
- peach
- green tea
- calendula
- bilberry fruit
- seaweed
- algae
- rosemary

Brontide + Lavender Extract Actual Refractive Index Data with Predicted Refractive Index Line

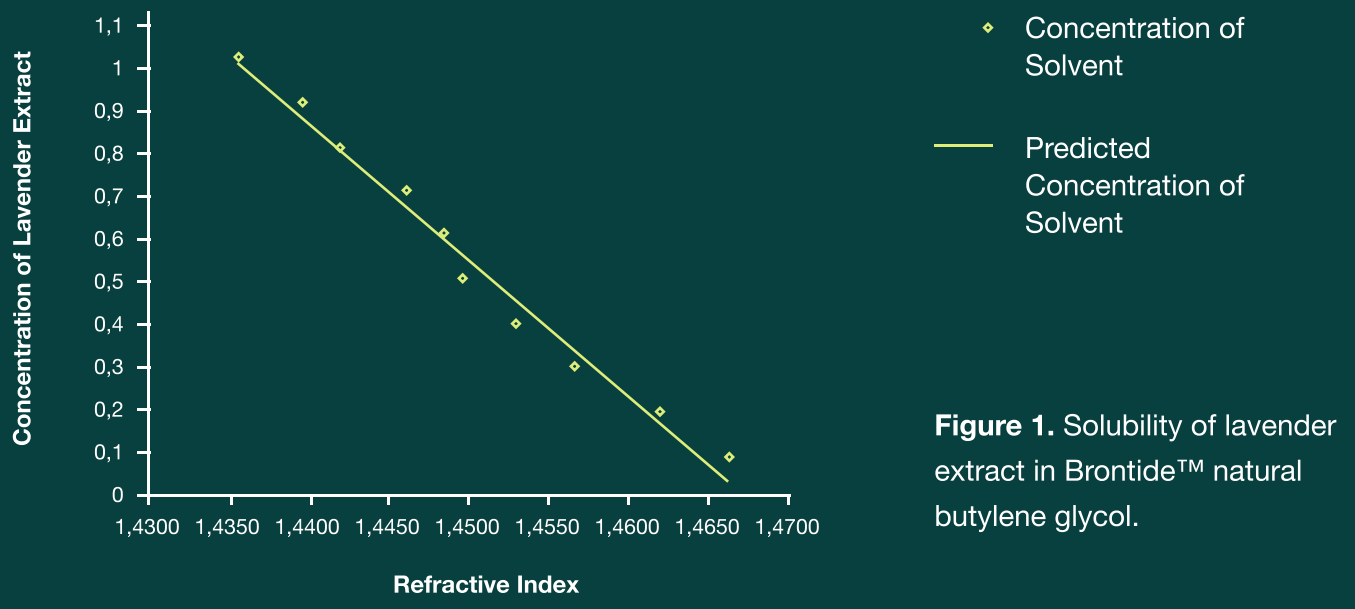


Figure 1. Solubility of lavender extract in Brontide™ natural butylene glycol.

[5] Geno Brontide Solubility Study, 2019, https://brontidebg.com/our-product/

The distance on a chart between the theoretical predicted slope and the actual data points in statistics is called a residual. Figure 2, below, shows the average of the 10 residual data points for each polyol and extract (with lower numbers desired).

