FOAMSCAN™ Advanced Characterization of Beer Foam Stability and Microstructure

KEY TAKEAWAYS

- Simultaneous measurement of foam stability, drainage and bubble microstructure.
- Identification of the physical mechanisms governing foam ageing.
- Complementary information to conventional EBC foam stability measurements.

INTRODUCTION

Why Beer Foam Matters?

Beer foam is a key quality attribute that strongly influences consumer perception[1,2]. A dense, stable foam enhances visual appeal, contributes to aroma retention and mouthfeel, and reflects the overall quality of the brewing process.

Foam performance results from a delicate balance between raw materials, brewing conditions, carbonation level and packaging. Even subtle changes in recipe composition or processing can significantly affect foam formation and persistence.

Routine quality control in breweries commonly relies on standardized methods developed by the European Brewing Convention (EBC), such as the NIBEM foam stability test. These methods provide a robust indicator of foam lifetime and are widely used to ensure production consistency.

However, foam collapse is a complex phenomenon involving several simultaneous physical processes, including liquid drainage, bubble coalescence and gas diffusion[1]. Measuring foam lifetime alone does not reveal the mechanisms responsible for foam destabilization.

FOAMSCAN™ complements conventional EBC measurements by providing a comprehensive characterization of foam ageing through the simultaneous monitoring of Foam volume evolution; Liquid drainage kinetics; Bubble size distribution; Bubble population dynamics. This multidimensional approach enables brewers to understand not only how long a foam remains stable, but also why it eventually collapses.

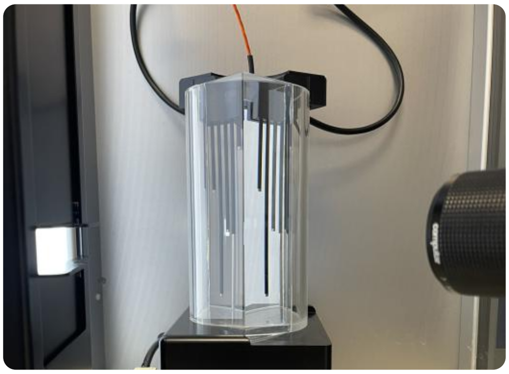

Fig1. FOAMSCAN™ configuration for foams generated externally and sampled by pouring

MEASUREMENT PRINCIPAL

The FOAMSCAN™ configuration used in this study is specifically designed for foams generated externally, such as beer foam, milk foams or surfactant foams (Fig1).

Immediately after pouring, the instrument simultaneously monitors several complementary parameters throughout the experiment.

Foam volume

Foam height is continuously determined by image analysis, allowing automatic calculation of foam volume and its evolution over time. The foam half-life (t½) is calculated as the time required for the maximum foam volume to decrease by 50%.

Liquid drainage

The amount of liquid retained within the foam is measured continuously by conductance. The resulting drainage curves quantify liquid loss from the foam and provide the liquid stability half-life.

Bubble microstructure

A right-angle prism integrated into the measurement column allows high-resolution imaging of the foam structure at a fixed position throughout the experiment.

Foam structure Images are processed using TECLIS BubbleStatistics™ software to determine:

- Bubble count;
- Bubble size and distribution;
- Local liquid fraction
- Polydispersity Index (PDI).

These parameters provide direct insight into bubble growth, coalescence and foam ageing mechanisms.

SAMPLES

Three commercially available beers were selected to illustrate the capabilities of the FOAMSCAN™.

- **Beer K:** Standard lager brewed with maize as an adjunct.
- **Beer K 0.0% :** Alcohol-free version of Beer K produced using dealcoholizing technology and adjusted with flavorings and carbon dioxide.
- **Beer L:** Abbey-style blond beer formulated with sugar and yeast, representative of a richer brewing recipe.

Beer K and Beer L were selected to compare the foam behavior of two conventional blond beers, while Beer K 0.0% was included to investigate the influence of alcohol-free formulation on foam formation and stability.

