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High Gravity Brewing for the Craft Brewer.

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Introduction

High gravity brewing is a relatively simple technique that is well established in the production of many lager beers (reviewed by Stewart, 2014) and one that is increasingly of interest to the craft brewer who is often producing other styles of beers. Ales and other beer styles that at one time may have been considered niche in many markets are enjoying huge growth in their popularity around the world. This is in no short measure due to the explosion of the craft brewing scene, where small brewers have had the flexibility to respond quickly to increasingly sophisticated consumer demands (Stewart, 2009). Or, alternatively used these products to carve a niche in what in an increasingly competitive market.

An essential factor to bear in mind that alteration of the fermentation conditions frequently has the potential to alter the final flavour profile of the product (Anderson & Kirsop, 1974). Significant amounts of time have been invested by many groups of researchers to examine the impact that high gravity brewing has on fermentation (Younis & Stewart, 1998; Cahill *et al*., 2000; Dragone *et al*., 2007) Increased gravity and the stresses this presents to the yeast population have implications for fermentation efficiency, with a tendency toward poor or stuck fermentations (Thomas & Ingledew, 1990). Several authors have determined that high gravity fermentations are associated with increased production levels of esters, higher alcohols and vicinal diketones (Saerens *et al*., 2008).

Materials & Methods

The work presented here used several strains of ale (*Sacharomyces cerevisiae*) yeast, using lager yeast (*Saccharomyces pastorianus*) as a control. In Study 1 the wort was produced on the 2 HL pilot brewery at the ICBD, in Study 2 malt extract was used. Yeast viability (citrate methylene blue), and gravity were monitored. Head Space-GC-FID was used to detect changes in higher alcohol, acetate esters and ethyl esters. Vicinal diketones were detected using Headspace-GC-ECD. For both analyses a Hewlett Packard 5890 series II, fitted with a CP-Wax-57-CB column and using nitrogen as the carrier gas was used. Data collection and analysis used Hewlett Packard Chemstation. Total Free Amino Nitrogen (FAN) content was assayed using the Ninhydrin method (ASBC Wort-12) and total carbohydrate content by ASBC Beer-41. Flocculation was determined by ASBC Yeast-11 and foam stability using ASBC Beer-22. It should be noted that the data presented are the aggregation of several sets of student experiments and should only be treated as indicative, further repetition and expansion of this work is required.