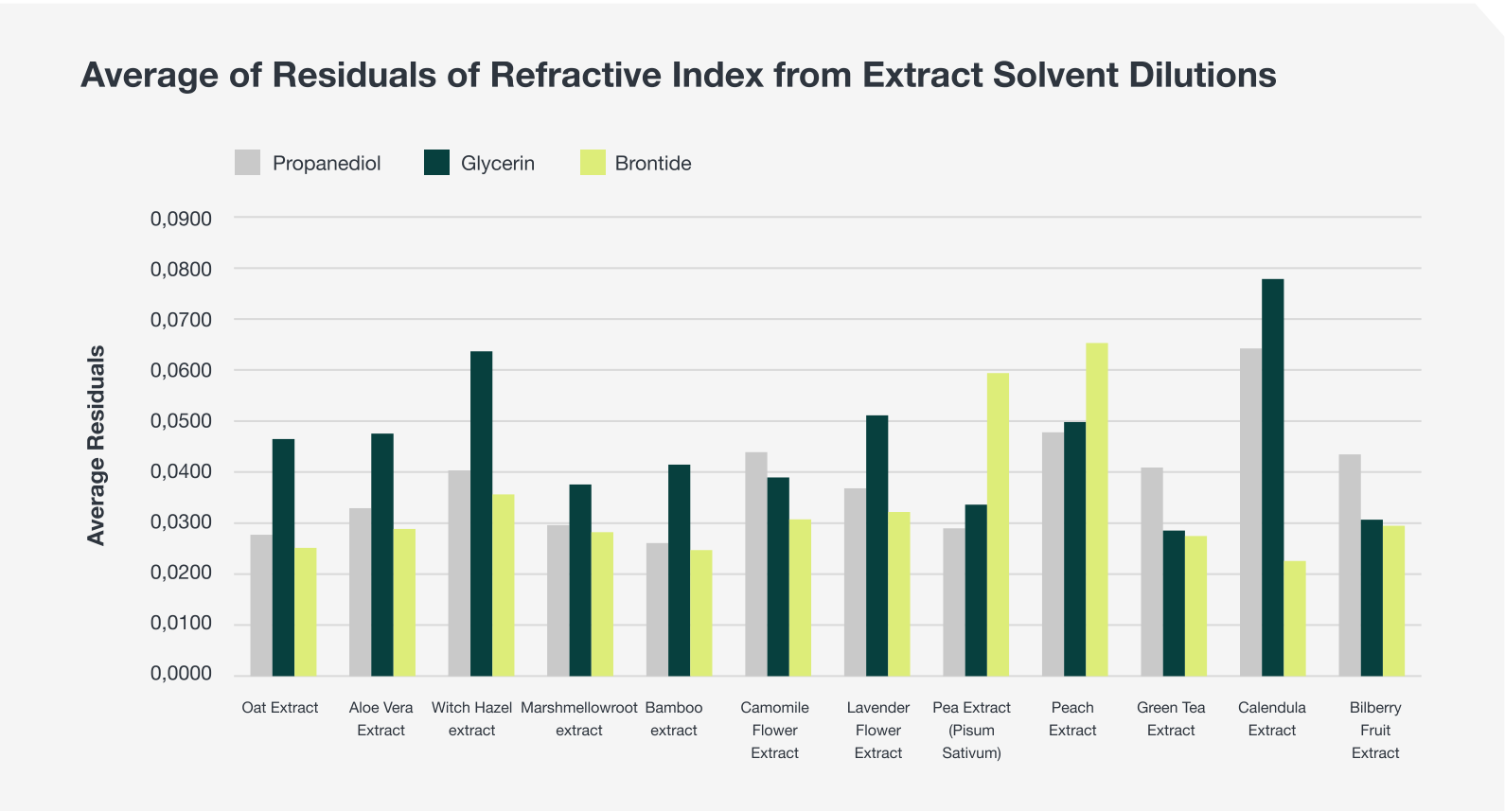


Figure 2: Average Statistical Residuals of Refractive Indeces in Polyol Dilutions

The Geno extract solubility study showed *Brontide* to be the best-performing solubilizer with the most consistent and predictable performance when compared to glycerin and propanediol.

Rheology in natural personal care formulations

Rheology studies the flow and deformation of fluids like pastes, gels or creams. Measuring rheological properties when creating personal care products, like skin care and hair care, is important because it affects consumer interaction, skin feel, efficacy and longevity. Measuring and manipulating rheology in formulations can be extremely complex because rheology is influenced by many factors in a formulation, including the type of ingredients being used and their interactions and concentrations, preparation steps and conditions, and storage and usage conditions. While this rheology section is not aimed to be a technical commentary on rheology, it speaks directly to research done by Geno on the impact of natural polyols on personal care formulations.

Many personal care formulations have a rheological property known as viscoelasticity, which is a combination of a fluid's "liquid-like" and "solid-like" properties. Viscosity is a key rheological property that refers to a liquid's resistance to flow. In general, the thicker the fluid, the higher its viscosity. Viscosity is the "liquid-like" property of viscoelastic fluids. Conversely, elasticity can be considered the "solid-like" property of viscoelastic fluids and speaks to a fluid's capacity to maintain its shape regardless of its viscosity.

Viscosity is often viewed as a critical quality control in personal care formulations. Products with a higher viscosity tend to be smoother and easier to spread, providing a better skin feel. Elasticity can be crucial when the fluid needs to be handled, contained or remain stationary and can impact a variety of sensory experiences when the product is spread, including the physical sensation of the formulation "pushing back."

When assessing how different solvents might influence the rheology of personal care formulas, it's useful to understand that various types of formulations exhibit unique viscoelastic behaviors based on their composition. In O/W personal care emulsions, oil droplets are enveloped by emulsifying agents, creating a three-dimensional network of microstructures within the emulsion that displays elastic or "solid-like" properties. As a result, such O/W personal care emulsions are viscoelastic fluids that are expected to exhibit dominating elastic behavior.

By contrast, single water-phase personal care formulations exhibit viscous or "liquid-like" properties that are mainly driven by rheology modifiers. However, polyols may also affect viscoelasticity. These single water-phase formulations create gel-like, continuous microstructures that are expected to exhibit dominating viscous behavior.