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EXPERIMENTAL PROTOCOL

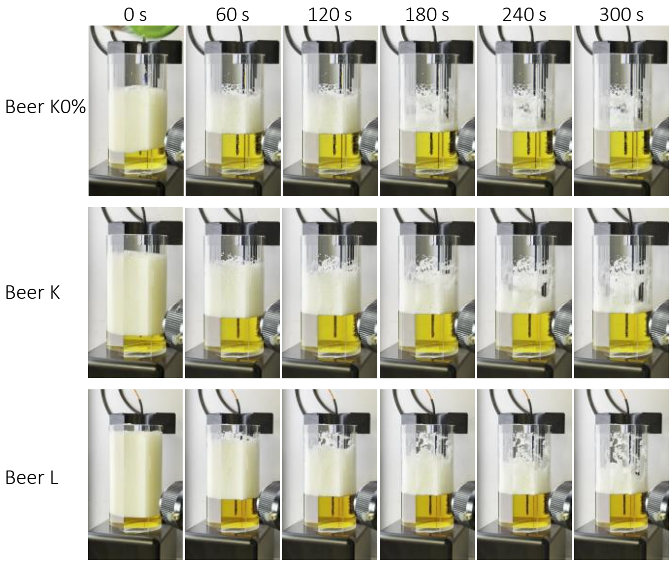
For each measurement:

- 180 mL of beer was poured into the measurement column from the bottle;
- data acquisition started immediately after pouring;
- foam structure images were acquired at a fixed observation height corresponding to approximately 200 mL liquid level;
- measurements were performed for 300 seconds;
- all experiments were carried out at room temperature
- each beer was analyzed in triplicate.

Prior to each experiment, the liquid conductance was calibrated for each beer sample to establish the relationship between liquid volume and electrical conductance. This procedure ensures accurate and reproducible determination of both drainage kinetics and foam liquid fraction.

RESULTS & DISCUSSION

1. Foamability and Foam Stability



Initial Foam Formation

Immediately after pouring, the three beers exhibited markedly different foam volumes (Fig2):

Beer L generated the largest foam head (475 mL), followed by Beer K (382 mL), whereas Beer K 0.0% produced a significantly smaller foam volume (258 mL). These differences illustrate the strong influence of beer formulation on foam generation during pouring.

Although Beer K 0.0% generated the smallest foam volume, it displayed the highest Foam Expansion (FE = 4.6), indicating that a relatively small amount of liquid produced a comparatively large foam volume.

This apparent contradiction is explained by the lower liquid content of the foam. Beer K 0.0% exhibited the lowest Foam Density (22%), meaning that its foam contained less liquid and a larger proportion of gas than the other beers. Such lightweight foams generally appear voluminous but possess thinner liquid films separating adjacent bubbles, making them intrinsically more fragile.

Conversely, Beer L produced the densest foam (28% liquid fraction), resulting in a more compact and mechanically robust foam structure immediately after pouring[2].

Foam Stability

The evolution of foam volume clearly differentiates the stability of the three formulations (Fig2): Beer L exhibited the longest foam half-life (120 s), followed by Beer K (107 s) and Beer K 0.0% (91 s).

Although all three foams progressively collapsed during the five-minute experiment, Beer L consistently maintained a larger foam volume throughout the measurement, indicating a greater resistance to structural degradation.

The shorter half-life observed for Beer K 0.0% demonstrates that the alcohol-free formulation produces a foam that destabilizes more rapidly. The reduced foam stability observed for Beer K 0.0% is most likely related to formulation changes associated with the production of alcohol-free beer rather than to the absence of ethanol alone.

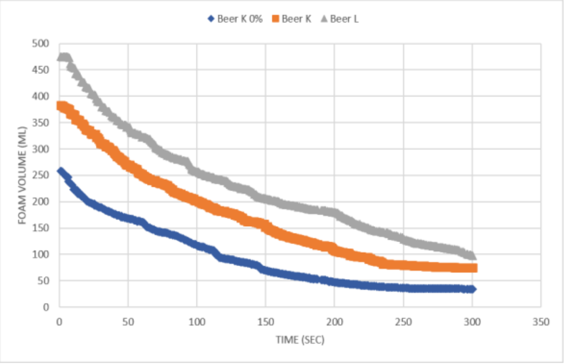


Fig2. Evolution of foam volume over 300 s.

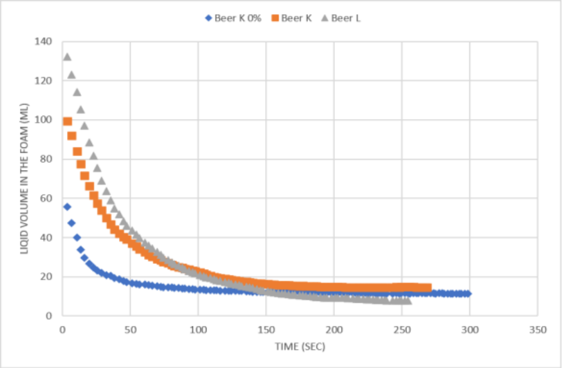


Fig3. Evolution of the liquid volume retained within the foam

Drainage Kinetics

The drainage curves provide valuable insight into the mechanisms responsible for foam destabilization (Fig3).