Study 1

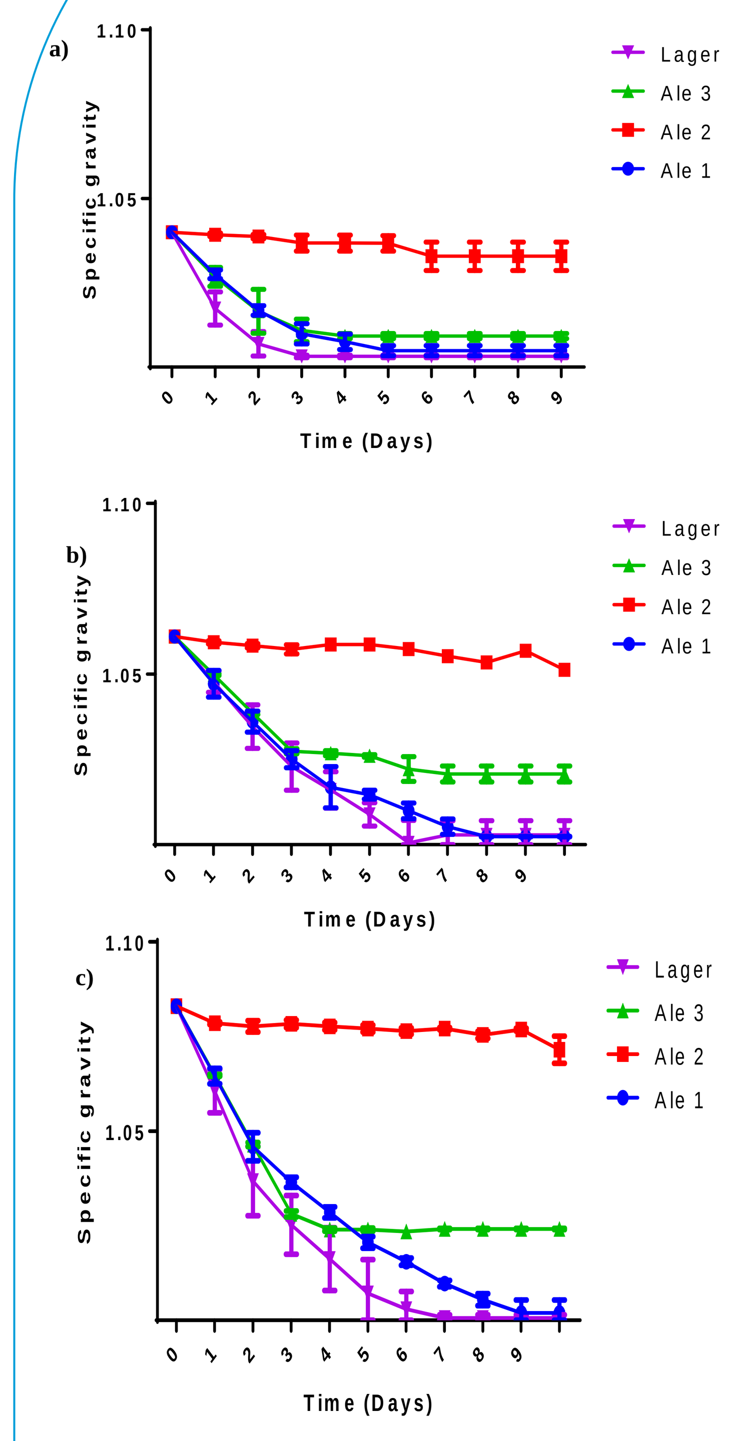

Figure 1. Fermentation profiles of worts with starting specific gravities of a) 1.04, b) 1.060 and c) 1.080.

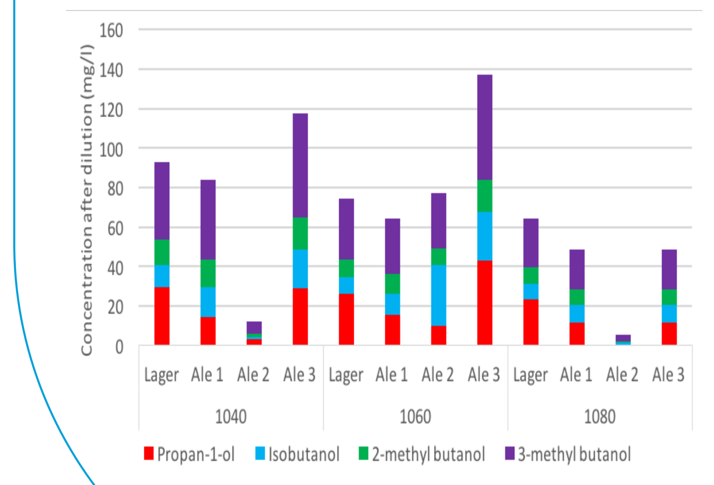

Figure 2. Higher Alcohol levels at the end of fermentation.

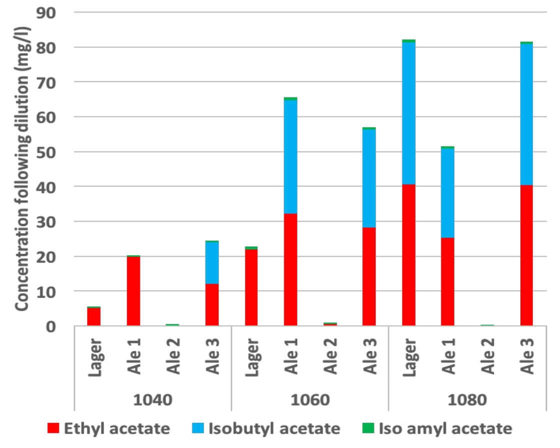

Figure 3. Acetate ester levels at the end of primary fermentation.

