Enhanced foaming properties and mildness on skin

Victor Low – Lonza, US

Mildness in cleansing systems for face and hair is a critical characteristic for consumers. Consumers are interested in low or no-irritation systems to maintain the health of their skin and hair. This is particularly true regarding facial cleansers and baby care products such as shampoos and body washes. Foam performance, such as building foam and foam texture, also are key to creating a successful commercial product.

Asia Pacific consumers are accustomed to these cleansing systems, and they use multiple products. For example: "South Korean Beauty routines can consist of up to 10 steps … (as consumers strive) … to achieve the so-called 'chok-chok' skin, which is supposed to look bright, fair, plump, dewy and youthful."[1]

Multiple-step regimes can have a compounding effect on irritation on skin, causing potential long-term damage. Ingredient suppliers and personal care manufacturers who offer alternative systems with low irritation profiles enable consumers to perform their skin and hair care routines with minimal discomfort.

When Lonza scientists looked at the company's Polyaldo® product line last year, they discovered Polyaldo 10-1-CC polyglyceryl ester (INCI name: Polyglyceryl-10 caprylate/caprate) had true surfactancy characteristics. Lonza determined to formally investigate the surfactancy properties of Polyaldo 10-1-CC mild surfactant (now referred to by its INCI name). We found Polyglyceryl-10 caprylate/caprate mild surfactant offers excellent foam generation while maintaining mildness in personal care surfactant cleansing systems such as baby shampoos, facial cleanser, and hand washes. Suitable for a wide range of formulation types, Polyglyceryl-10 caprylate/caprate mild surfactant is Ecocert-approved, Halal- and Kosher-certified, manufactured from 100% plant-derived raw materials and an excellent choice for PEG-free cleansing formulations.

Making the perfect polyglyceryl ester

Derived from our 50 years of expertise in polyglyceryl ester chemistries for food applications, Lonza has developed a non-ionic surfactant to help meet consumer needs. The Polyaldo polyglyceryl ester range is created via the esterification of a polyglyceryl and fatty acid in the presence of a proprietary catalyst.

To meet the market's expectations, we have commissioned independent, third-party studies in order to validate the benefits of Polyglyceryl-10 caprylate/caprate mild surfactant, highlighting foam performance, surfactancy attributes, irritancy profile, and skin penetration of surfactants.

Foam performance

To measure foam performance, Lonza commissioned a study from Lyon, France-based Teclis Scientific. The foam analyser used in the study generates foam images, then software translates the images into quantitative values. The objective was to measure the time it takes for the surfactant to generate 150 ml of foam and analyse the foam following its generation via image analysis.

The Research and Technology Team at Lonza created three face wash prototypes for the foam analysis study; one containing Polyglyceryl-10 caprylate/caprate mild surfactant, and two others containing PEG-80 sorbitan laurate and decyl glucoside, respectively. They accounted for varying concentrations by adjusting the use level so all three surfactants would be tested at 5% equivalent activity.

Figure 1 measures foam generation over time. PEG-80 sorbitan laurate, charted in green, took 700 seconds to achieve 150 ml of foam. Polyglyceryl-10 caprylate/caprate mild surfactant, denoted in orange, generated 150 ml of foam in about 200 seconds. Decyl glucoside generated the 150 ml of foam in about 100 sec.

The key takeaway from the foam generation study is the data generated within the first 50 seconds. Polyglyceryl-10 caprylate/caprate mild surfactant generated a comparable amount of flash foam compared to decyl glucoside. The isolation of the first 50 seconds of foam generation is important because many consumers spend