Immediately after pouring, all samples exhibited rapid liquid drainage caused by gravity. During this stage, liquid flows through the interconnected Plateau borders separating the bubbles, progressively reducing the liquid fraction of the foam.

After approximately one minute, drainage slowed considerably as capillary forces increasingly opposed gravity. This transition is characteristic of liquid foams and corresponds to the progressive drying of the bubble network.

Beer K 0.0% displayed the fastest drainage kinetics, with a liquid stability half-life of only 12 seconds, compared with approximately 30 seconds for Beer K and Beer L.

The rapid loss of liquid explains the early weakening of the alcohol-free foam. As the liquid films become thinner, bubbles are more prone to rupture or merge, accelerating foam collapse.

Interestingly, Beer L combines relatively rapid initial drainage with the highest foam stability[3]. This observation demonstrates that drainage alone does not determine foam lifetime[3]. Once the foam has partially drained, its subsequent stability largely depends on the mechanical strength of the bubble network and its resistance to bubble coalescence.

Summary of Foam Performance

AFTER POURING	BeerK 0%	BeerK	BeerL
Initial liquid volume (mL)	180,00	180,00	180,00
Final foam volume (mL)	**258,00**	**382,00**	**475,00**
Final liquid volume (mL)	124,40	80,70	47,80
Final liquid volume in the foam (mL)	55,60	99,30	132,20
FOAMABILITY			
Foam Expansion FE	**4,60**	**3,80**	**3,60**
Foam Maximum Density MD	22%	26%	28%
FOAM STABILITY			
Foam volume t1/2 (s)	**91,00**	**107,00**	**120,00**
Liquid Stability t1/2 (s)	12,00	30,00	28,00

Fig4. Summary of the main foam parameters measured using FOAMSCAN™

Several conclusions can be drawn from these measurements.

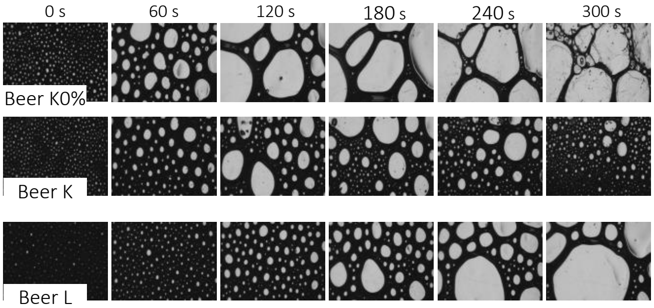
- Beer L produces the largest, densest and most persistent foam, indicating the highest overall foam quality.
- Beer K exhibits intermediate behavior for both foam generation and stability.
- Beer K 0.0% forms a lighter foam with faster drainage and a shorter lifetime, suggesting that the alcohol-free formulation significantly modifies the physical architecture of the foam.

While conventional EBC methods would primarily report differences in foam persistence, the FOAMSCAN™ measurements reveal the physical origins of these differences by separating foam formation, drainage behavior and structural evolution.

2. Foam Microstructure Analysis

Foam stability is governed not only by the persistence of the foam head but also by the evolution of its internal microstructure. Bubble population, liquid fraction and bubble size continuously change during foam ageing as drainage, gas diffusion and bubble coalescence progressively weaken the foam network.

Unlike conventional foam stability measurements, FOAMSCAN™ combines optical image analysis with liquid fraction monitoring to identify the physical mechanisms responsible for foam collapse.



Bubble Population Dynamics

The number of bubbles provides valuable information about the structural evolution of the foam (Fig5). A stable bubble population indicates that bubbles largely retain their integrity throughout the experiment, whereas a rapid decrease generally reflects extensive coalescence events[1], during which neighboring bubbles merge to form larger ones.

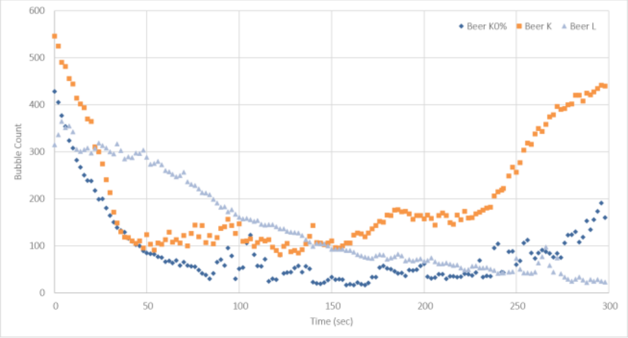


Fig5. Evolution of bubble count during foam ageing.