Ideally, a balance of viscous and elastic properties is preferred for spreadable O/W emulsions like hand cream and body butter, as these products need to be easily managed by the user and provide a pleasant spreading experience.

Brontide™ natural butylene glycol as a rheology modifier

Rheology experimental design

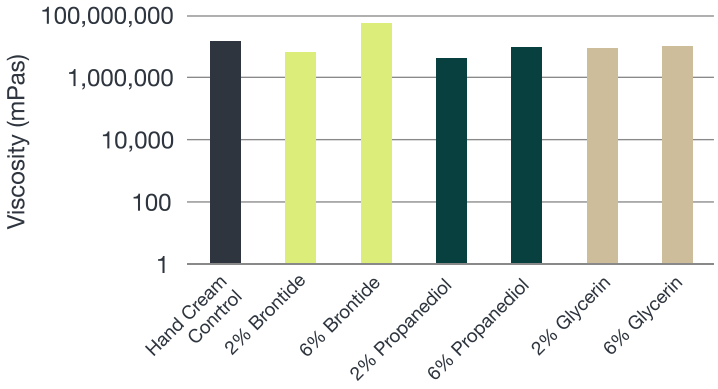
Five distinct formulations were developed to examine and compare their flow and deformation properties: a conditioner, shampoo, facial cleanser, hand cream and body butter. A rheometer was employed to measure how they flowed at different polyol concentrations, since the data did not show viscosities at different rheometer shear rates/speeds.

The products used for testing fell into one of two broad categories: either a single water-based solution or an O/W emulsion. Water-based solutions like shampoos and facial cleansers are typically pourable liquids. Conversely, O/W emulsions, which include conditioners, hand cream and body butter, are generally thicker and can be controlled when spreading more easily.

For each formulation, four versions were developed. The natural solvent in each mixture varied between natural butylene glycol, propanediol, glycerin or no polyol at all (control). Each of these test mixtures was created with two different solvent concentrations (2% and 6%) and representative samples were subjected to rheological testing under similar conditions and intended use scenarios.

Hand Cream Viscosity

The rheological advantages of *Brontide* can be observed in the viscosity of an O/Whand cream as shown in the Figure 3, right. Incorporating *Brontide* increases the viscosity of the formulation as a function of concentration compared to the control sample that contains no polyol. A similar effect is observed with the addition of glycerin, although the magnitude of increase in viscosity from 2% to 6% polyol loading is higher with *Brontide*. A higher hand cream viscosity is desirable because it improves select sensorial properties such as thicker, richer sensation on the skin, enhanced moisture retention and improved skin after-feel. By contrast, adding propanediol at both polyol loadings lowers hand cream viscosity compared to the control, which negatively impacts overall benefits associated with sensorial feel and product rheology.



2% viscosities for all formulations similar to control.
Brontide built viscosity significantly above control at 6%.

Figure 3: O/W Hand Cream Viscosity with 2%, 6% Polyol Concentrations

In Figure 4 below, hand cream elasticity was also measured showing each formulation maintaining a similar elasticity to the control in the 2% tests. The 6% polyol formulation elasticity testing shows more variety in the results, with Brontide™ natural butylene glycol increasing elasticity by more than 10% compared to the control. The glycerin and propanediol decreased elasticity in the 6% polyol formulations.

