Jungbunzlauer

From nature to ingredients®

facts

Investigation into the stability and foaming performance of Xanthan Gum in combination with different surfactants

Introduction

Foaming in household cleaning products

Cleaning agents are an indispensable part of modern life and are used in a variety of ways for personal care and household cleaning. Surfactants are essential components of cleaning agents. These amphiphilic substances are responsible for the cleaning effect and the foam formation. A distinction is drawn between strongly and weakly foaming systems, depending on the type of surfactant used. The foam volume and the stability of the foam depend on a variety of influencing factors, including pH, temperature, electrolytes, and other additives. For many applications, foam formation is very important as consumers often associate foam with superior detergent performance and hence better cleaning. Highly stable, small-bubble foams in cleaning products are often perceived as representing high quality. In applications like dishwashing liquids or car shampoos, where a good visual impression is important, foam is therefore an essential parameter for a successful formulation. Foam also increases the surface area and hence the concentration of surfactants at the interfaces, maximising the usefulness of the cleaning additives in the formulation. Applications such as carpet cleaners, drain cleaners and multi-surface cleaning mousses are particularly associated with a high degree of foaming.

In addition to surfactants, rheological additives are often used to optimise the viscosity of the cleaning agent and to adjust the foaming behaviour of the final formulation. Xanthan gum is well-known as a rheology modifier in a wide variety of applications and is especially used in household cleaners to optimise the viscosity of the surfactant in a cleaning formulation.

This study was designed to show the influence of different xanthan gum grades on the foaming behaviour and stability of surfactant-based cleaning formulations at different pH values. Three different types of traditional surfactant and one biosurfactant were therefore selected. To analyse stability, regular viscosity and pH measurements were taken over a period of six months. Finally, foam properties were investigated – specifically, foam formation, foam decay and foam structure of selected xanthan gum/surfactant combinations.

Jungbunzlauer's xanthan gum is a safe, odourless and bio-based product, and therefore represents an excellent thickening and stabilising agent for such applications, with outstanding foam properties. Since it is of natural origin, it fits well with the recent trend towards more sustainable household cleaning products.

Xanthan Gum – the natural thickener made by fermentation

Xanthan gum is a polysaccharide that is manufactured by fermentation processes using the microorganism *Xanthomonas campestris* and carbohydrate-containing raw materials from crops like corn. After several purification steps, including precipitation, drying, and milling, xanthan gum is obtained as a free-flowing, water-soluble powder. Its structure consists of a polymer backbone made up of glucose units, in which every second glucose unit is modified by a side chain consisting of mannose-glucuronic acid-mannose. With a molecular weight of about 2×10^6 to 2×10^7 g mol^{-1} xanthan gum imparts a high viscosity when dissolved in water and shows pronounced shear-thinning behaviour. Following modifications to the fermentation and downstream processes, different xanthan gum grades are now available on the market. Xanthan gum is a safe, odourless and bio-based product that is fully biodegradable and therefore suitable for natural product claims.

Xanthan Gum in household cleaning applications

The use of xanthan gum as a rheology modifier makes the handling of a cleaning formulation easier and increases the storage stability of products containing insoluble components. More importantly, however, the adhesion of the cleaner to surfaces is improved: a higher viscosity reduces dripping and run-off so that the cleaner exhibits a longer contact time with the soiled surface being treated. This results in better removal of obstinate soiling. Under conditions of high shear, the cleaner exhibits a low viscosity, thus making it easy to fill into and apply from the container and easy to remove from the surface after the cleaning action has taken place. Due to its pseudoplastic shear-thinning character, xanthan gum is well suited for spray applications. Jungbunzlauer offers a special acid-stable xanthan gum grade suitable for low-pH conditions. As household cleaning applications often require transparent solutions, a clear type is also available.