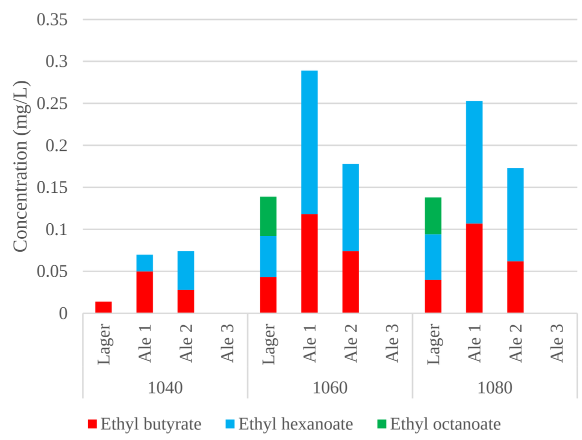

Figure 4. Ethyl ester levels at the end of primary fermentation.

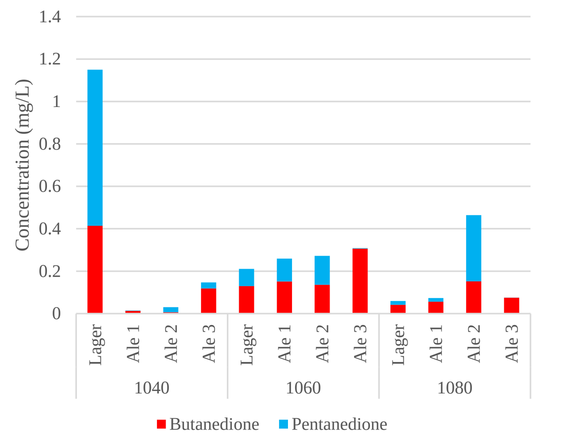

Figure 5. Vicinal diketone levels at the end of primary fermentation.

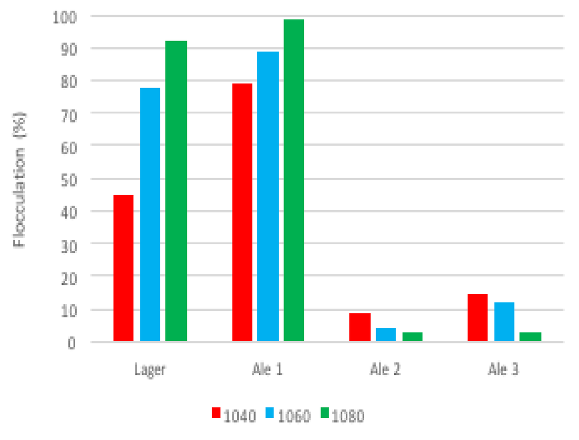

Figure 6. Change in flocculation pattern with increasing gravity.

Results & Discussion

- There appears to be a strain specific response to increased original gravity in both Study 1 (Figure 1) and Study 2 (Figure 7). The yeast strain designated Ale 2 (Study 1), did not respond well to any fermentation conditions, including 'standard' gravity, the reasons for this remain unclear.
- The focus of Study 1 was to examine the influence of high gravity brewing conditions on fermentation by-product metabolites whereas Study 2 looked for changes in wort nutrient utilisation, foam stability and flocculation.
- Generally, the concentration of higher alcohols (Figure 2) decreased with the increase in gravity. Correlating with the data published by Saerens *et al*., (2008).
- Study 1 also examined changes in ester production levels and the levels of these appear to be strain specific (Figures 3 and 4). However, the total levels are generally observed to increase with increase in gravity. Again, these results correlate with the work of Anderson & Kirsop (1974) and Saerens *et al*., (2008).
- Total vicinal diketone levels appear to increase with the increase in starting gravity (Figure 5), but the pattern does not appear to be consistent. Saerens *et al*., (2008) suggested that high gravity fermentations may demonstrate low levels of VDK at the end of fermentation due to the impact has on flocculation, keeping more cells in suspension and therefore reducing VDK to below flavour threshold levels. Some of the data presented does correlate with this hypothesis and deserves further investigation.
- The total carbohydrate content of the wort was determined at the start and end of each fermentation (Figure 8). The increase in gravity appeared to correspond to a decrease in the proportion of carbohydrate that was utilised but also suggested that the responses are strain specific.
- The preliminary data from Study 2 suggests that the utilisation of FAN decreases in ale strains with the increase in initial specific gravity (Figure 9). Examining the impact of increasing gravity on foam stability found that the effect is likely to be strain specific (Figure 10). The control, did however display the broadly opposite pattern of response to Ale 4 and Ale 5 strains.
- The fermented wort produced by strains Ale 4 and Ale 5 displayed reduced foam stability at a higher gravity (18° Plato), but increased or similar stability at very high gravity (23.5° P). Foam stability is known to be reduced in beers that have been brewed under high gravity conditions (Cooper *et al*, 1998; 2000), however the results from these studies do not conform to these patterns and merits further investigation.
- The impact of increasing wort starting gravity on the flocculation capability of yeast strains was found to be strain specific in Study 1 (Figure 6) and Study 2 (Figure 11). Suihko *et al*., (1993) determined that as wort gravity increases, flocculation decreases. In three of the six strains examined across the two studies the highest gravity conditions did result in a reduction in flocculative capacity.

