

Malt Attenuation – An Australian Brewer’s Perspective

Mark R. Goldsmith

Fosters Group, Melbourne, Australia

Abstract

The last fifteen years has seen the introduction of new beer styles to the Australian market, including low alcohol, midstrength and low carbohydrate beers. Add to this list, full strength beers and the result is a portfolio with a very broad range of attenuation limits. Combined with adjunct usage, brewers control malt attenuation to give the required beer style. This paper will discuss the malt attenuation requirements of the different beer styles, and the control parameters with their limitations that brewers use to produce these different beer styles. Finally a comparison between malt attenuation limit results using different mash profiles is presented.

Keywords: malt, adjuncts, fermentability, attenuation

Malt attenuation requirements of traditional beer styles

Traditionally the majority of beers produced by Fosters in Australia were full strength, bitters lagers and draughts. The attenuation limit of these beers was similar and consequently the requirement for malt attenuation was also similar, Figure 1A. Malt attenuation requirements of a beer are not only determined by the beer attenuation but are also dependent on the beer recipe; the amount of adjunct used, if any, and the type of the adjunct have a major impact.

Typically Australian brewers use both sugar and wheat syrups as adjuncts. Sugar syrups (Brewers Liquid Sucrose – BLS) are 100% fermentable where as the fermentability of wheat syrups can be varied to suit the customer. Traditionally brewers used maltose syrup (Brewers Liquid Maltose - BLM) that is 80% fermentable. The effect of using either BLS or BLM on malt attenuation requirements of bitters, lagers and draughts is shown in Figure 1A. (The effect can be quite large, for example the malt attenuation requirement for a draught beer increases from 80% when BLS is used to 90 % when BLM is used.) While varying the type of adjunct offers the brewer a range of fermentability to help achieve beer attenuation targets, the decision to use BLS or BLM is a commercial one based on price and availability and often a combination of both is used.

The effect of the amount of adjunct used i.e. the malt to adjunct ratio on malt attenuation requirement of a Lager beer is shown in Figure 1B. Varying the malt from 100 to 60 % can alter the malt attenuation requirement by 10%. BLS will decrease the malt attenuation requirement while BLM has the opposite effect. Of course this option is not available to the brewer as changes to the malt to adjunct ratio will change the flavour and character of the beer.

Overall, the theoretical malt attenuation requirement, in the past, was from 79 - 90 %. However in practical terms, considering commercial implications for adjunct supply, the range was around 80 - 85%, which was well matched with the commercial attenuation achieved in Australian breweries of varieties such as Clipper and Schooner.

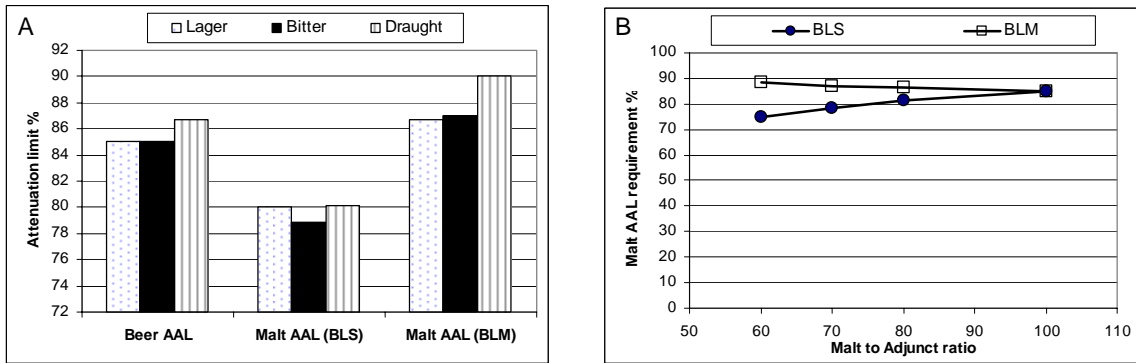


Figure 1A. Theoretical malt attenuation requirements of typical full strength beers produced with either BLS or BLM. **Figure 1B.** Effect of malt to adjunct ratio on malt attenuation requirement of a lager beer produced with either BLS or BLM.