Materials and methods

Material

Three different grades of xanthan gum (standard technical [TN], clear solution [TNCS], and acid-stable clear solution [TNAS-CS]) were investigated to determine their compatibility with three traditional surfactants, an anionic surfactant (sodium lauryl sulphate [SLS], MANSKE®), a non-ionic surfactant (alkyl polyglycoside [APG], BASF), an amphoteric surfactant (cocamidopropyl betaine [CAPB], BASF) and a biosurfactant (sophorolipid [REWOFERM® SL ONE], Evonik). The pH ranged from acidic to alkaline. Stability measurements were conducted for all tested surfactant systems, while foam properties were only investigated for SLS and the sophorolipid.

Stability measurements

A xanthan gum concentration of 0.5% was selected for the stability measurements, with the surfactant concentration varying between 5 and 10%. The pH was adjusted to 2, 3, 7 or 10. Regular (1 day, 1 week, 1 month, 3 months and 6 months post-preparation) viscosity and pH measurements were taken over a period of six months. The flow curve was measured by rotational viscometry (Anton Paar MCR 302, plate-cone geometry C35-2, 21°C). Apparent viscosity was determined at continuously increasing shear rates from 0.01 to 1000 s^{-1}. Since a change in viscosity was observed over time at low shear rates it was decided to use viscosity at 0.1 s^{-1} for the comparison.

Foam properties

The influence of the xanthan gum grade, concentration (0.5, 1.0 and 1.5%) and pH (3, 7 and 10) on the foam properties of 10% sodium lauryl sulphate was investigated. Additionally, the foam properties of 10% sophorolipid were tested with 0.5% xanthan gum TNCS at a neutral pH. Prior to measurement, the surfactant/xanthan gum solution was diluted with demineralised water to a ratio of 1:10. The foam formation, decay, and structure were evaluated using a SITA FoamTester by SITA Messtechnik GmbH (Dresden, Germany). To evaluate the foam properties, flasks were filled with 250 mL of the diluted mixture at room temperature (21°C) and then 30 foaming cycles (1200 rpm stirring speed, 10 s stirring time, 10 s measuring time) were performed with three repetitions. Total volume and the volumes of foam and liquid were determined to assess foam formation and decay. Foam decay was observed over a period of at least seven minutes. In order to determine the number of bubbles and the average area of foam bubbles, images were captured at the end of the foam formation and the foam decay. All images were analysed via image analysis.

Results & Discussion

Stability measurements

A stable viscosity at low shear rates is of importance for the storage stability of household cleaning formulations. For optimal cleaning performance, a high low-shear viscosity also plays a significant role, as it affects the adhesiveness of the detergent and therefore the contact time.[1] At low shear rates, differences were observed when viscosity was measured. At high shear rates no differences were observed. For this reason, the low shear viscosity at 0.1 s^{-1} was used for the comparison.

Table 1 presents the viscosity changes (in %) at a shear rate of 0.1 s^{-1} over a period of six months for the surfactants tested. No influence of the surfactant concentration on stability was evident. At an acidic pH of 2, xanthan gum TNAS-CS exhibited superior stability at low-shear viscosity compared to xanthan gum TN and TNCS; this was true for all surfactants. At a pH of 3, the viscosity drop was generally less pronounced, although xanthan gum TNAS-CS still demonstrated the best results. At a neutral pH it made no difference which grade of xanthan gum was used; all grades showed excellent results in combination with all four different surfactant types. The same was observed for alkaline pH with SLS, APG and CAPB, with all grades demonstrating suitability for stabilisation. No stability measurements for pH 10 were taken for the sophorolipid, as its manufacturer Evonik does not recommend its use in highly alkaline conditions (Evonik recommends a pH of 5 to 8 [2]).

