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DYNAMIC FERMENTATION: OPTIMIZING YEAST VIABILITY AND SYSTEM PERFORMANCE

(Alyce Hartvigsen/Alfa Laval)

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INTRODUCTION

Modern beer fermentation processes can present particular challenges for yeast viability. High Gravity Brewing (HGB) exposes the yeast to high ethanol concentrations and premature yeast settling. The use of large tanks with high aspect ratios subjects the yeast to high hydrostatic pressure and concentrations of dissolved CO_2. Yeast packing in the cone limits access to nutrients and can result in hot spot formation. All of the these conditons can contribute to yeast stress, decreased viability and formation of stress by-products such as acetaldehyde and SO_2.

Dynamic fermentation using rotary jet mixing has been demonstrated to effectively address the above issues by maintaining the yeast in homogenous suspension during the fermentation, providing improved heat transfer and uniform temperatures throughout the fermenter, and reducing dissolved CO_2 concentrations in the wort. As a result, the use of rotary jet mixing particularly for HGB fermentations has resulted in improved yeast viability, more consistent fermentations, time savings in fermentation and improved beer quality.

CONVENTIONAL FERMENTATION

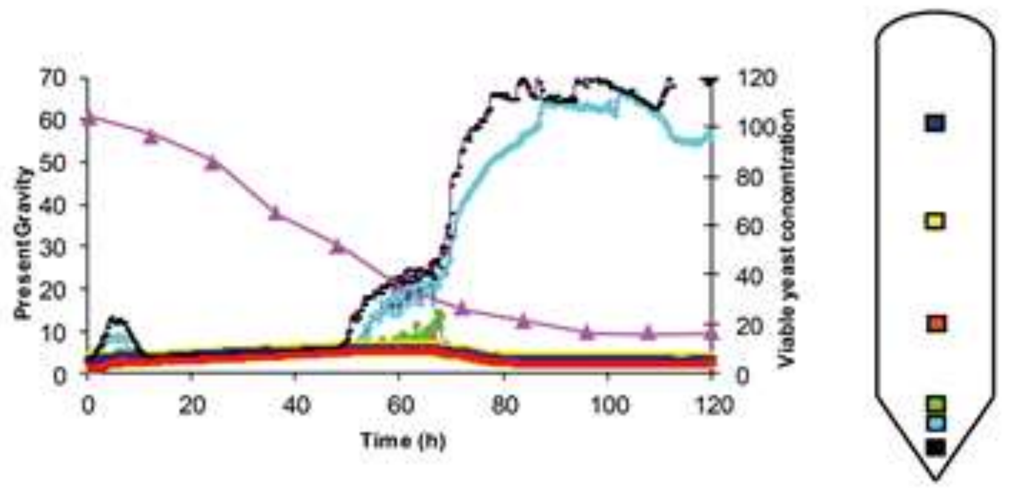

Figure 1. Actual measurements of viable yeast concentrations throughout a CCT during the course of a conventional (unmixed) fermentation, clearly illustrating the premature settling of yeast in the cone of the tank.

DYNAMIC FERMENTATION SYSTEM

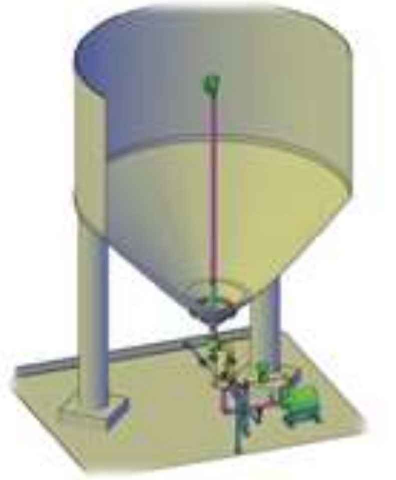

Figure 2. Dynamic fermentation system utilizing rotary jet mixing with bottom-entry installation. Liquid is circulated from the tank outlet through a centrifugal pump to the mixer, which distributes the incoming liquid to all areas of the tank. The system is installed through the tank swing cone and bottom outlet flange, minimizing necessary tank modification.