Hand Cream Elasticity

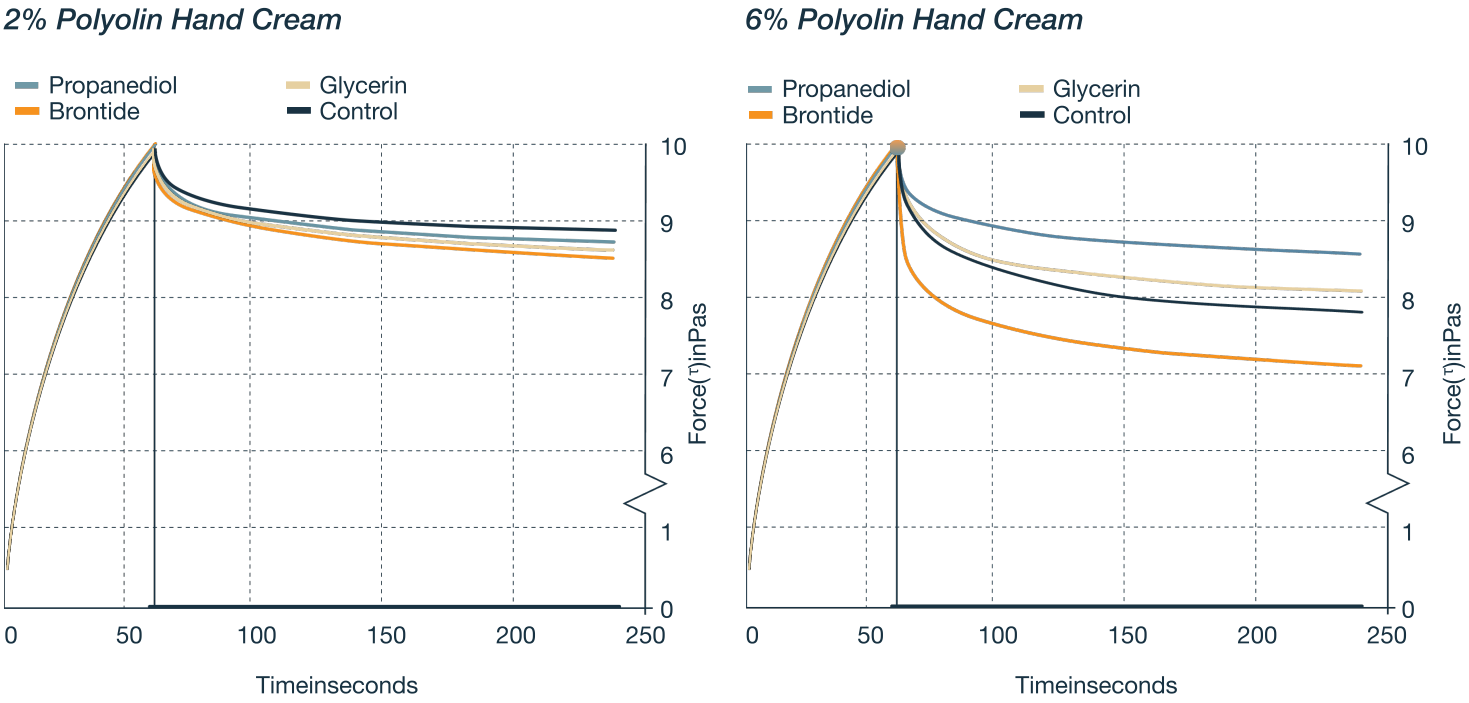
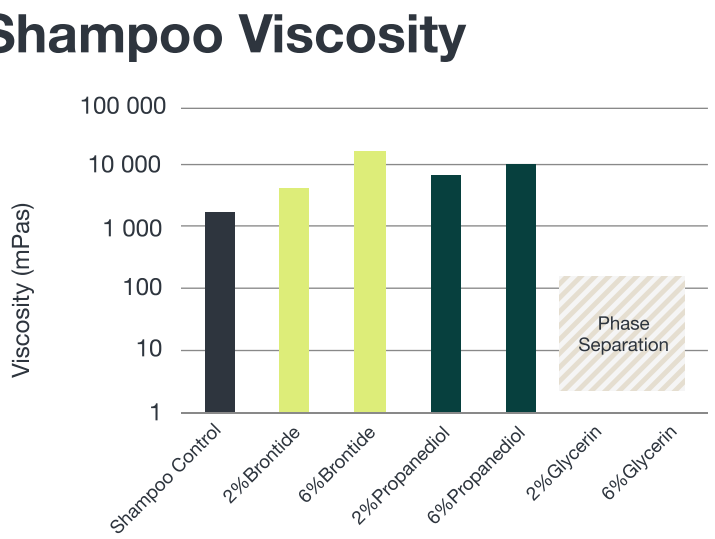


Figure 4: O/W Hand Cream Elasticity

> Advice from Dr. Brew: The addition of a solvent into a hand cream formulation can potentially provide further benefits including increased viscosity and improved viscoelastic properties such as moisturization, which reduces the need for additional salts. Adding a solvent is advantageous because salts are typically used to modify viscosity. However, they have the tendency to reduce the moisture content and strip out natural oils in hair and skin, leaving it feeling dry and brittle.

Polyols are used in shampoo formulations as a humectant to help moisturize the hair and to balance the drying effect of other ingredients, namely surfactants. Rheology modifiers can be added to shampoo formulations to improve viscoelastic properties such as increasing the thicker/richer sensation while still allowing the shampoo to be easily worked into the hair. The viscosity of water-phase aqueous shampoo formulations was measured. Figure 5, below shows improvements in viscosity at 2% and 6% loading of Brontide™ natural butylene glycol and propanediol. As observed with O/W emulsions, the magnitude of viscosity enhancement is larger from 2% to 6% *Brontide* compared to similar propanediol formulations, including glycerin at comparable concentrations, produces a destabilizing effect, resulting in an undesirable phase separation of the formulation after two weeks of aging at ambient temperature.

In addition to viscosity, elasticity was also me asured for the single-phase liquid formulation, however, no deviation in elasticity compared to the control was observed and presentation of viscoelastic charts foregone in this document.