Table 1: Change of viscosity in % compared to starting value at a shear rate of 0.1 s^{-1} over six months for SLS, APG, Betaine and sophorolipid

		5% SLS			10% SLS		
		TN	**TNCS**	**TNAS-CS**	**TN**	**TNCS**	**TNAS-CS**
pH	2	-61	-64	-39	-58	-60	-39
	3	-36	-34	-23	-31	-36	-32
	7	-6	-8	9	0	11	-6
	10	-19	-9	-15	-21	-18	-18

		5% APG			10% APG		
		TN	**TNCS**	**TNAS-CS**	**TN**	**TNCS**	**TNAS-CS**
pH	2	-51	-48	-23	-54	-53	-31
	3	-35	-47	4	-24	-33	-12
	7	-11	-8	-7	-9	0	-16
	10	-16	0	-10	-15	-12	-18

		5% Betaine			10% Betaine		
		TN	**TNCS**	**TNAS-CS**	**TN**	**TNCS**	**TNAS-CS**
pH	2	-60	-57	-35	-58	-58	-37
	3	-40	-44	-33	-32	-35	-21
	7	-14	-10	-14	-6	-12	-15
	10	-19	-3	0	-6	14	-7

		5% Sophorolipid			10% Sophorolipid		
		TN	**TNCS**	**TNAS-CS**	**TN**	**TNCS**	**TNAS-CS**
pH	2	-60	-59	-39	-53	-61	-28
	3	-35	-34	-27	-24	-49	-16
	7	-22	0	-6	20	-7	-2

> -10%	-10%> X > -20%	-20%> X > -30%	-30%> X > -50%	< -50%

Foam properties

Foam formation and decay

Foam formation, foam decay and foam structure were analysed to establish foam properties. The first aspect of the investigation was to evaluate the influence of the xanthan gum grade and concentration on the foam properties. SLS at a neutral pH was chosen as the matrix. Figure 1 shows that the SLS base rapidly formed foam, with approximately five foaming cycles necessary to achieve the final foam volume. In the absence of xanthan gum, the maximum foam volume that could be achieved was 1100 mL. The addition of xanthan gum resulted in a reduced foam volume. With a concentration of 0.5% xanthan gum the foam volume was between 945 and 980 mL (figure 1a). The xanthan gum grades TN and TNCS demonstrated comparable foam formation, while xanthan gum TNAS-CS produced a slightly smaller volume of foam. Increasing the xanthan gum concentration to 1% resulted in a further reduction of the foam volume to 900 mL for TNCS (figure 1b). At a concentration of 1.5% the trend continued, with a reduction in foam volume to 850 mL. In general, the reproducibility of the experiments was satisfactory. It can be concluded that an increase in xanthan gum concentration results in a reduction in foam volume. It can be hypothesised that there is a correlation between foam volume and viscosity. One possible explanation for this is that the higher viscosity limits air intake, resulting in a reduction in foam volume. Another explanation could be that xanthan gum influences the surface tension and hence foam formation. A comparison of the xanthan gum grades revealed no significant differences.

