KRÜSS

Application Report

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Ross Miles Foam Analyzer – RMFA

Benchmarking the foaming properties of a new, mild surfactant formulation according to ASTM D 1173-07

Ross Miles Foam Analysis of Polyaldo™ 10-1-CC compared to PEG-80 Sorbitan Laurate and Decyl Glucoside Surfactants

The foaming properties of a recently developed, non-ionic and mild surfactant, Polyaldo™ 10-1-CC, were investigated and compared to two standard surfactants used in personal care products. In order to facilitate also a proper comparability with possible other surfactant systems the study was performed as a benchmark test following the well-established ASTM D 1173-07 Ross-Miles standard for foam analysis. All experiments were done using the KRÜSS Ross Miles Foam Analyzer – RMFA, the first instrument which facilities an automatic analysis according to ASTM D 1173-07 and thereby leaving no room for uncertainties in experimental conditions. In addition to foamability and foam stability as defined in the ASTM standard also the foam density was evaluated, which can correlate with sensory properties of the foam. Foam created from Polyaldo™ 10-1-CC shows properties at ambient conditions comparable to PEG-80, while outperforming this mild surfactant at an elevated temperature of 49 °C. This foam study is part of a more comprehensive study comparing three surfactants which will be published in the SOFW Journal [1].

Background

Surfactants are an essential ingredient of personal care formulations, as they facilitate the removal of sebum and soil from skin and hair. New regulations on chemical ingredients, as well as a demand for natural and mild alternatives push the development of new surfactant formulations.

One important criterion when developing surfactant formulations is their foaming behavior. Volume, stability, and the sensory properties of foam generated are aspects that can lead to the commercial success of a finished product and therefore need to be controlled and analyzed carefully [2].

Whereas recent instrumentation for foam analysis facilitates a large variety of well controlled foam-up methods, sophisticated scientific analysis, and result parameters [3-5], foam studies following the ASTM D1173-07 [6], which is based on more than 70 years of publication [7], are still of great support due to the following two reasons:

Firstly, all foam-up parameters are intrinsically fixed by the instrumentation, leaving no room for variation in experimental conditions and, therefore, establishing this technique as the first choice to benchmark new formulations.

Secondly, the Ross-Miles foam-up method easily facilitates obtaining information about both foamability as well as foam stability for highly concentrated surfactant solutions (> 5-fold critical micelle concentration). The latter reason, in particular, might not be serviced by some of the other foam-up methods as e.g. sparging with gas.

The combination of both points above also highlights why automatic analysis according to ASTM D 1173-07 with the Ross Miles Foam Analyzer – RMFA is an excellent choice for quality control of foaming properties for a large range of surfactant systems and concentrations.

Experimental section

In this study, the foamability, foam stability and foam density of a newly developed, extra mild non-ionic surfactant, Polyaldo™ 10-1-CC Polyglyceryl Ester was tested according to ASTM D 1173-07, using the Ross Miles Foam Analyzer – RMFA (fig. 1, b). To provide a frame of reference when evaluating Polyaldo™ 10-1-CC polyglyceryl ester, two market standard surfactants were included in the study. PEG-80 sorbitan laurate is well-known for mildness on skin. It is found in many cleansing products promoting gentleness such as baby care and products designed for sensitive skin. Decyl glucoside is an alkyl polyglucose (APG) surfactant derived from plant-based alcohols. It is a good skin cleanser and provides excellent flash foaming to cleaning formulations.

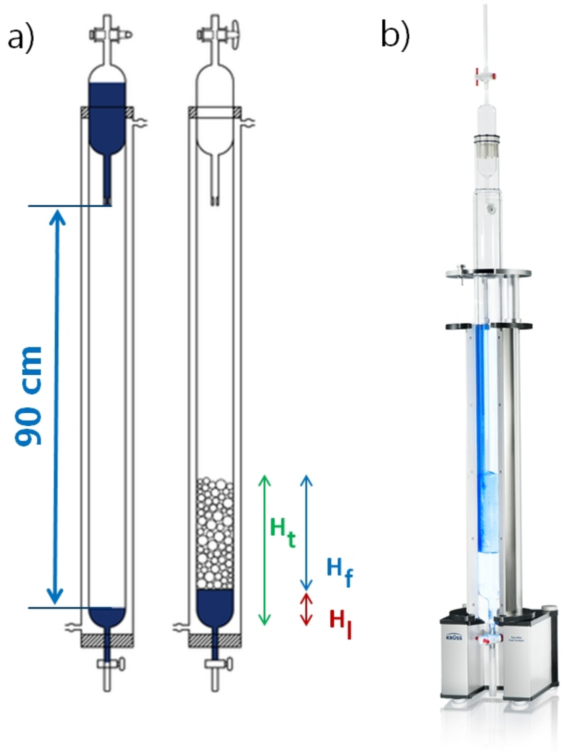

Fig. 1: a) Sketch of Ross-Miles foam analysis before (left) and after foam generating process (right). The colored arrows indicate total height H_t, liquid height H_l and net foam height H_f as detected by the instrument. b) Picture of the KRÜSS RMFA for automated foam analysis according to the Ross-Miles standard ASTM D1173-07