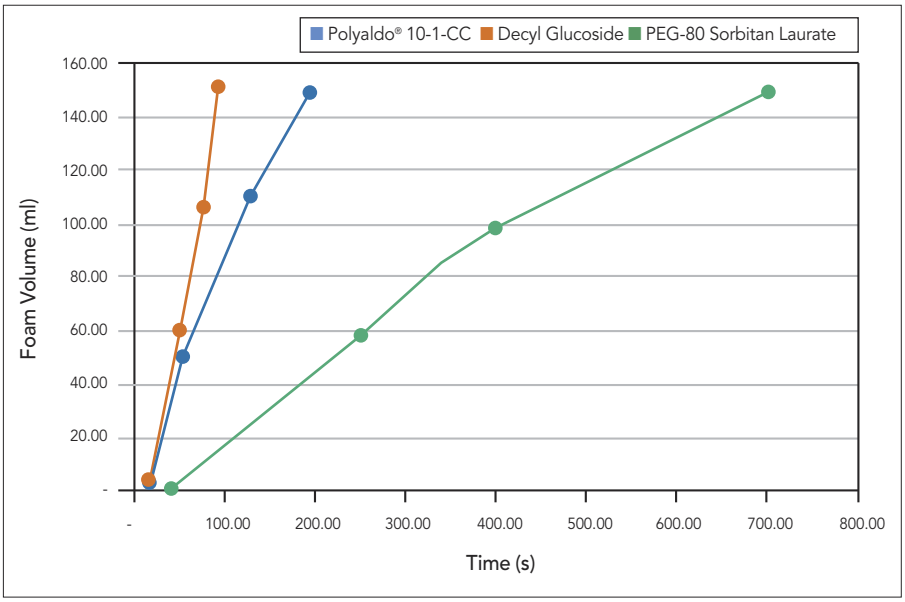

Figure 1: Flash foam analysis of Polyaldo 10-1-CC mild surfactant vs. PEG-80 sorbitan laurate vs. decyl glucoside.

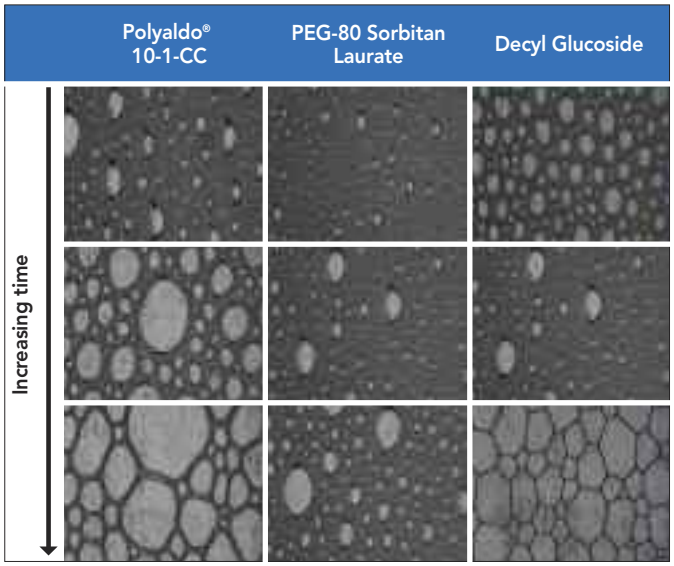

Figure 2: Foam image analysis of face washes with the different surfactants

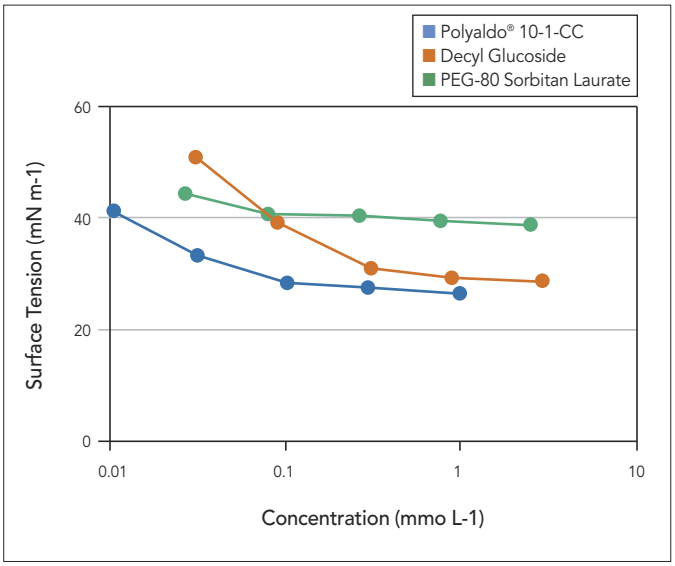

Figure 3: Dynamic surface tension analysis.

no more than this amount of time generating foam, providing more real-world context to the data.

Figure 2 shows a foam image analysis of the three face washes, with the images taken at time zero (when the prototype formulation has achieved 150 ml of foam), 300 seconds and 800 seconds.

The foam images for PEG-80 sorbitan laurate (centre) show it does not form a traditional foam matrix and support claims it is a poor surfactant. Compare PEG-80 sorbitan laurate to the other benchmark, decyl glucoside (right), and you can see the difference. Decyl glucoside creates large bubbles in high concentration which provides a dry, crackly foam. However, the walls of the bubbles are very thin. This leads to poor foam stability and will cause the foam to 'crash' or collapse on itself quickly.