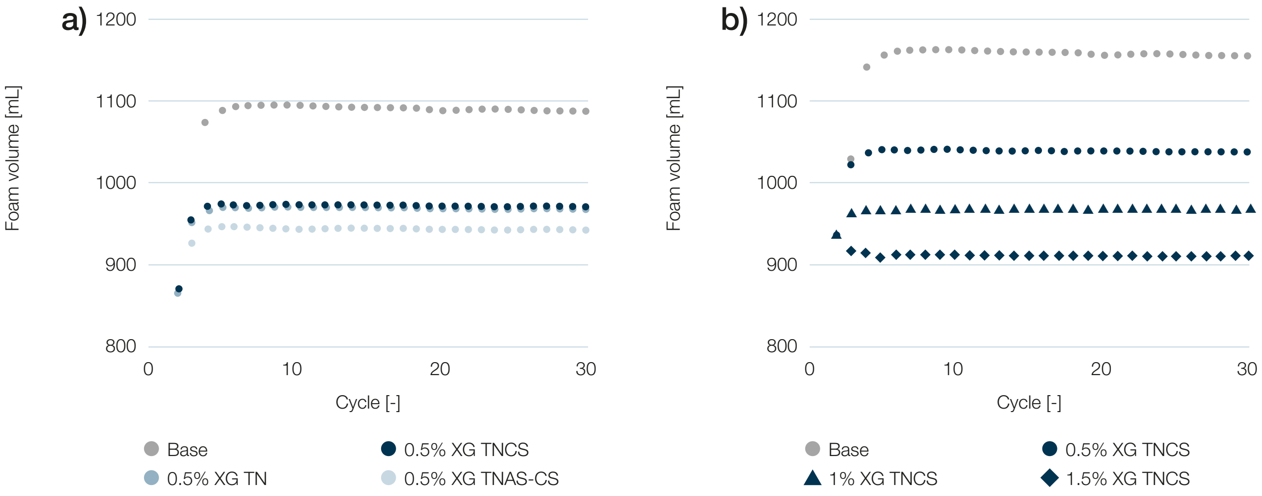


Figure 1: Comparison of foam formation for xanthan gum in combination with 10% SLS (pH 7): a) Variation of xanthan gum grades; b) Variation of xanthan gum concentrations for XG TNCS

In figure 2, a significant decline in foam stability is observed in the absence of xanthan gum. The liquid volume of the SLS base increased during the eight minutes of foam decay to almost 200 mL, indicating that the majority of the liquid was drained out of the foam. The addition of xanthan gum, regardless of grade, resulted in foam that was stable for a minimum of five minutes. Xanthan gum demonstrated excellent foam-stabilising properties even at a low concentration of 0.5%, with only 20 mL of liquid volume measured during foam decay (figure 2a). Figure 2b shows that for concentrations of 1% and 1.5% of xanthan gum the foam volume remained constant, and there was no drainage over the eight-minute period.