Viscosity build appears to be load-dependent from 2-6%. Brontide displaying superior viscosity build.

Figure 5: Single Phase Aqueous Shampoo Viscosity

These rheological studies reveal that natural butylene glycol could improve the elasticity of two-phase O/W emulsions while having a minimal effect on the elasticity of single-phase liquid formulations. Additionally, based on the concentration, natural butylene glycol could successfully adjust the flow and deformation behavior of single-phase water products and O/W emulsions. In the case of the shampoo formulation, natural butylene glycol consistently heightened the viscosity as its concentration was increased from 2% to 6%, like the effect of propanediol. In the body butter formulation, natural butylene glycol did not significantly impact elasticity, but at a concentration of 6%, it considerably enhanced the viscosity. Contrarily, propanediol reduced the viscosity at both 2% and 6% concentrations.

Increases in viscosity and elasticity in O/W emulsions and single-phase aqueous formulations are particularly desirable as they are perceivable features to the consumer, generally indicating desirability and overall product quality. These insights pair well with the sensory study discussed in the next section.

Brontide™ natural butylene glycol can improve the sensory experience in skin care

Brontide can provide superior or comparable performance for many attributes contributing to a consumer's skin care product experience[7]. While many skin care products are intended to impart some desirable effect on the skin or hair, the tactile user experience can also greatly impact the perceived value and repeat purchases. This allows brands to differentiate themselves from competitors by providing a more desirable or luxurious consumer experience.

[7] Huston, K, 2023, "Improve Sensory Attributes in Skin care Formulas", *Happi*

Sensory experimental design

A basic O/W hand cream was developed to determine which polyol contributes to a more desirable user sensory experience. Polyol solvents (propanediol, glycerin and Brontide™ natural butylene glycol) were prepared at a fixed concentration of 3% in identical formulations at a fixed concentration of 3%.

The remaining ingredients in the prototypical hand cream were aqua, coco-caprylate/caprate, guar gum, parfum, sunflower seed oil, squalene, potassium sorbate, avocado oil, tocopherol, sodium benzoate, phenoxyethanol and glyceryl stearate.

The study defined a set of nine sensorial attributes with which to evaluate each formulation. These parameters were selected for their critical value in determining the effectiveness of a hand cream and identifying the areas where a multifunctional diol solvent could potentially influence the consumer experience. Each dimension was evaluated on a scale of one to nine.

Sensorial Attributes

- **Appearance** (Integrity of shape before application): 1 (Flattens) - 9 (Retains Shape)
- **Gloss/Shine** (The amount of reflected light of the cream): 1 (Dull) - 9 (Glossy/Shiny)
- **Rub-out** (Amount of moisture perceived while rubbing): 1 (None) - 9 (Very Watery)
- **Spreadability** (Ease of moving product over the skin): 1 (Difficult/Drag) - 9 (Easy/Slip)
- **Grease:** 1 (None) - 9 (Very Greasy)
- **Afterfeel** 1 (Rough) - 9 (Smooth)
- **Stickiness** 1 (Not Sticky) - 9 (Very Sticky)
- **Slipperiness** (Ease of moving fingers across the skin): 1 (Difficult/Drag) - 9 (Easy/Slip)
- **Amount of residue after application** 1 (Strongly Disagree) - 9 (Strongly Agree)

Brontide™ natural butylene glycol was perceived to be comparable or better than the glycerin and propanediol in a basic O/W emulsion hand cream in eight of the nine tested parameters. The scores of positive attributes categories — appearance, gloss/shine, rub-out, spreadability, slipperiness and after-feel — for the three diols are shown in Figure 6, below.