Polyglyceryl-10 caprylate/caprate mild surfactant forms spherical micelles, generates creamier foam and is more stable than PEG-80 sorbitan laurate and decyl glucoside. The micelles have thicker walls than the decyl glucoside bubbles, indicating more water and more surfactant in the walls. The additional surfactant helps support the bubbles and improve foam stability. The water-containing walls also contribute to a creamier skin-feel for a more aesthetically pleasing foam compared to decyl glucoside.

Surfactancy attributes

Surface tension describes the value of the surface activity of a surfactant. It is a measure of a liquid and its ability to resist an external force due to the cohesive properties of its molecules. Surface activity is the measure of how well a surfactant can spread water across a surface.

A surfactant lowers the surface tension of the liquid in which it is dissolved. Measuring the surface tension of a liquid containing a surfactant helps scientists analyse the surface activity and performance — building and generating foam – of the surfactant. A high-performing surfactant will support foam stability as well as foam generation.

Surface tension study methodology

A study was commissioned to measure the dynamic surface tension of surfactants with a Sigma 700 tensiometer (from KSV Instruments, Helsinki, Finland) using the Wilhelmy (platinum) plate method. Concentrations ranged from 0.001% to 3%. As with the foam generation studies, the Lonza scientists evaluated Polyglyceryl-10 caprylate/caprate mild surfactant, PEG-80 sorbitan laurate and decyl glucoside.

As the concentration of Polyglyceryl-10 caprylate/caprate ester increases, surface tension decreases, leading to increasing surface activity. At >0.01% concentration Polyglyceryl-10 caprylate/caprate average surface tension is about 27mN/m to 30mN/m (Fig 3). In general, an effective surfactant averages in the range of 25 mN/m to 32 mN/m.

By contrast, PEG-80 sorbitan laurate achieves a surface tension value no better than 39 mN/m. This result indicates PEG-80 sorbitan laurate is less surface active and indicates a less effective surfactant. The lower surface activity of PEG-80 sorbitan laurate also explains the minimal foam generation in previous data.

Irritation profile

Lonza contracted independent skin and eye irritation tests. These tests are *in vitro* alternatives to animal testing and industry standards for determining irritation potential for consumer safety.

The Epiderm™ Skin Irritation Test showed Polyglyceryl-10 caprylate/caprate mild surfactant to be classified as a non-irritant surfactant on the skin (Table 1).

To perform the test, the study utilised simulated human skin with *in vitro* skin cells, and inoculated them the various surfactants. The mean tissue viability is the percentage of skin cells left in the medium 60 minutes after inoculation. A mean tissue viability greater than 50%, indicating that the surfactant left more than 50% of

Table 1: Epiderm Skin Irritantion Test (SIT)

Product	Mean Tissue Viability (%)	Classification
Polyaldo 10-1-CC	104.5*	Non-Irritant
PEG-80 Sorbitan Laurate	98.9	Non-Irritant
Decyl Glucoside	17.0	Irritant
Cocamidopropyl Betaine	32.7	Irritant
Phosphate Buffered Saline (negative control)	100.0	Non-irritant
5% Sodium Dodecyl Sulfate (positive control)	3.1	Irritant

*Within the margin of error for 100%.

Table 2: EpiOcular irritation test.

Product	Mean Tissue Viability (%)	Classification
Polyaldo 10-1-CC	32.3	Mild
PEG-80 Sorbitan Laurate	256.0	Minimal
Decyl Glucoside	16.0	Moderate to Severe
Cocamidopropyl Betaine	<1.0	Severe

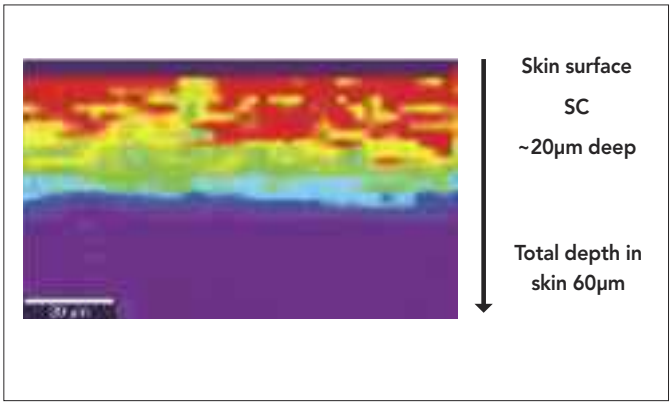

Figure 4: Confocal Raman image analysis: SDS-applied skin.