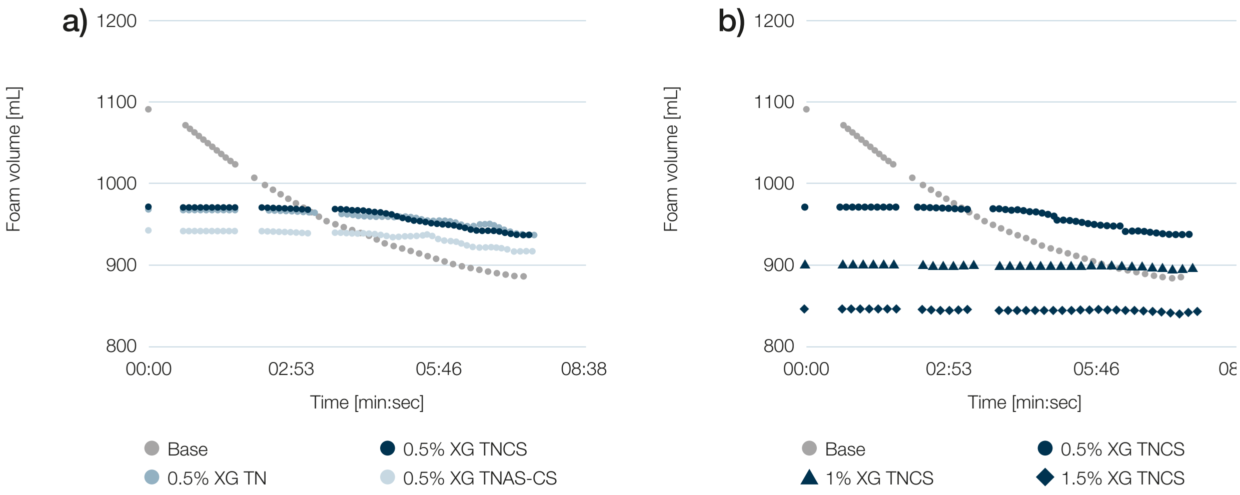
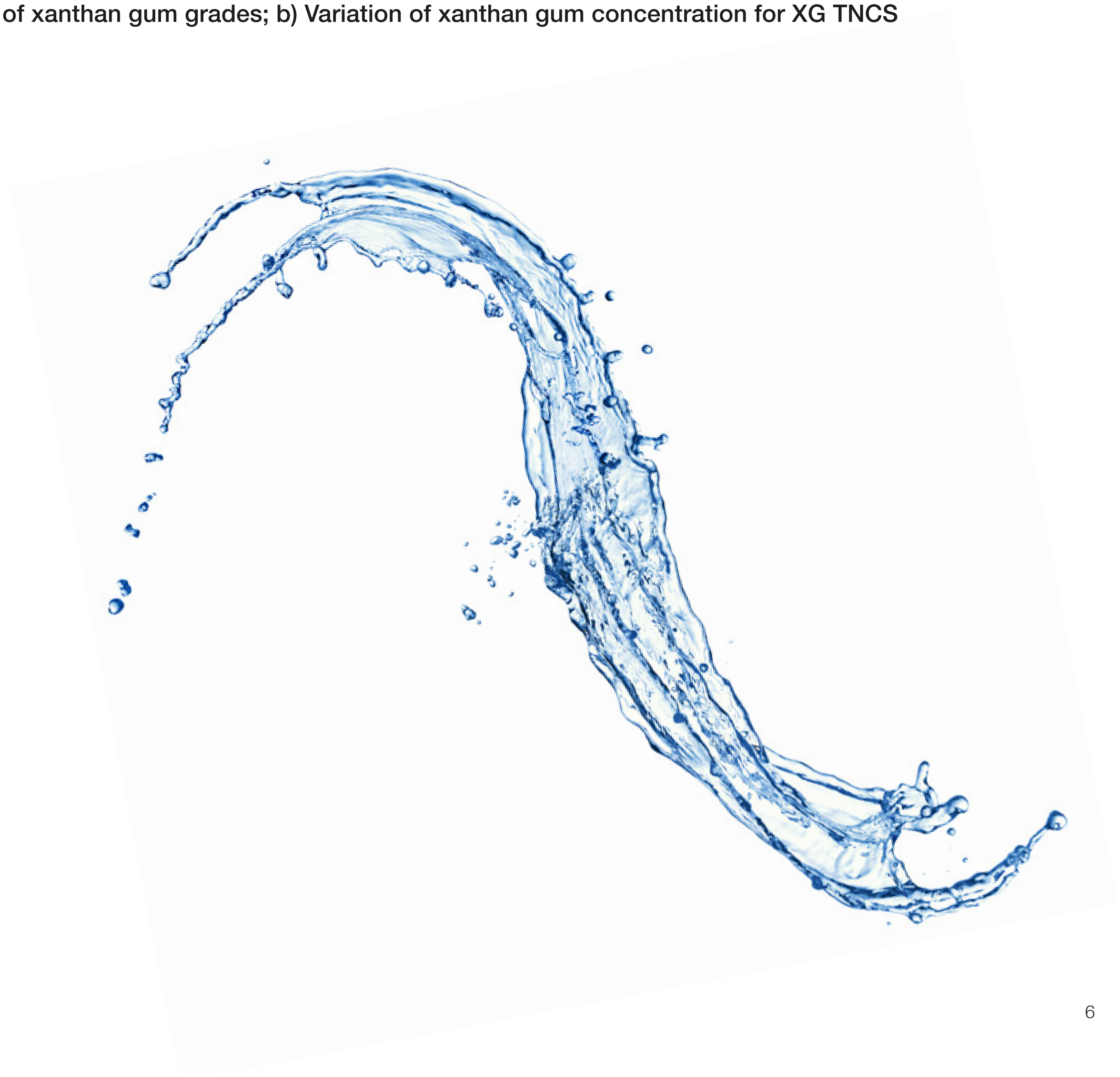


**Figure 2: Comparison of foam decay for xanthan gum in combination with 10% SLS (pH 7):
a) Variation of xanthan gum grades; b) Variation of xanthan gum concentration for XG TNCS**