Natural Diol Sensory Performance

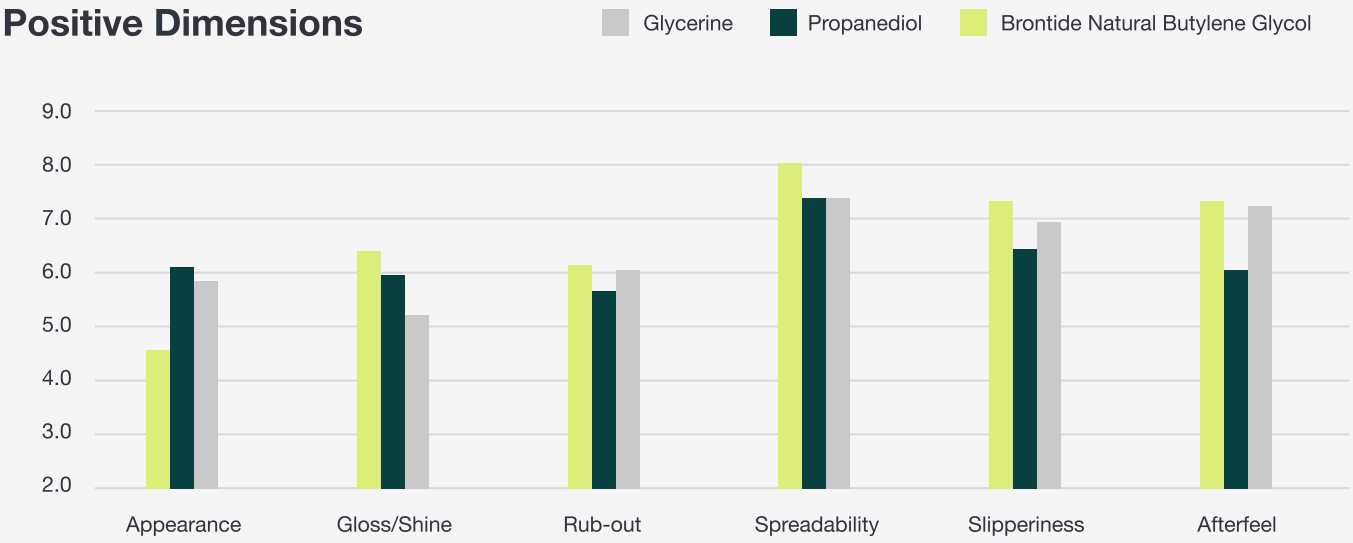
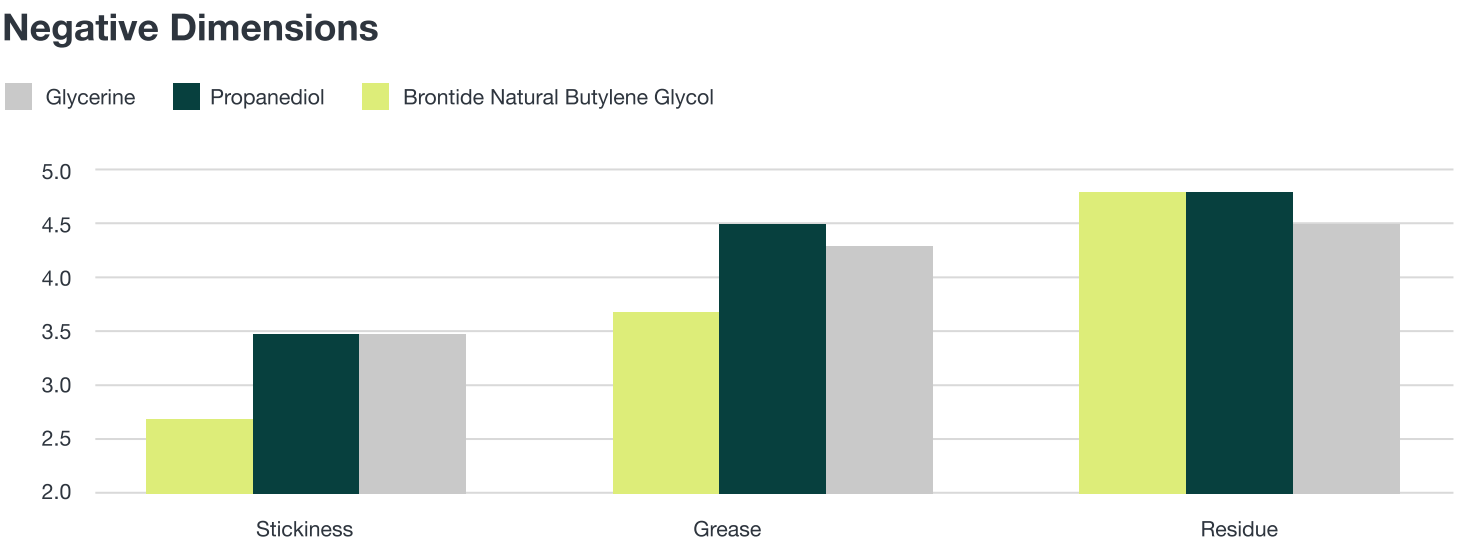


Figure 6: Natural Polyol Sensory Results (Positive Dimensions)

Brontide achieved superior performance scores in the positive attribute categories of gloss/shine, spreadability and slipperiness. In addition, the sample containing *Brontide* was perceived to deliver comparable performance in rub-out and after-feel when compared with the samples containing glycerin or propanediol.

Appearance, or the integrity of shape, was the one area where *Brontide* did not outperform the competing formulations. However, the ingredient's performance could be improved through formulation changes such as including waxes or other rheology modifiers.

Negative attribute categories such as stickiness, grease and residue were also tested, and the results are shown in Figure 7, below. *Brontide* was considered the least sticky and greasy compared to glycerin and propanediol and had a similar residue compared to propanediol.