Malt attenuation requirements of new beer styles

The relatively recent introduction of low and midstrength alcohol and dry or low carbohydrate beers into the Australian market has increased the range of beer attenuation limits and consequently the range malt attenuation requirements have also increased. This is because, for low and midstrength beers, the amount of non fermentable carbohydrate is increased to improve mouthfeel and body. However, for dry and low carbohydrate beers the amount of non fermentable carbohydrate is reduced to provide lower calories. So, low alcohol and low carbohydrate beers require malts with low and high attenuation respectively.

Once again adjuncts can be used to help control attenuation and achieve beer attenuation limit targets. The introduction of low alcohol beers in the 1990's also saw the use of low fermentable maltose syrups (BLE), which consist of approximately 45% fermentable sugars. BLE has quite a large effect on malt attenuation requirements. For example, for a low alcohol product the malt attenuation requirement increases from 43 to 66% for BLS and BLE respectively. Again the malt to adjunct ratio will have an effect but is not available for manipulation.

The theoretical malt attenuation requirement for the range of beers in the portfolio now is 43 - 114%, Figure 2. Commercially, of course, this is limited with sensible selection of adjuncts and the practical range is reduced to 66 - 91%. This still presents some challenges for the brewer particularly when trying to reduce malt attenuation. More recently released barley varieties, such as Gairdner, Baudin and Flagship that have higher attenuation are creating difficulties producing low alcohol beers and given the commercial preference for sugar adjuncts, may/will create problems producing full strength beers.

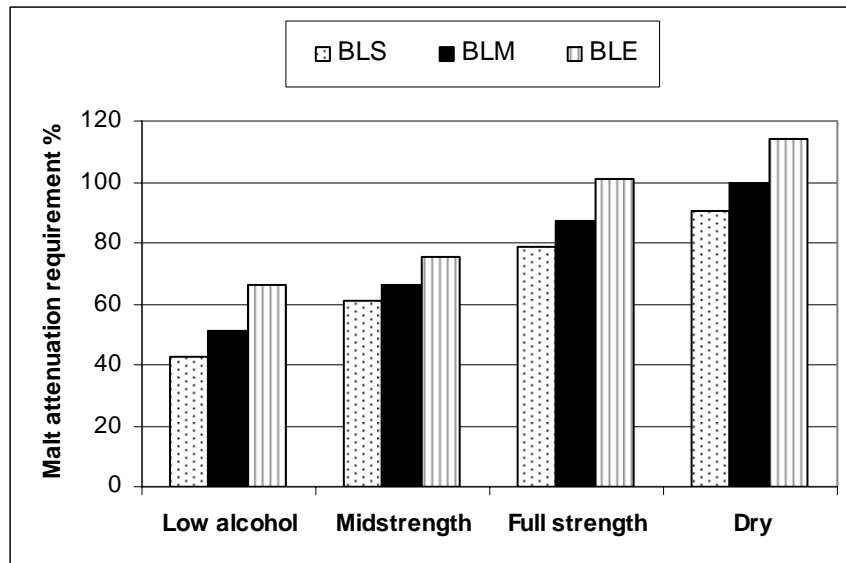


Figure 2. Comparison of malt attenuation requirements for different beer styles using BLS, BLM and BLE as adjuncts.

Controlling malt attenuation

Apart from malt to adjunct ratio and adjunct type brewers have traditionally used mash time and temperature to control attenuation limits. Where possible the optimum saccharification temperature of 65°C is used (with a limit of 70°C) and mash time is altered. This is because of the exponential increase of linoleic acid released from the malt at temperatures above 68°C, Figure 3A and the direct negative effect that linoleic acid has on ester formation, Figure 3B.