The second part of the investigation into foam properties examined whether the test results could be transferred to a different surfactant. In addition to the traditional surfactant SLS, the foam properties of a biosurfactant, sophorolipid, combined with xanthan gum are shown in figure 3. In general, the foam formation for the sophorolipid alone was much slower than for SLS. Thirty foaming cycles were needed to reach the maximum foam volume of 1040 mL. As with SLS, the addition of xanthan gum resulted in a smaller volume of foam. However, probably due to the slower foam formation, the solution containing xanthan gum still eventually reached a foam volume of 900 ml, comparable to that with SLS.

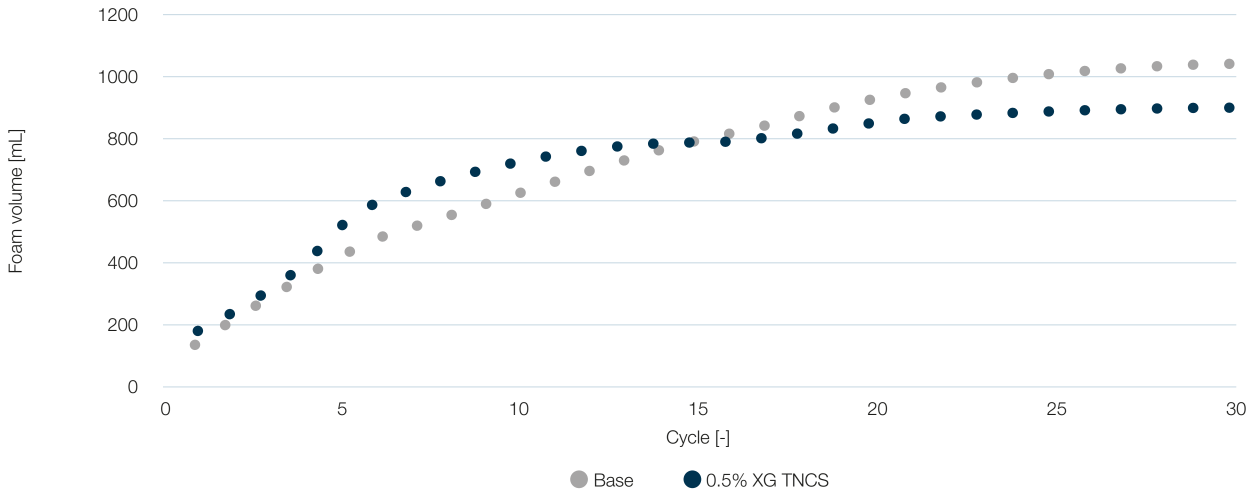


Figure 3: Foam formation for xanthan gum TNCS (10% sophorolipid, pH 7)

The addition of xanthan gum once more resulted in enhanced foam stability, as shown in figure 4. The foam volume for sophorolipid thickened with 0.5% xanthan gum TNCS was almost stable over five minutes. In the absence of xanthan gum, the sophorolipid foam volume decreased immediately.