All experimental details and information about the automated height detection can be found in the ASTM standard [6] and elsewhere [3]. In the study, 250 mL of the surfactant solution are poured via an orifice with 2.9 mm diameter at a height of 90 cm into 50 mL of the same surfactant solutions. The instrument then detects the liquid/foam and foam/air boundaries via light transmission as a function of time, with up to 20 readings per second. In contrast to this high temporal resolution, the ASTM standard limits the result parameters to only the total height at its maximum value after foaming and one, three, and five minutes after the point of maximum total height. Experiments were performed at two different temperatures, 25 °C and 49 °C, according to the ASTM standard. For this, the liquid receiver and reservoir volumes were pre-heated to the desired temperature prior to filling the instrument. The double-walled glass column of the instrument was kept at the desired temperatures by means of an external circulator, guaranteeing constant liquid and foam temperatures throughout the whole experiment. For all three surfactants, dilutions of 0.5 g/L in distilled water were prepared and measured using the RMFA within 24 hours after sample preparation. Each sample was measured in triplicate.

Results and Discussion

Fig. 2 shows exemplary curves for the time dependence of the total height and the net foam height for all three surfactants (Decyl Glucoside (APG), Polyaldo™ 10-1-CC and PEG-80 Sorbitan Laurate) at 25 °C. These curves contain a variety of information, but for the sake of simplicity will focus here on the ASTM result parameters indicated also by the arrows in fig. 2.

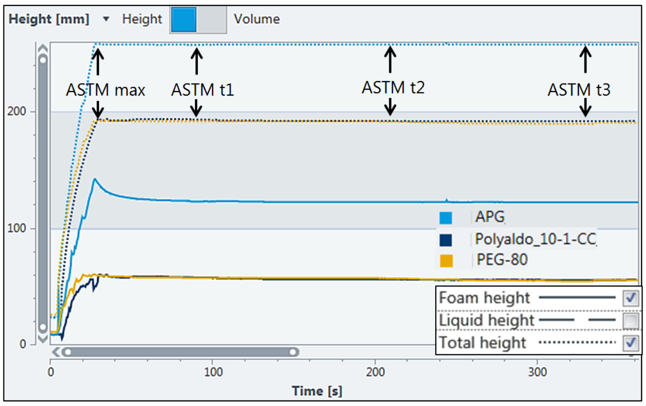

Fig. 2: Comparison of the net foam height and the total height as function of time for all three surfactants investigated. The arrows indicate the discrete time steps t_0, t_1, t_2, t_3 as defined in the ASTM standard. The values at those time steps are automatically read out by the KRÜSS ADVANCE Software.

Fig. 3 depicts a comparison of the ASTM standard result values for all three samples investigated at 25 °C and 49 °C. The error bars reflect the standard deviations as obtained from a minimum of three consecutive experiments. At both temperatures, APG shows a significantly higher initial foam volume and better foam stability than Polyaldo™ 10-1-CC polyglyceryl ester and PEG-80 sorbitan laurate.

Whereas at 25 °C, Polyaldo™ 10-1-CC polyglyceryl ester exhibits a very similar foam behavior to PEG-80 sorbitan laurate, at 49 °C it clearly outperforms the latter in terms of both initial foam height and foam stability. APG and Polyaldo™ 10-1-CC polyglyceryl ester show an increase in initial foam height with temperature. This can be intuitively understood considering increased surfactant mobility and changes in surface tension and viscosity. However, PEG-80 sorbitan laurate shows less foaming performance with rising temperature. This is due to the well-known behavior of Polysorbate 80 to undergo hydrolysis in aqueous media at elevated temperature. [8]