All three beers exhibited an initial decrease in bubble count during the first minute. This behavior is expected as the foam rapidly reorganizes immediately after pouring while liquid drainage begins.

Beyond this initial stage, distinct behaviors emerged.

Beer L maintained the most stable bubble population throughout the experiment. The relatively small decrease in bubble count suggests limited coalescence and good preservation of the foam network. This observation is fully consistent with the longest foam half-life measured previously.

Beer K showed an intermediate behavior, with a gradual reduction in bubble population, indicating progressive but controlled structural evolution.

Beer K 0.0% exhibited the most pronounced decrease in bubble count. This rapid loss of bubbles indicates that coalescence occurs early during foam ageing, accelerating structural degradation and ultimately leading to premature foam collapse.

The bubble count therefore provides direct evidence that the superior stability of Beer L results not only from slower foam collapse but also from better preservation of its microscopic structure.

Local Liquid Fraction

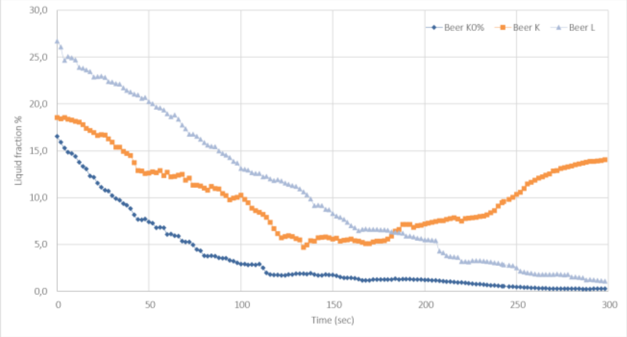


Fig6. Evolution of the local liquid fraction

The local liquid fraction reflects the amount of liquid surrounding the bubbles at the observation height (Fig6). Since liquid drainage is one of the primary mechanisms driving foam destabilization, monitoring this parameter provides direct insight into foam drying.

For all samples, the liquid fraction decreased rapidly during approximately the first 150 seconds, confirming that drainage dominates the early stages of foam ageing.

Beer K 0.0% exhibited the fastest decrease, indicating rapid depletion of liquid within the Plateau borders. As the liquid films separating adjacent bubbles become thinner, their mechanical resistance decreases, making rupture and coalescence increasingly likely.

Beer K and Beer L displayed slower drainage kinetics, allowing the foam structure to remain hydrated for a longer period. This prolonged liquid retention contributes to maintaining stronger bubble walls and delays structural failure.

After approximately three minutes, all foams reached a very low liquid fraction. At this stage, the bubble network had become essentially dry, leaving only thin liquid films between adjacent bubbles. Foam stability was then governed primarily by bubble coalescence rather than by drainage.

These observations demonstrate that drainage controls the early evolution of the foam, whereas microstructural stability becomes the dominant factor during the final stages of foam ageing.

Bubble Size Distribution

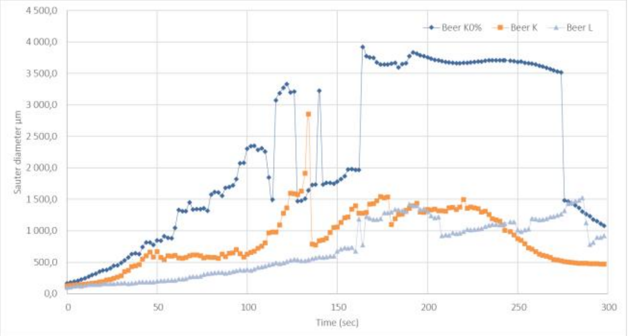


Fig7. Sauter Mean Diameter (D32) versus time

The Sauter Mean Diameter (D32) represents the diameter of a sphere having the same volume-to-surface ratio as the measured bubble population (Fig7). It is particularly sensitive to bubble growth and coalescence.

For all beers, D32 increased progressively during the experiment, reflecting the natural ageing of the foam. However, the magnitude of this increase differed substantially between formulations.

Beer L maintained the smallest increase in average bubble diameter throughout most of the experiment. This indicates that the original fine bubble texture was largely preserved despite ongoing drainage.

Beer K showed moderate bubble growth consistent with gradual foam ageing.