Study 2

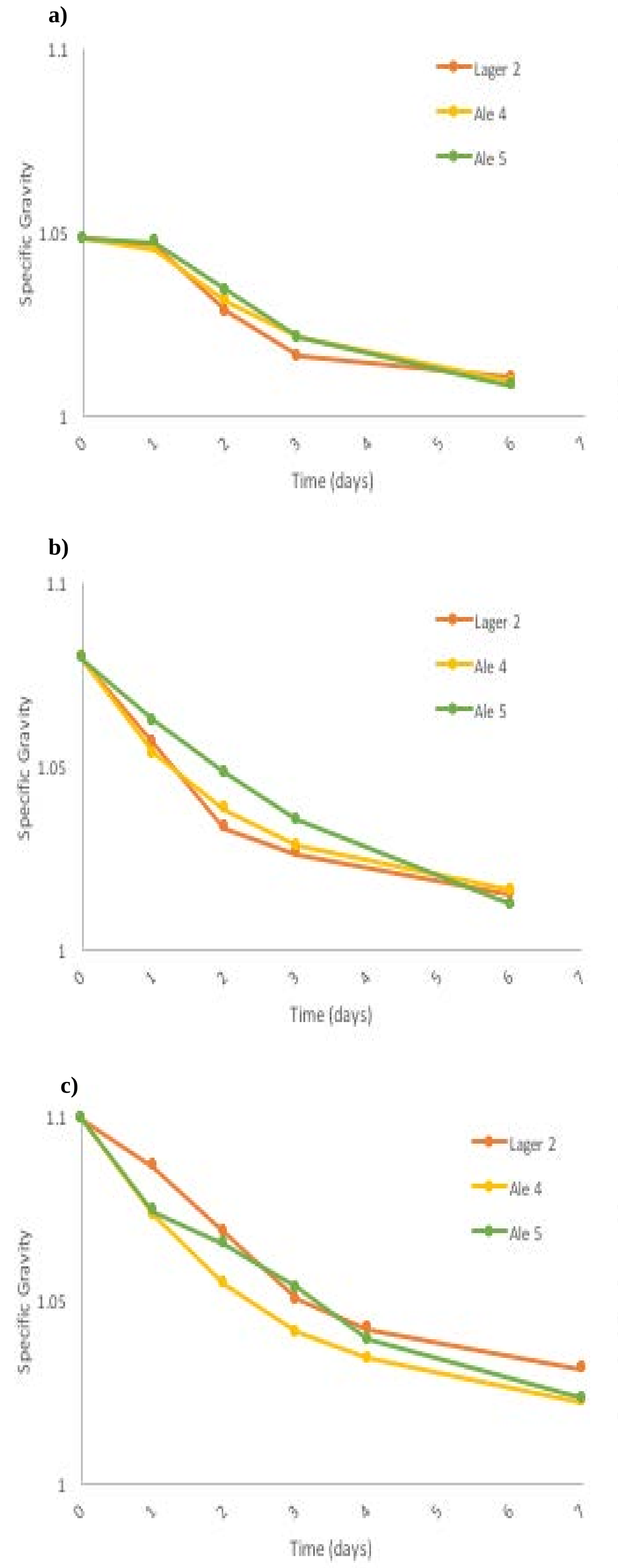

Figure 7. Fermentation profiles of worts with starting specific gravities of a) 1.048, b) 1.079 and c) 1.099.