EFFECTS OF DYNAMIC FERMENTATION

Mixing during fermentation provides benefits to the process and yeast viability through three primary mechanisms:

1. Maintenance of yeast in homogenous suspension during primary fermentation
2. Uniform temperature distribution in the tank and improved heat transfer to the tank jackets through forced convection
3. Nucleation of super-saturated CO_2 (reduction of dissolved CO_2 levels in the wort and allowing gradual CO_2 release, minimizing foaming)

It is recommended to begin mixing as early in the process as possible, typically during the filling of the tank. Early mixing ensures that the yeast is well distributed from the start and enables the earlier onset of fermentation, as evidenced by increased CO_2 production in the early stages.

The effects of mixing on the fermentation process, yeast health and beer quality parameters are summarized below:

- Reduced fermentation process time, typically 10-20% but up to 40% for HGB and VHGB
- Potential increase in fermentation capacity corresponding to reduced tank residence time.
- Reduction in acetaldehyde off-flavor concentration, typically 50%
- Reduction in sulfur dioxide off-flavor concentration, typically 15-30%
- Increase in %RDF and final alcohol content, particularly for HGB and VHGB
- Decrease in residual extract (higher yield)
- Increase in concentration of certain volatiles, particularly iso-amyl acetate
- Foam duration similar or improved
- Flavor true to type
- Flavor stability same or improved
- Yeast viability same or improved

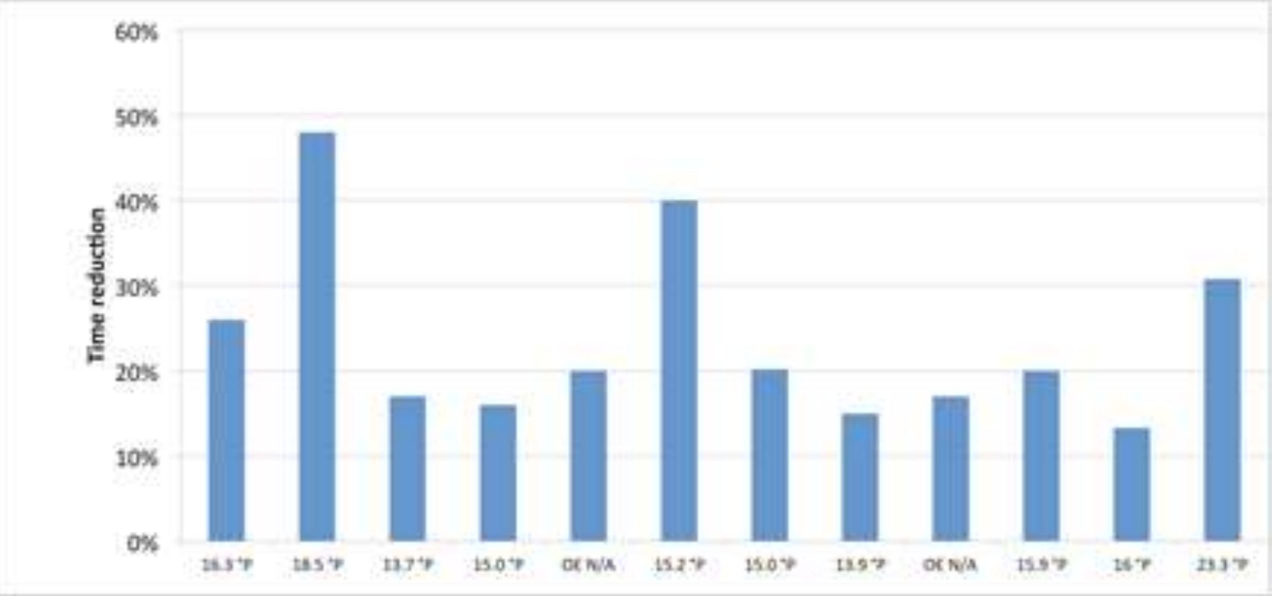

Figure 3. Process time reductions for dynamic fermentation. Results for 11 different breweries and 12 different brands, including OE for each case, when known.