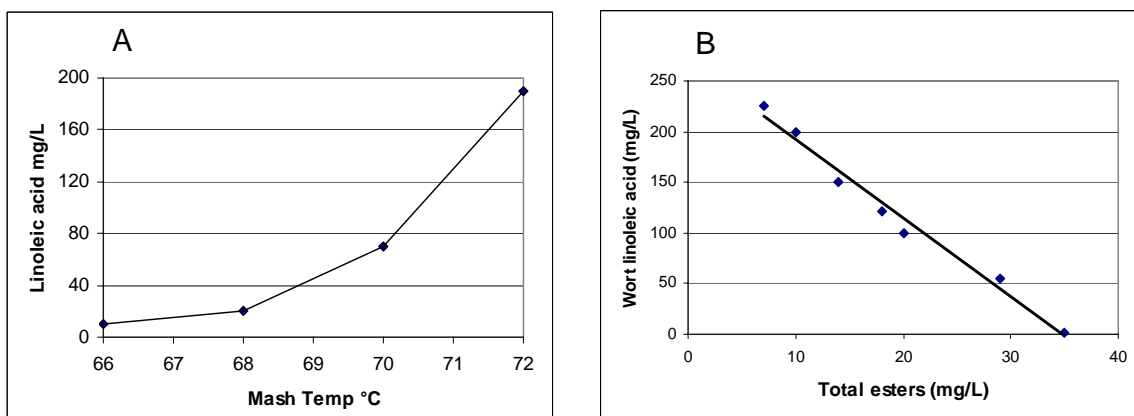


Figure 3A. Effect of mash temperature on release of linoleic acid from Schooner malt. **Figure 3B.** Effect of linoleic acid concentration on ester formation.

Due to the growth of high attenuating barley varieties and the risk they impose to controlling malt attenuation and hence the production of beer within specification, methods of controlling attenuation was revisited. The effect of mash temperature, pH, liquor to grist ratio and the possibility of using adjuncts with even lower fermentability were examined.

Experimental

Effect of mash temperature – malt samples of the varieties currently being used at Fosters sites (Schooner Vic, Gairdner Vic, Gairdner Tas, Gairdner WA and Grimmett Qld, Table 1) were collected and the following small scale brewing procedure was used at mash temperatures of 66, 68, 70, 72 and 74°C.

Malt	100%
Adjunct	0%
Gravity	13.2 °P
Volume	500 mL
Liquor to grist	3:1
Gypsum	1.9 g/kg
Strike temp	1°C above stand temp
Profile	Stand for 20 min, then raise to 75°C (1°C / min), hold for 10 min then transfer.

Effect of pH – pH was adjusted by adding either acid or caustic directly to the mash. Gairdner malt was used for this experiment and for the liquor to grist ratio experiments.

Results

Mash temperature

The effect of mash temperature on wort attenuation is not linear, Figure 4A and while Gairdner has the highest attenuation it is not the same at each site. Gairdner from WA is consistently more attenuating than Gairdner from Victoria and Tasmania. This could be due to environmental factors and or the different processes used at the matlings and are the subject of further research. There was exponential release of linoleic acid from Schooner malt at temperatures above 68°C, as before, and Grimmett malt showed a similar pattern, Figure 4B. However, Gairdner malt did not show an exponential increase with only a slight increase of linoleic acid at temperatures up to 72°C. It is possible that Gairdner will provide brewers the option of using higher mash temperatures without suffering the loss of ester formation. This is the subject of further research.

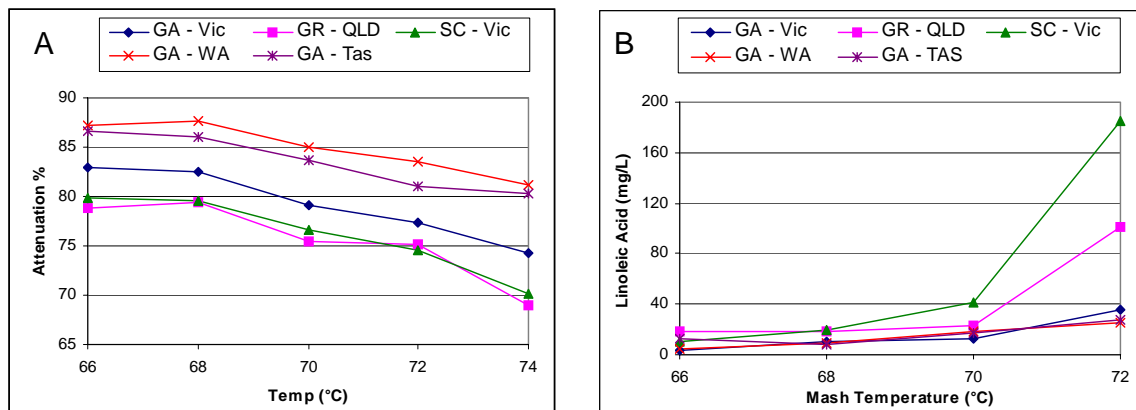


Figure 4A. Effect of mash temperature on attenuation. **Figure 4B** effect of mash temperature on linoleic acid extraction.