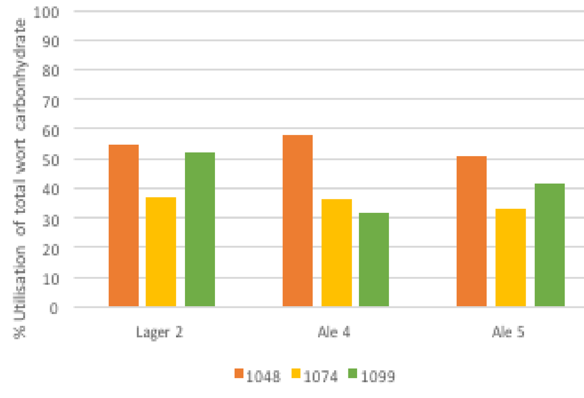

Figure 8. Utilisation of the total carbohydrate content from the wort.

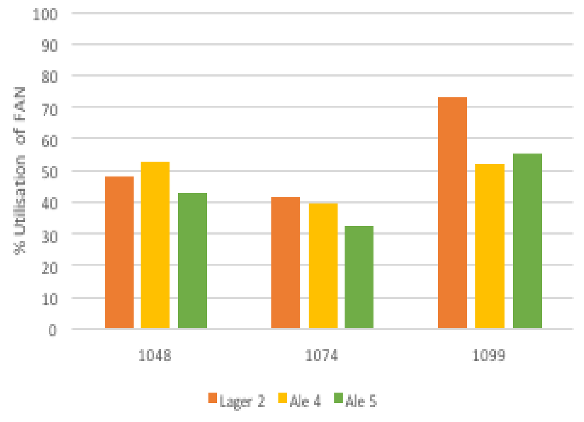

Figure 9. Utilisation of Free Amino Nitrogen (FAN) from the wort.

Figure 10. Foam stability with increased starting gravity.

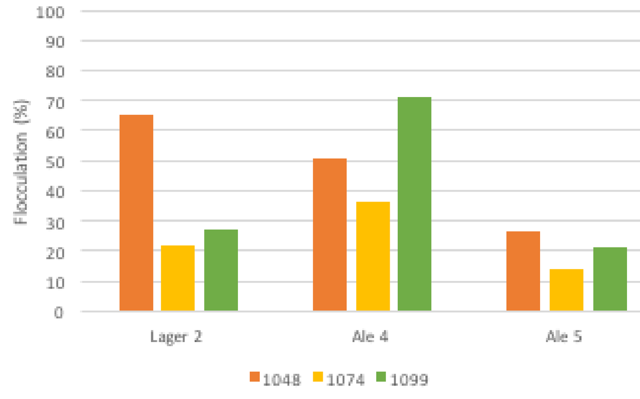

Figure 11. Change in flocculation pattern with increasing gravity.

Conclusion

The ale strains that have been studied in these pieces of work have demonstrated that the response of these strains to high gravity brewing conditions are strain specific, often appearing to conform to the overall patterns observed in lager strains of yeast. Importantly ale strains generally demonstrated increased concentrations of esters and higher alcohols, therefore as with lager fermentations, careful flavour matching of products would be needed if using these production techniques.

This work was undertaken to begin to fill the gap which surrounds the use of ale yeast in high gravity fermentations, the clear majority of the published material being focussed on lager yeast. Greater understanding of how ale yeast perform under high gravity conditions will allow users of these strains to consider the impact high gravity brewing may have on their final product whilst at the same time allowing an increase in production volume.

These results mean that the response of the strains investigated to worts with higher gravities are strain specific, and if utilising high gravity brewing techniques, as with lager yeast, trials will be needed to ensure that the final diluted sales gravity beer matches the profile of the original product.

A great deal of further work is needed in this area, suggestions for areas to receive some more detailed focus include determining the impact of stresses associated with high gravity brewing on the physiology of these yeast strains, the consequences of serial re-piching, and therefore multiple rounds of stress exposure and finally to investigate the influence of coloured and speciality malts and grains in the production of these beers. A design of experiments approach would allow the internal relationships to also be investigated.

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