HEAT TRANSFER AND COOLING OPTIMIZATION

In addition to these benefits during primary fermentation, the forced convection from the rotary jet mixer provides a considerable improvement in the efficiency of heat transfer in the tank. This benefit is observed in more uniform temperature distribution throughout the tank, and especially during the chill-back of the beer. Operation of the mixer during chill-back results in a significant time savings in cooling, thereby reducing total tank occupancy time and minimizimg heat loss during the chill-back process.

The improvement in cooling efficiency and flexibility of the system can potentially enable a change from a two-tank to a unitank process, thereby saving tank occupancy and reducing process complexity.

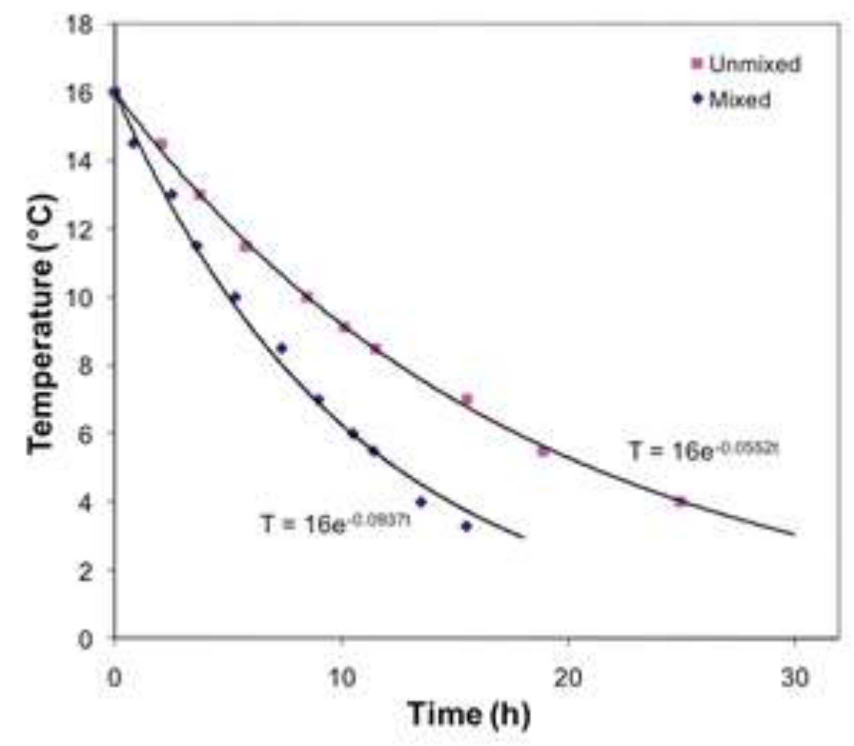

Figure 4. Effect of mixing on cooling time in an 1800 hL CCT.

APPLICATIONS FOR DYNAMIC FERMENTATION

While dynamic fermentation can offer benefits in most beer brewing processes, it is especially recommended for certain applications in which there are particular challenges for the fermentation process and the yeast viability, or for which special process flexibility is required. Examples of these are as follows:

- High Gravity Brewing and Very High Gravity Brewing applications (especially for OE>18°P)
- Very flocculant yeast strains prone to premature settling
- Large fermentation tanks (high aspect ratio and/or large diameter), in which uniformity in temperature profile and heat transfer are issues
- Special fermentations, e.g. cider or flavored beers, requiring the addition and dispersion of liquids, gases or solids during the fermentation process
- Fermenters with inadequate or non-uniform cooling jacket coverage or capacity