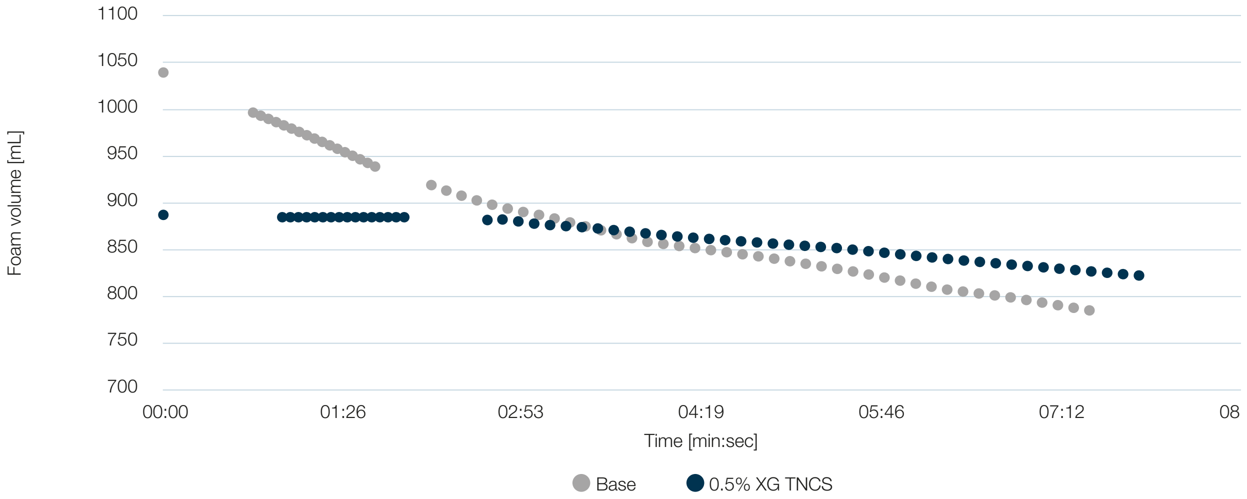


Figure 4: Foam formation for xanthan gum TNCS (10% sophorolipid, pH 7)

Foam structure

Analysing the foam structure presented certain challenges, and compromises were made in the choice of parameters – in particular with regard to exposure time – in order to ensure comparability. It should be noted that the images for the foam analysis were not optimised for the detection of the smallest bubbles in the foam. Figure 5 shows the number of foam bubbles and the average area of the bubbles. In the absence of xanthan gum, the average size of the countable bubbles was greater. Consequently, the foam produced was coarser. During the experiment it could be observed that at the beginning of foam decay, a small number of foam bubbles near the surface was visible. After the foam decay, many large foam bubbles were visible. During the process of foam decay drainage occurred, resulting in a coalescence and Ostwald ripening of the foam bubbles.[3]

When the xanthan gum concentration was increased the number of foam bubbles and their average size decreased. This resulted in the formation of very small, countable foam bubbles. It can therefore be concluded that the foam bubbles which are not countable are even smaller. The large gas volume also indicates a large number of small foam bubbles. This result thus demonstrates that an increase in xanthan gum concentration leads to a finer foam. Moreover, no difference between the grades was observed in the images from the experiment.

For the sophorolipid, the number of countable foam bubbles in the solution with xanthan gum was thus found to be greater than with the surfactant alone. Moreover, the size of the countable bubbles was significantly smaller. This confirms that the addition of xanthan gum resulted in the formation of a finer foam.