Negatively Viewed Sensorial Dimensions (lower numbers are more favorable)

Figure 7: Natural Polyol Sensory Results (Negative Dimensions)

> Advice from Dr. Brew: If a formulation is displaying an undesirable amount of stickiness and a formulator is unable to adjust the level of the causative additives, incrementally increasing the butylene glycol load by small amounts (up to 1% additional) can be an option for reducing the sensation of stickiness or greasiness. From a formulator's experience, the addition of Brontide natural butylene glycol, a C-4 glycol, increases hydrophobic (oily) attributes versus the C-3 derivatives. This reduces the interactions between all the formulation ingredients when mechanical forces are applied, resulting in a smoother, less sticky sensory experience.

Formulation stability

Incorporation of glycols within the formulation process has multiple functions, including anti-freeze properties that could enhance a formulation's stability during freeze/thaw cycles. In a 2023 Geno study, six formulations made with O/W and aqueous emulsions were run through three subsequent freeze/thaw cycles and observed for visual phase separation change. Each formulation was loaded with 6% polyol (Brontide™ natural butylene glycol, propanediol, glycerin and a control with no polyol). A visual inspection used a scale between 1 (no phase separation) and 4 (distinct phase separation).

Results in Figure 8, below show that *Brontide* proved to be superior in preserving the integrity of various formulations as the only polyol to maintain stability after three freeze-thaw cycles.

In addition to performance benefits, Brontide natural butylene glycol enhances the phase stability and coupling attributes of all tested formulations, minimizing the risk of phase separation.

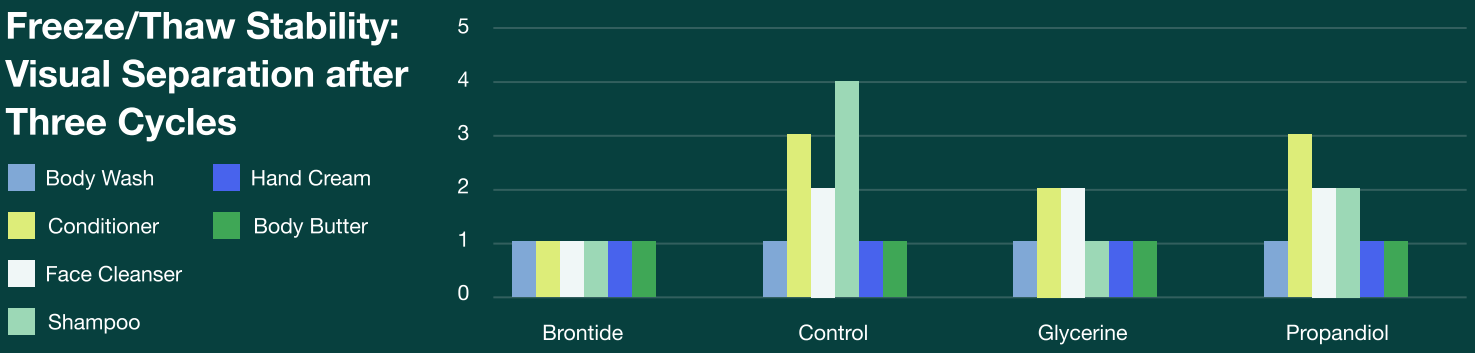


Figure 8: Freeze/Thaw Stabilty Test Results, Visual Inspection of Formulation Separation

> Advice from Dr. Brew: Due to the nature of the O/W emulsion, it's exceptionally difficult to predict how a solvent will impact product stability This means it's critical to age the finished formulation at different temperatures (4, 25 and 40 degrees Celsius for example) and assess stability at time zero, 24 and 48 hours. Assuming the preparation passes these scenarios, product stability should also be reviewed after 1, 2, 4, 8 and 12 weeks.

Brontide proved to be superior in preserving the integrity of various formulations as the only polyol to maintain stability after three freeze-thaw cycles.

Antimicrobial benefits

One of the main concerns of a formulator will always be microbiological stability. The time and effort invested in creating a physically and structurally intact product can be in vain if the product fails the microbiological stability test. Not having a microbiologically stable product in place will mean the following: As microbes grow in the formulation, they may not only create an unsightly appearance in color or a bad odor but may also release hazardous toxins into the formulation. The product cannot be sold to the public in these cases as it is already unsafe before being stocked on shelves.

