Using FOAMSCAN™ to characterize foams produced by an external device

INTRODUCTION

Hands disinfection particularly arose over the covid19 sanitary crisis. Because they are convenient in use and cost-effective, foam dispensers are commonly used to deliver hands-disinfectant in the form of foam. The foam is generated by pressing the actuator of the dispenser. Then a volume of air is injected into the disinfectant solution while it is pumped, which produces the foam. For hands- disinfectant manufacturers, it is of the utmost importance to control the volume of foam delivered by the dispenser and the properties of the foam, such as stability or texture, when it is mashed in the hands.

FOAMSCAN™ foam analyzer enables to characterize the foam properties by measuring 2 key parameters: liquid fraction and foam structure (size and distribution of the bubbles).

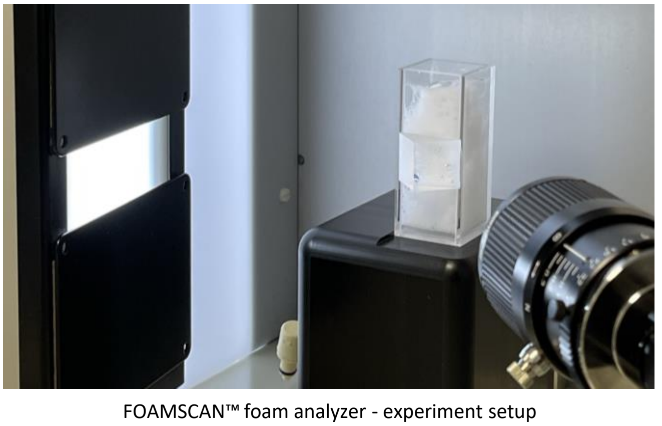
METHODOLOGY

FOAMSCAN™ foam analyzer is used to study 3 foaming solutions A, B and C produced by 3 foam dispensers. Foam A is made from an hydroalcoholic solution, Foams B and C are made from water-based solutions.

FOAMSCAN™ software measures foam volume and foam stability over the time whereas the structure of the foam (bubble size and distribution) as well as foam liquid fraction is analyzed using the CSA software.

Foams A, B, C are directly produced from the dispensers into a Quartz glass cuvette (ID 25*25*65 mm) equipped with prisms. Measurement starts right after filling the cuvette with foam and lasts for 600 sec.

Experiments are performed 3 times to ensure measurement reproducibility.



FOAMSCAN™ foam analyzer - experiment setup

FOAM PROPERTIES ANALYSIS

After foam formation, the images of the foam structure show that Foam A exhibits homogeneous bubbles in size while foams B and C are more heterogeneous in bubbles size (Fig.1). The large field of view (10 mm²) allows to visualize several hundreds of bubbles (more than 700 for foam A at start) and ensure a good statistical representation of the bubble's population.

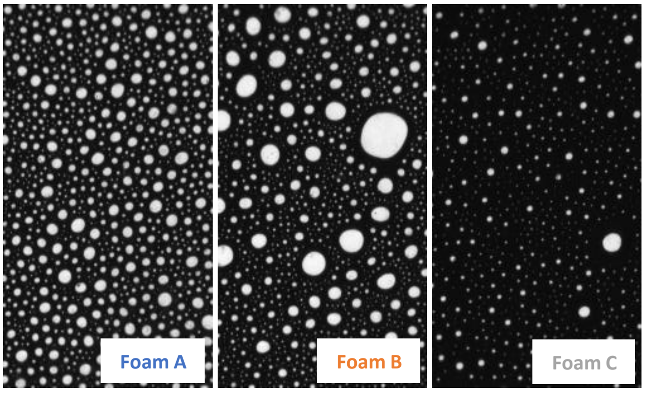


Fig. 1 Foam bubbles images captured by the CSA camera just after foam production, bar = 2.3 mm

The statistical analysis of the foam structure over time shows that although the 3 foams are similar in bubble's size, just after being formed; they are ageing differently. Indeed, at t=10 sec., average mean radius is 35 µm, 45 µm and 55 µm for the foam C, B and A respectively (Fig.2). Foam C bubbles size increases very quickly from 35 µm to large bubbles up to 0.5 mm mean radius; while foams A and B bubbles' size growth is much lower and slowly than foam C. The increase in bubble size is explained by 2 simultaneous foam aging mechanisms which are ripening and coalescence [Boos 2013].

The analysis of the polydispersity index from T=0 to t=100 sec. (Fig.2) indicates there are more coalescence events in foam C while the stability of the polydispersity index for foams A and B suggests fewer coalescence events and more ripening i. e. gas transfer from the smallest to the largest bubbles.

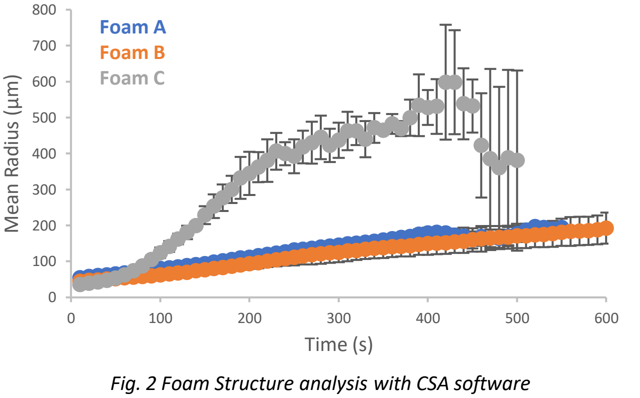
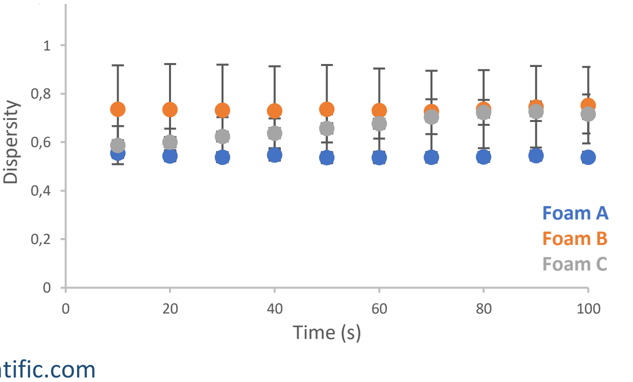