pH and liquor to grist ratio

The effect of pH and liquor to grist ratio on attenuation is shown in Figures 5A and 5B respectively. The optimum pH for attenuation is around 5.4 with slight reductions at lower and higher pH's. Given the relatively small effect of pH change and the difficulty of introducing pH change on a commercial scale this is not a viable option for attenuation control. Liquor to grist ratio of 2 to 1 reduces attenuation while similar results were obtained between 3 and 5 to 1. However the physical constraints of commercial grist hydrators limit the liquor to grist ratio to around 2.5 to 1 and where

possible, this ratio has already been introduced. Overall neither parameter offers new opportunity for change on a commercial scale.

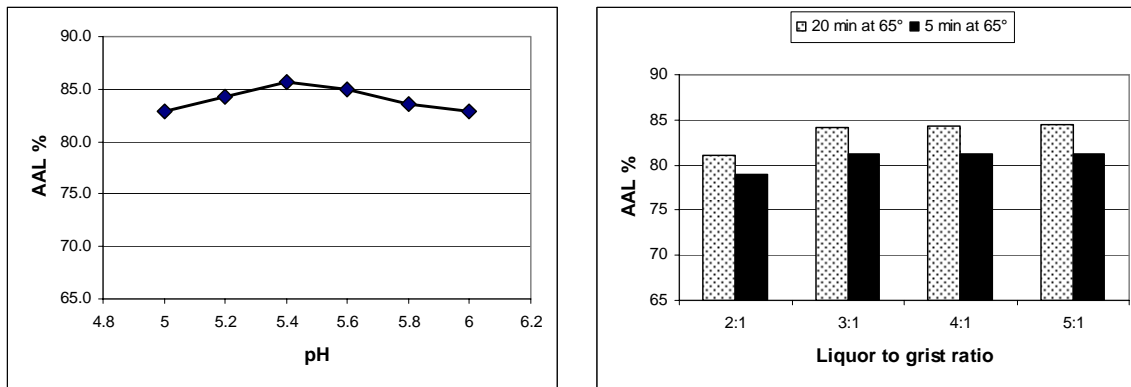


Figure 5A. Effect of pH on attenuation. **Figure 5B** Effect of liquor to grist ratio on attenuation.

These results suggest that mash time and temperature and adjunct fermentability still remain the only parameters for controlling attenuation. For some brands mash time is already at minimum limits. So which has more effect, mash temp or adjunct fermentability?

Adjunct Fermentability

Light alcohol and midstrength beer are already being produced with BLE, a low fermentable adjunct with a fermentability of 45%. Syrup manufacturers advise that the practical lower limit for brewing adjuncts is syrup with a fermentability of 35%. Reducing the fermentability of the adjunct from 45 to 35 for a low alcohol beer would provide an increase of 4% to theoretical malt attenuation requirement. An equivalent change could also be obtained by increasing the mash temperature from 70 to 72°C, Figure 4A. However, since decreasing the adjunct fermentability to 35 % would increase its viscosity to a point where heating of tanks and heat tracing lines would be required, increasing the mash temperature to 72°C is a more simple approach. Therefore, the effect of using higher mash temperatures on both controlling attenuation and product quality are the subject of further research.

Predicting malt attenuation

The ability to predict malt fermentability allows brewers to keep better control of the conversion process. Traditionally diastatic power (DP) has been used as the indicator of malt fermentability, however more recently this relationship has become less reliable. Older malt varieties such as Schooner still show a relatively good correlation between DP and commercial attenuation, Figure 6A, however newer varieties such as Gairdner show a poor correlation, Figure 6B, consequently DP results are unreliable. A parameter that more accurately predicted malt attenuation would help the brewer gain better control over the mash conversion process and reduce the number of times wort is produced outside of specification.

Apparent attenuation limit (AAL) is a parameter that can be routinely measured on lab extracts (although time consuming) and may give brewers a more reliable prediction of brewhouse conversion; however the standard IOB and EBC mash profiles, used to produce the extract, do not reflect the way wort is produced commercially. The purpose of this study was to evaluate the accuracy of predicting malt attenuation using alternative mash profiles.