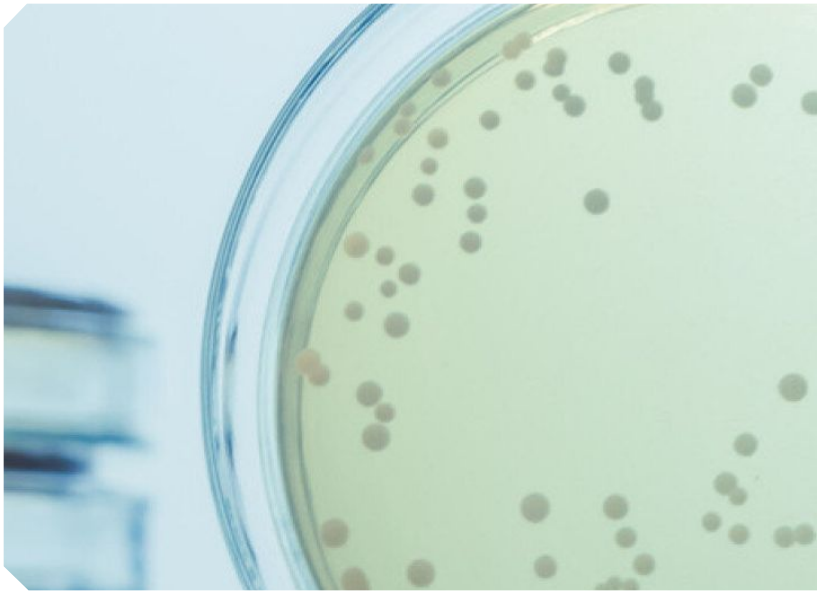
Some of the largest threats to formulators are microorganisms like bacteria and fungi like mold. Bacteria that are the most challenging to kill include Staphylococcus aureus, Pseudomonas aeruginosa and E. coli; therefore, formulations will generally include the necessary preservatives to inhibit microbial growth.

> **Advice from Dr. Brew: Every product developed for commercial sale is evaluated to determine whether it needs to be preserved. This process often includes the individual raw materials that go into personal care or household care formulations. The choice of preservative will vary depending on the nature of the finished formulation and the market it's sold into. Most formulators have a finite group of antimicrobial actives they select from, but there must be a game plan developed before formulation to determine the preservatives best suited for the job. The incorporation of alcohols/glycols, quaternary ammonium compounds, isothiazolinones and organic acids, etc. can all play a role, but these materials are not all safe or recommended in personal care applications. Using butylene glycol can offer a major advantage in that it is safe and provides antimicrobial properties.**

Microbes are more likely to grow in water-based formulations such as facial cleansers and shampoos compared to O/W-based formulations like hand creams. A minimum inhibitory concentration (MIC) test was performed to determine the lowest polyol concentration in the water needed to inhibit microorganism growth in the formulation. Notably, Brontide™ natural butylene glycol can inhibit bacterial and fungal growth and boost the preservation of water-based formulations, as found in the 2022 Geno study and depicted in Figure 9.

A solvent with antimicrobial properties

Brontide™ natural butylene glycol is shown to have superior antimicrobial propertis compared to natural common diols. Minimum inhibitory concentration (MIC) tests indicate Brintide natural butylene glycol has an increased ability to inhibit microbial growth compared to propanediol and glycerin.



Brontide can play a role in preservative efforts.

Organism	Brontide	1,3 PG	Glycerin	Glycerin 1,3 PG (1:1)	Glycerin + Brontide (1:1)
S aureus	225	300	>350	>350	300
E coli	100	225	>350	>350	250
P aeruginosa	175	200	>350	>350	200
C albicans	225	250	>350	>350	300
A brasiliensis	>350	>350	>350	>350	>350

Lower values represent stronger antimicrobial efficacy.

Figure 9: Minimum Inhibitor Concentration (MIC) Test Results with Natural Polyols

Lower or similar *Brontide* concentrations are required compared to other polyols for all microorganisms that were tested in the MIC study. Furthermore, lower/similar Brontide™ natural butylene glycol concentrations are required for a polyol mixture with glycerin compared to another polyol mixture of glycerin and propanediol.

Why Brontide® natural butylene glycol?

Brontide is a biobased alternative to petroleum glycols and glycerin. It's ideal for formulators looking for high performance and sustainability in personal care and cosmetic formulations. Brontide™ natural butylene glycol can be used in various body and skin care applications including moisturizers, hair care products, facial cleansers and deodorants. This novel, natural solvent has been proven to deliver skin feel and appearance benefits (e.g., spreadability, after-feel, gloss/shine and reduced stickiness, etc.) and provides excellent solubilization and stabilization properties for various personal care matrices.

About geno.

Geno (Genomatica, Inc.) is harnessing biology to remake everyday products to be more sustainable and natural. Geno's technology, built over the last 20 years, now commercializes and scales sustainable alternatives to commonly used ingredients and materials across several industries including functional foods and beverages, beauty, apparel, automotive, home and personal care, and packaging. Geno is partnering with world-leading brands including Aquafil, Asahi Kasei, lululemon, Unilever, Kao and L'Oréal.