Beer K 0.0% exhibited the largest increase in D32, particularly after approximately one minute. Such rapid bubble growth is characteristic of extensive bubble coalescence and confirms the rapid degradation already observed through foam volume and bubble count measurements.

Maintaining small bubbles is essential for producing high-quality beer foam because fine bubbles create a larger interfacial area, slow liquid drainage and improve the mechanical rigidity of the foam network[2].

The D32 results therefore confirm that Beer L preserves its fine foam texture for significantly longer than the other formulations.

Bubble Size Homogeneity

The Polydispersity Index (PDI) describes the width of the bubble size distribution.

A low PDI indicates a homogeneous foam composed of bubbles of similar size, whereas an increasing PDI reveals the coexistence of very small and very large bubbles, a characteristic signature of bubble coalescence and heterogeneous foam ageing.

Beer L exhibited the lowest and most stable PDI throughout the experiment, indicating that the foam retained a relatively uniform bubble population despite progressive drainage.

Beer K displayed moderate fluctuations while maintaining an acceptable level of structural homogeneity.

In contrast, Beer K 0.0% showed a marked increase in PDI after approximately 90 seconds. This broadening of the size distribution reflects the simultaneous disappearance of small bubbles and formation of larger ones through repeated coalescence events.

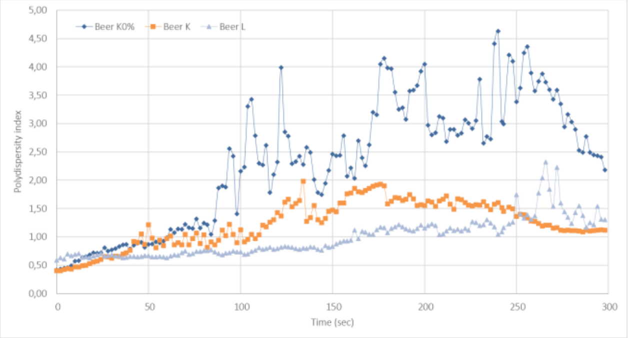


Fig8. Evolution of the bubble size polydispersity index (PDI)

The combined analysis of D32 and PDI clearly demonstrates that the alcohol-free formulation undergoes faster structural reorganization, explaining its reduced foam stability.

Linking Microstructure to Foam Stability

The combination of foam volume, drainage and microstructural measurements provides a comprehensive understanding of foam ageing.

Although Beer L experiences substantial liquid drainage during the early stages, its bubble network remains remarkably stable. Bubble count, D32 and PDI all indicate limited coalescence, allowing the foam to maintain its integrity over time.

Conversely, Beer K 0.0% combines rapid drainage with extensive bubble coalescence, leading to accelerated structural degradation and early foam collapse.

These results demonstrate that foam lifetime cannot be interpreted solely from macroscopic observations. Similar drainage profiles may ultimately produce different foam stabilities depending on the resistance of the bubble network to structural rearrangement.

By simultaneously monitoring these complementary parameters, FOAMSCAN™ provides mechanistic information that cannot be obtained from conventional foam stability measurements alone.

CONCLUSION

Looking Beyond Foam Lifetime

Foam stability is traditionally assessed using standardized methods such as the EBC NIBEM test, which provides a reliable and reproducible measurement of foam persistence for routine quality control. However, foam collapse results from several interacting physical phenomena (including liquid drainage, bubble coalescence and structural reorganization) that cannot be distinguished using a single foam lifetime measurement[1].

This study demonstrates how FOAMSCAN™ complements conventional foam stability testing by combining foam volume, drainage monitoring and quantitative image analysis to identify the mechanisms governing foam ageing.

Although the three beers exhibited comparable macroscopic foam behaviour, their ageing mechanisms differed significantly. Beer L maintained the most stable bubble network despite substantial drainage, whereas the alcohol-free Beer K 0.0% underwent rapid drainage, accelerated bubble growth and extensive coalescence, resulting in the shortest foam lifetime. Beer K displayed intermediate behaviour.

By distinguishing the respective contributions of drainage and microstructural evolution, FOAMSCAN™ provides information that extends beyond conventional foam stability measurements. This mechanistic understanding supports formulation development, ingredient selection, process optimization and troubleshooting of foam-related quality issues.

Rather than replacing standardized EBC methods, FOAMSCAN™ complements them by explaining why beers with similar foam lifetimes may exhibit very different ageing mechanisms, providing brewers with deeper insight into foam behaviour and more effective tools for product development.

References

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