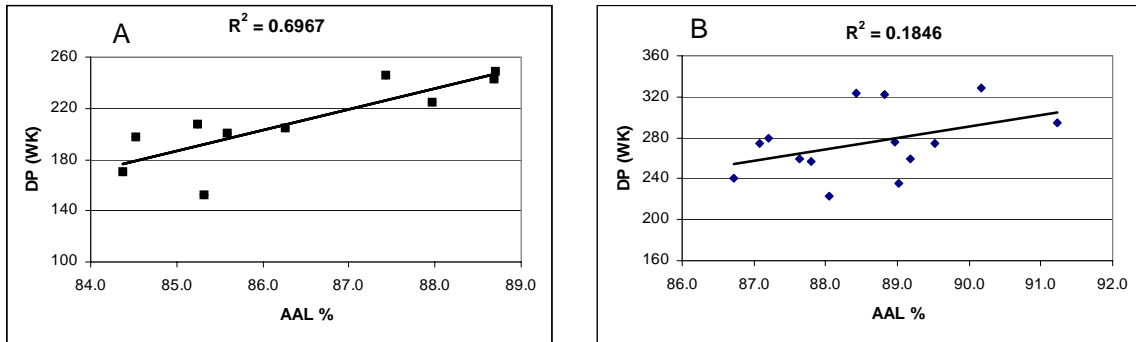


Figure 6. Relationship between AAL and DP for Schooner malt (A) and Gairdner malt (B)

Experimental

Samples of 11 malt varieties produced for pilot brewing in 2005 were collected and wort was produced using the standard IOB mash profile, a modified IOB profile (CUB profile) and the standard EBC profile (see Table 1 for details). Attenuation was measured using Mauribrew 497 dried lager yeast.

Table 1. IOB, modified IOB (CUB) and EBC extract procedure.

	IOB	CUB	EBC
Malt (g)	50	50	50
Water (mL)	360	160	200
Water/Grist	7.2 / 1	3.2 / 1	4.0 / 1
Gypsum (mg)	0	90	0
Mash profile	65°C / 60 min	65°C / 30 min	45°C / 30 min
			Raise to 70°C
			Add 100 mL water
			Hold for 60 min
	Cool to 20°C	Raise to 75°C	Cool to 20°C
Make up water temp	20°C	75°C	20°C
Final weight (g)	450	450	450

Results

Attenuation results from the three different mash profiles are shown in Figure 7. As expected Schooner showed low fermentability and the varieties such as Baudin and Flagship showed high fermentability. Interestingly AAL results using the EBC mash profile were lower than the IOB and CUB profile results across all varieties. Correlations between IOB AAL, CUB AAL and EBC AAL and apparent extract are shown in Figures 8A, B and C respectively. The IOB and CUB mash profile gave good correlations while the EBC profile showed a poor correlation. Plotting IOB AAL vs CUB AAL gave an excellent correlation with an r^2 of 0.9028, Figure 8D, indicating no significant difference between the two mash profile styles.

Since the CUB style mash didn't give any improvement to the prediction of attenuation and it alters the results of other parameters derived from the wort produced (higher extract and colour; results not shown) and is more difficult to carry out, no further work was carried out.