Fig. 2 Foam Structure analysis with CSA software



Measuring the volume of foam over time allows to evaluate the overall stability of a foam. Expected Foam stability obviously varies from one application to another. In the case of hands disinfectant produced by a foam dispenser: the foam needs to remain stable the time for the person to spread it all over the hands.

Foam volume over time (Fig.3) shows that foam B is the most stable foam. Its volume decreases very slowly over 600 sec., a much longer time than required by application. The volume of foam C decreases rapidly and its half-life time $t_{1/2}$ = 220 s is the shortest. Foam A shows a middle stability two times longer than Foam C ($t_{1/2}$ = 440 s).

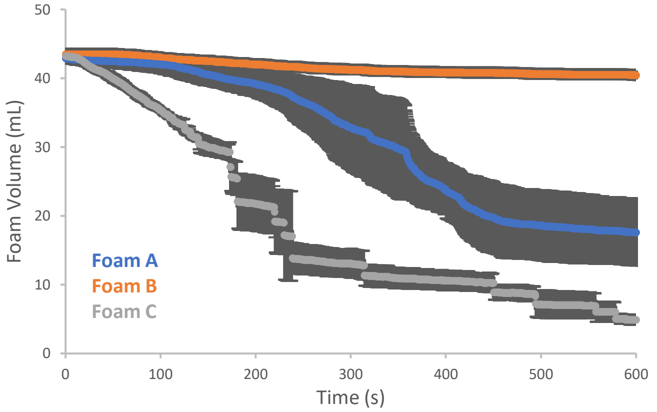


Fig. 3 Foam volume over time, n=3

Drainage and coalescence are the two main dissipation mechanisms that occur. Whereas coalescence is hard to quantify, drainage can be characterized by the liquid fraction measurement.

The Foam liquid fraction represents the amount of liquid in the foam. This liquid fraction can be calculated by image analysis using the CSA software [Forel 2016]. Monitoring this liquid fraction over time indicates how the drainage plays a role in the decay of the foam.

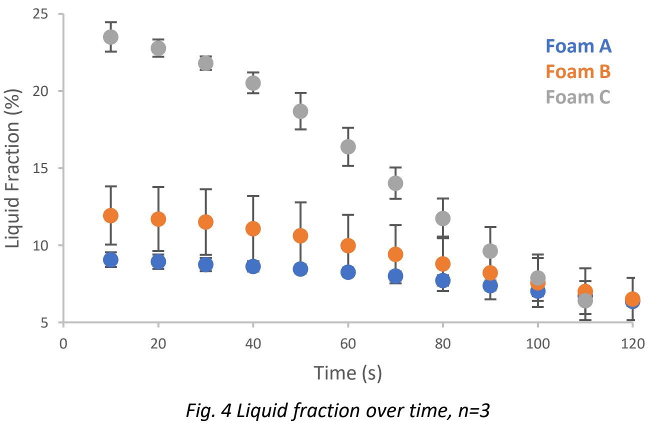


Fig. 4 Liquid fraction over time, n=3

At start, foams A, B, and C show initial liquid fractions of 9%, 12%, and 23%, respectively (Fig. 4) . Foam C is the wettest foam. Over the time, drainage is faster for foam C than for foams A and B. When the foams are spread on the skin, the sensation felt by the person will be different depending on whether the foam is wet or not and whether the drainage is fast or slow. It is interesting to relate this quantitative data with the results of qualitative consumer research.

In addition, the liquid fraction is involved in the yield stress of the foam. After using the 3 hands-disinfectant foam dispensers, we observed two different behaviors when the foam is spread on the hands. Foams A and B remain quite firm while foam C falls apart and flows. Foam C flows on the skin because of its too high liquid fraction. It can not sustain its own weight. Smaller bubbles size would be requested to bring this formulation a higher yield stress.

CONCLUSION

Foam properties depend not only on the formulation of the disinfectant solution but also on the foam dispenser used to produce the foam.

The foam analyzer FOAMSCAN™ can measure the properties of foams generated by any external device which makes it a powerful tool to optimize the cost-effectiveness of the final product:

- Improve the formulation of the foaming solution
- Choose the best process or device to generate the foam

References

Boos, J.; Drenckhan, W.; Stubenrauch, C., Protocol for studying aqueous foams stabilized by surfactant mixtures. *Journal of Surfactants and Detergents 2013, 16 (1), 1-12.*

Yazhgur, P.; Rio, E.; Rouyer, F.; Pigeonneau, F.; Salonen, A., Drainage in a rising foam. *Soft Matter 2016, 12 (3), 905-13.*

Volp, A. R.; Willenbacher, N., Shear modulus and yield stress of foams: contribution of interfacial elasticity. *Soft Matter 2021, 17 (14), 3937-3944.*

Forel, E.; Rio, E.; Schneider, M.; Beguin, S.; Weaire, D.; Hutzler, S.; Drenckhan, W., The surface tells it all: relationship between volume and surface fraction of liquid dispersions. *Soft matter 2016, 12 (38), 8025-8029.*