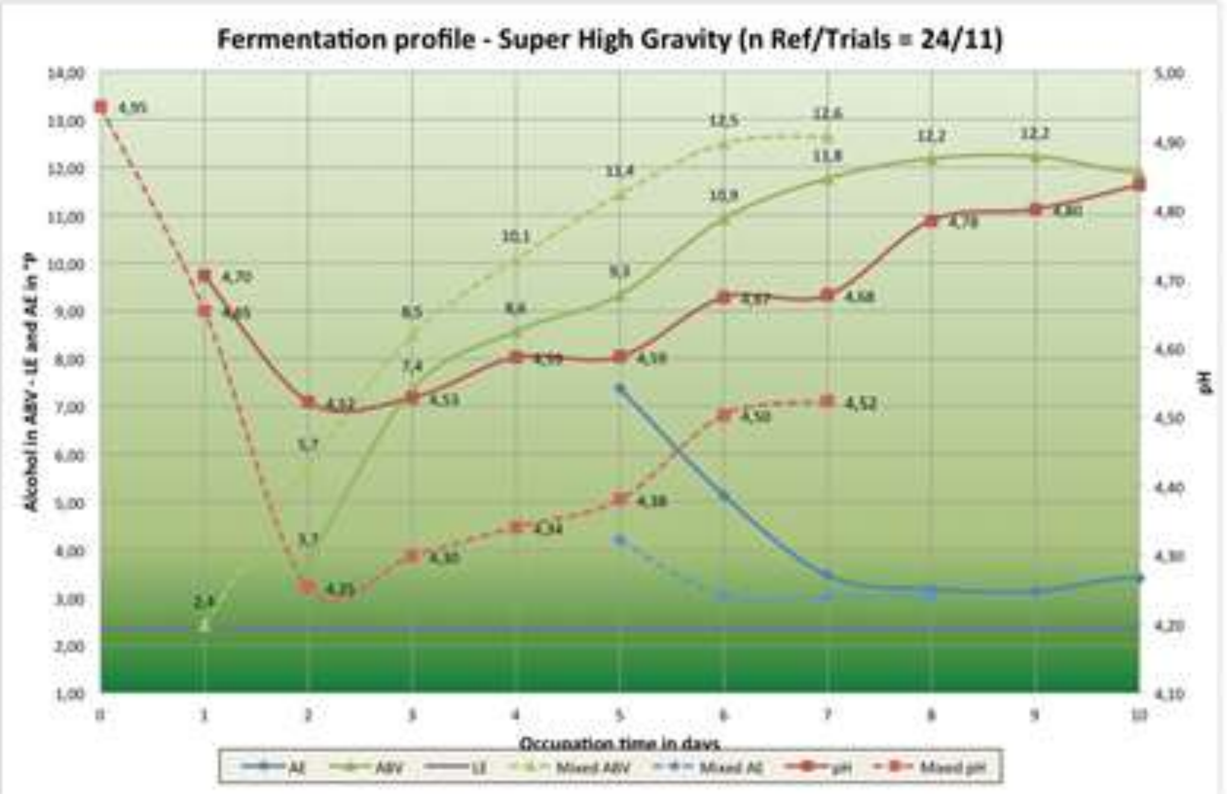

Figure 5. Fermentation profiles for Dynamic vs. Standard fermentation of VHG beer (OE=24.5°P), showing the differences in extract, alcohol and pH trends

Summary: Improvements with Dynamic Fermentation for Super High Gravity Beer

		Super High Gravity	
		Unmixed	Mixed
Quality (average values BBT)	Haze 25° EBC	0,82	0,39
	Haze 90° EBC	1,17	0,67
	pH	4,82	4,54
	Foam NFS	265	284
	Acetaldehyde ppm	10,5	5,4
	Isoamyl Acetate ppm	2,50	3,55
	Taste		No off-flavours detected
COG & other	RDF in SV	69,82%	71,93%
	RDF in SV increase		2,11%
	RDF in BBT	70,37%	71,93%
	RDF in BBT increase		1,56%
	Antifoam kg/brew	12,5	6,25
	Occupation time (days)	13,6	9,4

Figure 6. Process and Quality Improvements for Dynamic vs. Standard fermentation of VHG beer (OE=24.5°P).

CONCLUSIONS

The accumulated experience from commercial scale trials and full cellar installations of dynamic fermentation systems using rotary jet mixer technology has demonstrated considerable benefits for the fermentation process, beer quality and yeast viability. Reductions in fermentation process times have enabled capacity increase without the installation of additional tanks, and High Gravity and Very High Gravity Brewing can be implemented while maintaining the highest beer quality, consistent fermentations and a high level of yeast viability. With the current trends toward minimizing environmental impact and cost reduction, dynamic fermentation with rotary jet mixing is expected to become more widespread in the years to come.