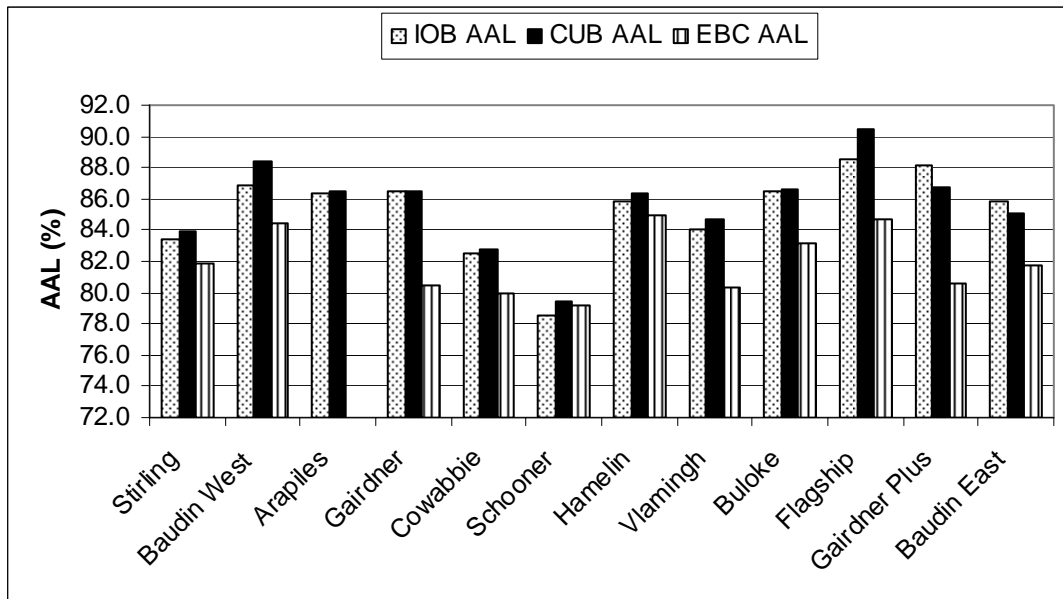


Figure 7. Attenuation results of malt varieties (PBA 2005) using different mash profiles.

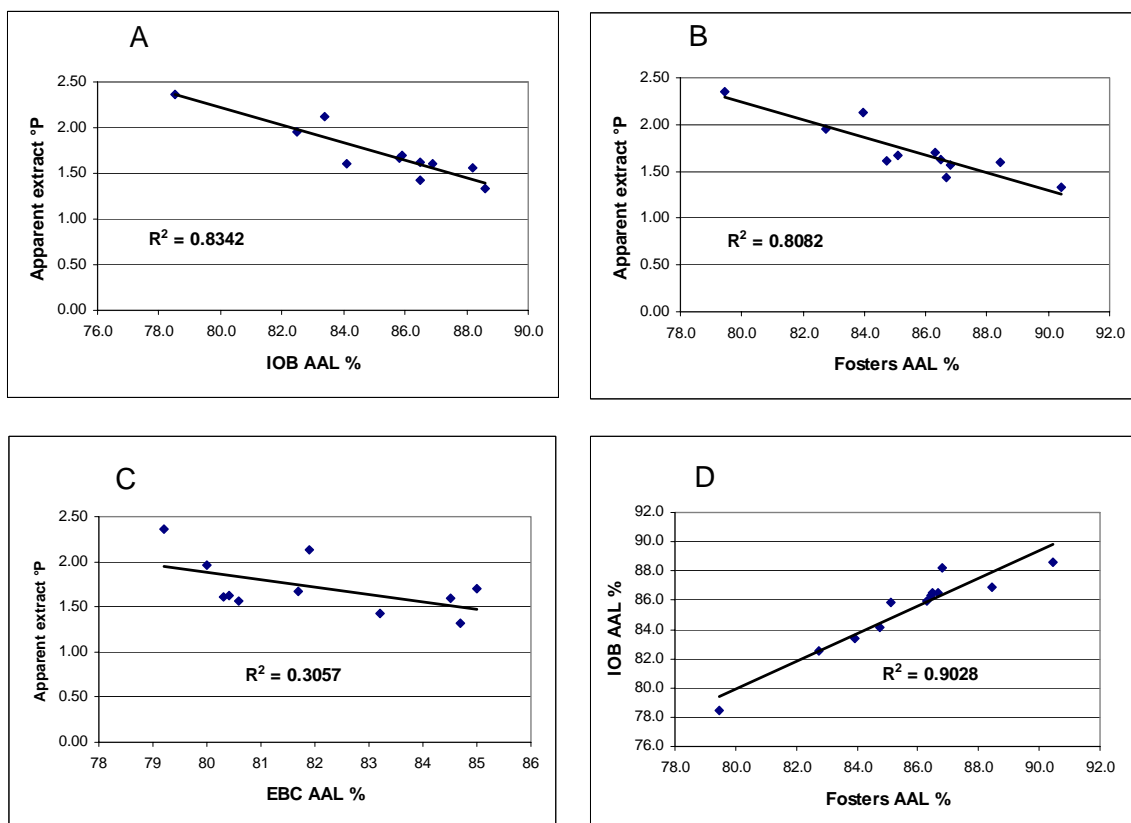


Figure 8. 2005 PBA malts – correlation between apparent extract and (A) IOB AAL and (B) CUB AAL and (C) EBC AAL. Figure 8D Correlation between IOB and CUB AAL.