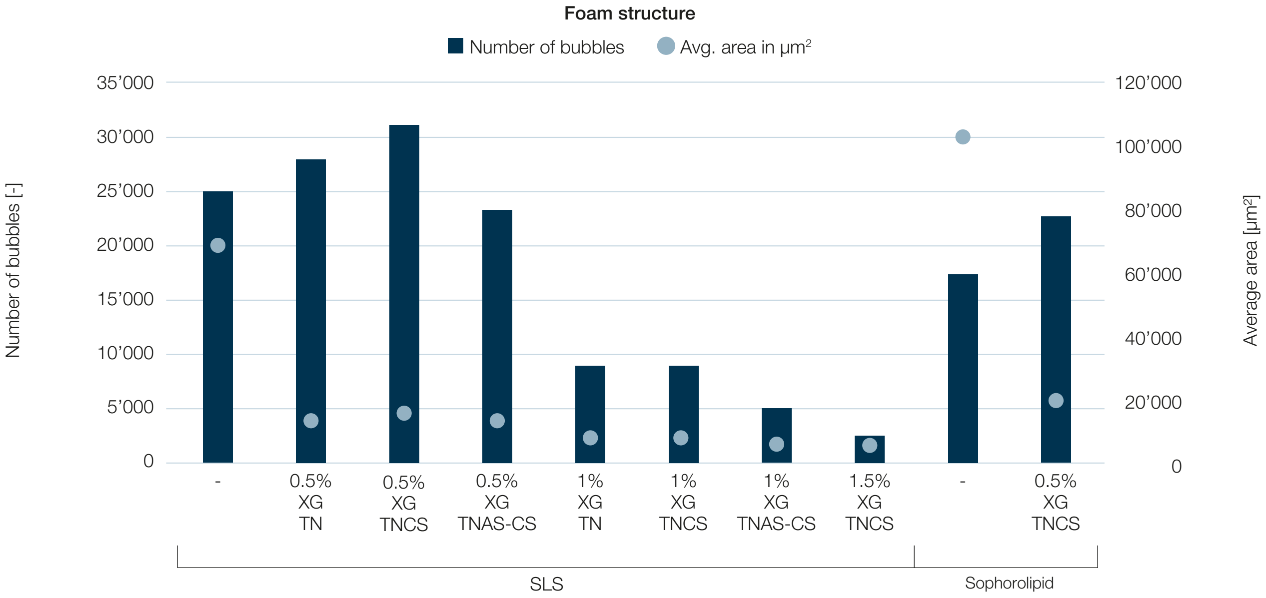


Figure 5: Comparison of foam structure (number of bubbles, average surface area) for different xanthan gum grades and concentrations (10% SLS/sophorolipid, pH 7)

Conclusion

Xanthan gum is an excellent stabiliser for household cleaning applications. In general, xanthan gum showed great compatibility with various traditional surfactants and also with a biosurfactant. Different grades of xanthan gum are recommended for different pH levels. For acidic pH, xanthan gum TNAS-CS would be the preferred choice. For neutral and alkaline pH, in general xanthan gum TN is recommended and for a clear solution xanthan gum TNCS. The addition of xanthan gum to a surfactant solution results in a much finer and more stable foam. A stable foam is achieved even with low concentrations of xanthan gum, but the higher the concentration of xanthan gum, the finer the foam bubbles. Consequently, the addition of xanthan gum represents an optimal approach for foam stabilisation in household cleaning applications. Due to its excellent compatibility, stabilising and foaming properties, Jungbunzlauer's xanthan gum is an excellent choice as a thickening and stabilising agent for household cleaning applications. It is a safe, odourless and bio-based product, and its natural origin is in line with the recent trend towards more sustainable household cleaning products.

References

[1] K. Henning, Wasch- und Reinigungsmittel: Inhaltstoffe, Eigenschaften, Formulierungen. Verlag für chemische Industrie, 2014

[2] S. Jentsch, Powerful Cleaning and a Pleasant Skin Feel with REWOFERM® Biosurfactants. Presentation (16 March 2023)

[3] J. Wang, A. Nguyen, S. Farrokhpay, A critical review of the growth, drainage and collapse of foams. Advances in Colloid and Interface Science 2016;228:55–70

About Jungbunzlauer

Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Thanks to continuous investment, state-of-the-art manufacturing processes and comprehensive quality management, we are able to provide outstanding product quality.

Our mission – From nature to ingredients® – commits us to protecting people and their environment.

The Authors

Amirah Bajawi – Application Technology, Jungbunzlauer Ladenburg GmbH
amirah.bajawi@jungbunzlauer.com

Dr. Katja von Nessen – Application Technology, Jungbunzlauer Ladenburg GmbH
katja.vonNessen@jungbunzlauer.com

Dr. Felix Weiher – Application Technology, Jungbunzlauer Ladenburg GmbH
felix.weiher@jungbunzlauer.com

Jens Stomps – Product Management, Jungbunzlauer Suisse AG
Jens.stomps@jungbunzlauer.com

Discover more on
www.jungbunzlauer.com

Headquarters **Jungbunzlauer Suisse AG**
4002 Basel · Switzerland · Phone +41 61 295 51 00 · headquarters@jungbunzlauer.com · www.jungbunzlauer.com