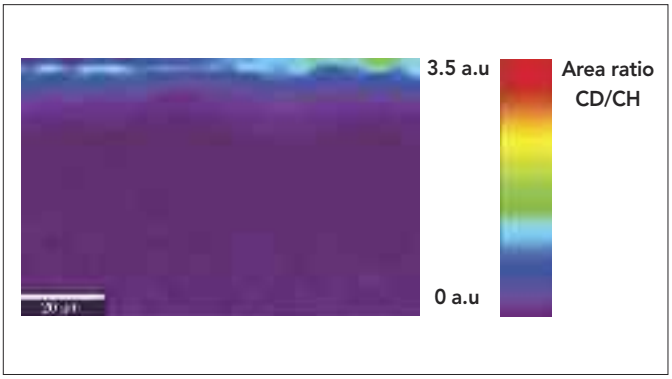

Figure 5: Confocal Raman image analysis: skin applied with Polyaldo 10-1-CC mild surfactant + SDS.

the cells intact, classified a surfactant as a non-irritant. A mean tissue viability less than 50%, indicating that a surfactant destroyed more than 50% of the skin cells, classified a surfactant as an irritant.

Polyglyceryl-10 caprylate/caprate mild surfactant and PEG-80 sorbitan laurate scored close to the saline negative control of 100%, and thus qualified as non-irritants. Decyl glucoside, by contrast, had a mean tissue viability of just 17%, classifying it as an irritant.

Polyglyceryl-10 caprylate/caprate mild surfactant has an excellent skin irritation profile, equal to PEG 80 sorbitan laurate, and generates foam as well as decyl glucoside. PEG-80 sorbitan laurate also has an excellent irritation profile but does not foam well, as highlighted in the previous study.

The EpiOcular™ Irritation test (Table 2) evaluates possible eye irritation of the various surfactants. PEG-80 sorbitan laurate, with a mean tissue viability of 256 – determined by the MatTek specific gravity method — was classified as a minimal irritant. Polyglyceryl-10 caprylate/caprate mild surfactant, with a mean tissue viability of about 33, is classified as a mild irritant. Polyglyceryl-10 caprylate/caprate mild surfactant outperformed decyl glucoside and cocamidopropyl betaine.

Skin penetration test

Traditional surfactants have the potential to penetrate the stratum corneum, which resides about 20 um below the skin surface. A key property for a cleanser is to stay closer to the skin surface and avoid penetrating the stratum corneum, where it can cause potential damage and disruptions to the moisture balance of the skin.

The goal of the skin penetration study is to evaluate Polyglyceryl-10 caprylate/caprate mild surfactant for the ability to mitigate the penetration of surfactants into the stratum corneum, thus reducing the negative effects caused by some surfactants. The surfactant skin penetration test used surgical human abdominal skin (*ex vivo*) as the medium. In addition to evaluating the Polyglyceryl-10 caprylate/caprate mild surfactant, Lonza evaluated sodium dodecyl sulfate (SDS), recognised as a positive skin irritant.

Samples of Polyglyceryl-10 caprylate/caprate + SDS surfactants, and SDS alone were each applied to the *ex vivo* skin medium and measured via a WITec Alpha 300R Plus Confocal Raman Microscope. Scientists measured the penetration of SDS into the stratum corneum - the outer layer of the skin, 20 microns beneath the skin surface - and the presence of water in the stratum corneum. The images were processed with WITec Project Plus software.

Skin applied with SDS alone had significant SDS penetration into the stratum corneum (Fig 4). High surfactant penetration can compromise the surface of the skin and cause disruptions to the stratum corneum.

Figure 5 shows skin applied with a surfactant combination of Polyglyceryl-10 caprylate/caprate mild surfactant and SDS. Surfactant presence is limited to the skin surface, mitigating the penetration of SDS into the stratum corneum.

The Polyglyceryl-10 caprylate/caprate mild surfactant thus protects the surface of the skin and the stratum corneum from potential damage caused by some harsh surfactants.

Traditional surfactants have the potential not only to damage the stratum corneum, but disrupt the delicate balance of water and potentially create issues with how the skin functions. The effects of surfactant penetration can be shown by measuring the amount of moisture in and below the stratum corneum.

Figure 6 shows the presence of water in untreated healthy skin, the control for the water content analysis. Red, yellow and orange indicate higher concentrations of water in the skin. Purple indicates low water content, and the dotted line represents the skin surface. In general, there is less water content nearer to the surface because more

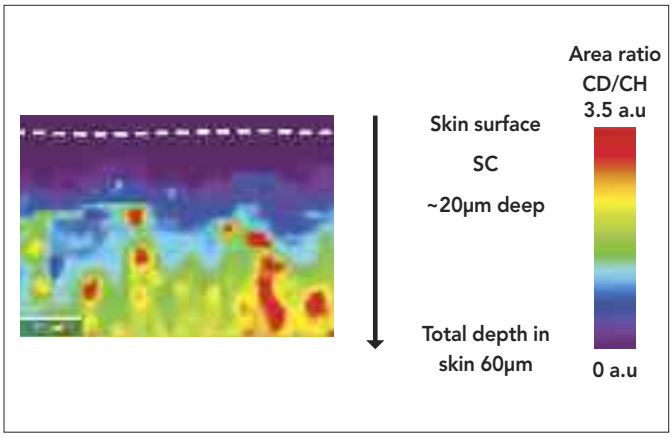

Figure 6: Confocal Raman image analysis of water content: Untreated, control skin.