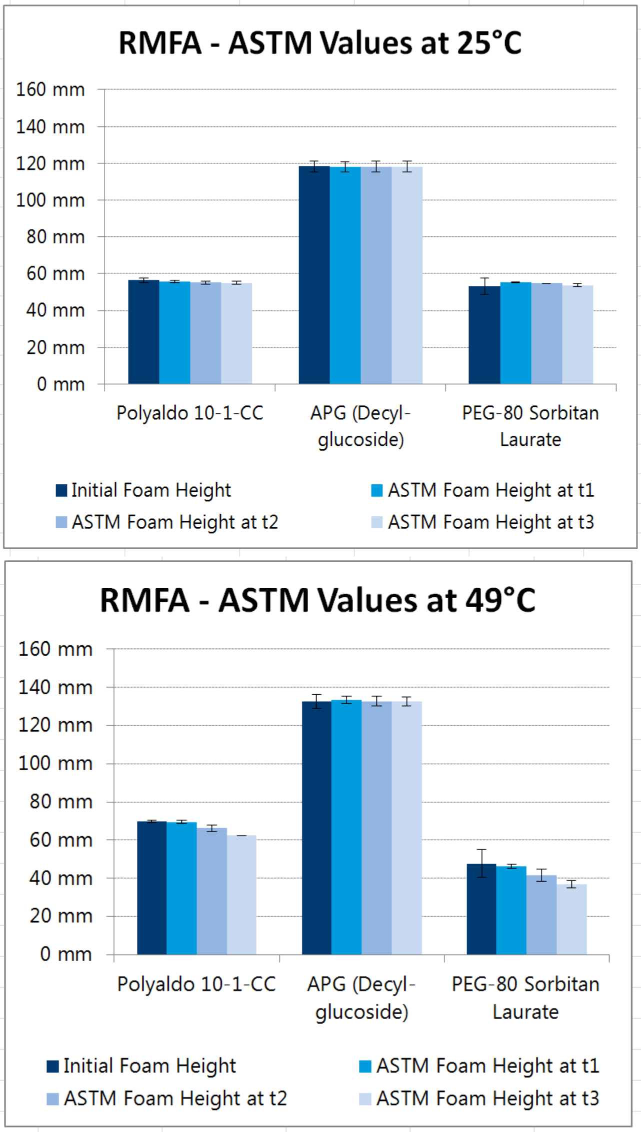

Fig.3: Comparison of ASTM standard result parameters for three samples investigated at 25 °C (top) and 49 °C (bottom)

The measurement of the liquid height versus time provides information about the initial foam density (i.e. wetness) and its drainage behavior. Both are valuable pieces of information going beyond the scope of the ASTM standard result parameters. Next to the foam volume, the initial foam density and its time dependence are important parameters describing the wetness of the foam. The foam density is defined as the ratio of the maximum liquid volume stored in the foam to the net foam volume. The foam density can affect the foam stability, but it is also considered to be – among other factors – related to the sensory properties of the foam. Fig. 4 shows a comparison of the initial maximum foam densities.

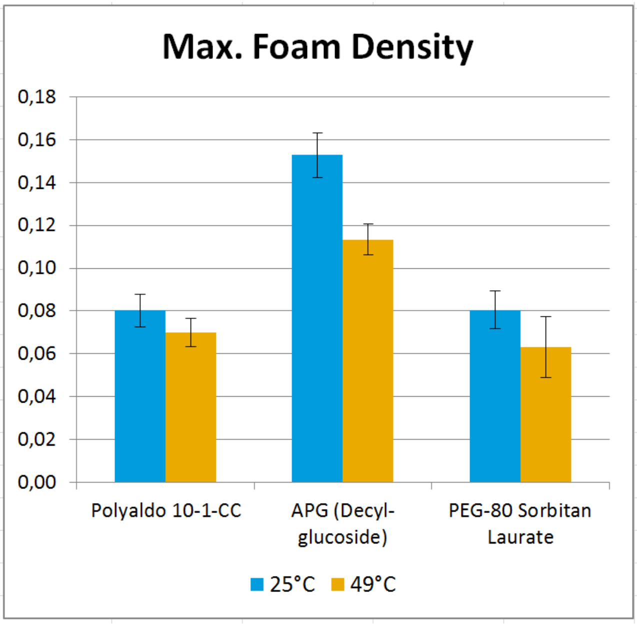

Fig. 4: Comparison of the maximum foam density of all three surfactants investigated at 25°C and 49°C

Whereas at 25 °C, APG can store about two times more liquid in the foam, at 49 °C, the foam density (i.e. wetness) of APG exceeds that of Polyaldo™ 10-1-CC polyglyceryl ester and PEG-80 sorbitan laurate by only about 50%. Again, compared to PEG-80 sorbitan laurate, Polyaldo™ 10-1-CC polyglyceryl ester shows a comparable foam density at 25 °C but a significantly higher one at 49 °C.

Summary

To summarize, compared to APG, Polyaldo™ 10-1-CC polyglyceryl ester shows minor foaming properties in terms of initial foam height, foam stability and wetness, but is clearly compatible with PEG-80 sorbitan laurate at 25 °C and even outperforms it at elevated temperatures.

The recently launched KRÜSS RMFA facilitated this comparative study on foaming properties with the highest reproducibility, thereby resulting in minimum error bars. This, in combination with the ASTM D1173-07 (which is implemented in the instrument and software), will guarantee good lab-to-lab reproducibility and allow for further benchmark studies based on the data presented here.

This Ross-Miles foam study is part of a more comprehensive study comparing also the basic properties (e.g. color, viscosity, pH value etc.), in-vitro epidermal and epiocular irritation, surface tension, critical micelle concentration, and foam structure (i.e. bubble size distribution) of the three surfactants investigated to be published in the SOFW Journal [1].

Literature

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