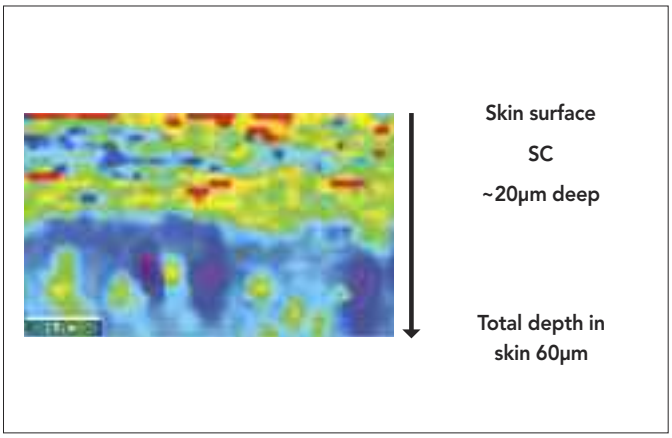

Figure 7: Confocal Raman image analysis of water content: SDS-applied skin.

moisture evaporates from the surface.

Skin applied with SDS alone had higher concentrations of water near the surface (Fig 7). As noted, SDS disrupts the water content in the stratum corneum – shown by the concentration of bright red, yellow and orange on the skin — and has the potential to cause damage to the stratum corneum.

Skin applied with Polyglyceryl-10 caprylate/caprate and SDS surfactants matched the control (Fig 8). Much of the water content exists below the surface of the skin and stratum corneum. This result shows the balance of water in the skin is not as affected by SDS when the skin is is in contact with Polyglyceryl-10 caprylate/caprate mild surfactant. Thus Polyglyceryl-10 caprylate/caprate mild surfactant can help maintain the stratum corneum moisture balance, and protect the skin from potential damage caused by harsh surfactants.

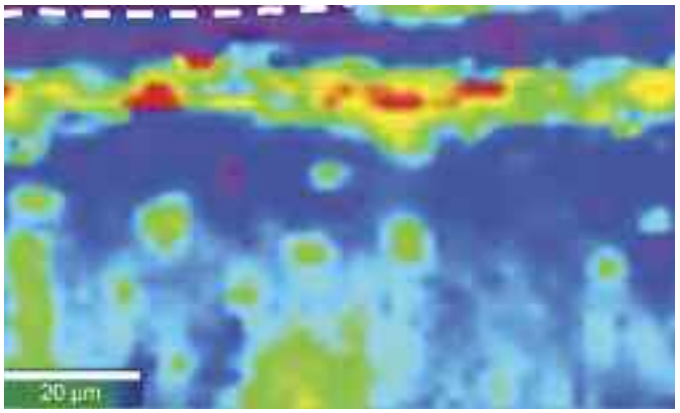

Figure 8: Confocal Raman image analysis of water content: skin applied with Polyaldo 10-1-CC mild surfactant + SDS.

Conclusion

Polyaldo 10-1-CC mild surfactant delivers the best of both worlds. It offers an excellent irritation profile, with mildness on a par with PEG-80 sorbitan laurate, combined with the initial flash foaming speed of decyl glucoside, a moderate to severe irritant (based on our study).

Polyaldo 10-1-CC mild surfactant builds foam structure faster than PEG-80 sorbitan laurate, and creates a more stable foam structure and creamier foam. It has higher surface activity than PEG-80 sorbitan laurate, resulting in efficacious cleansing and a better cost-performance ratio. Classified as very low-irritating, it is a gentle surfactant for skin and hair applications where mildness is needed. In addition, Polyaldo 10-1-CC mild surfactant mitigates surfactant penetration into the stratum corneum, protecting skin from potential damage caused by harsh surfactants and maintaining the stratum corneum moisture balance.

Reference

1 Jane Jang, Senior Beauty Analyst at Mintel, From "A Bright Future: South Korea Ranks Among the Top 10 Beauty markets globally, Mintel. Published April 4, 2017. Accessed July 5.

PC