Attenuation results from the malts produced for pilot brewing in 2006 were compared using the IOB and EBC mash profile, Figure 9. Again the EBC mash profile underestimated the attenuation potential with lower results across each variety. Correlations between IOB and EBC AAL and apparent extract were both poor, Figure 10A and B, respectively. This could possibly be due to the small number of samples and the small range of attenuation results obtained, Table 2. However importantly, for the

Australian brewer, both data sets indicate that the EBC profile underestimates the attenuation potential of varieties which give a high result using the IOB mash profile. While neither mash profile was correlated with this data set, practical experience using high attenuating varieties has shown that the AAL results from the IOB style mash are more likely to be indicative of commercial plant performance.

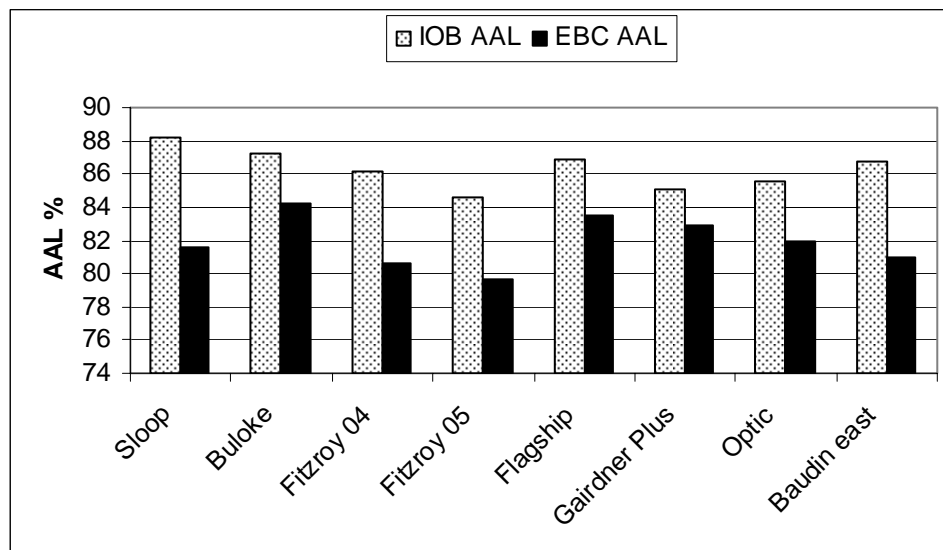


Figure 9. Attenuation results of malt varieties (PBA 2006) using different mash profiles.

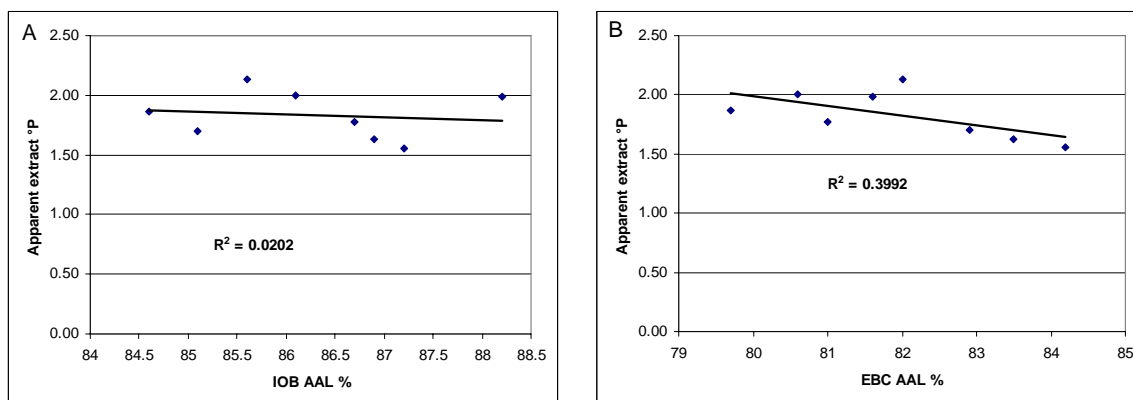


Figure 10. 2006 PBA malts - correlation between apparent extract and (A) IOB AAL and (B) EBC AAL.

Table 2. AAL results for PBA malts using either the IOB or EBC mash profile.

AAL	IOB 2005	EBC 2005	IOB 2006	EBC 2006
No. of samples	11	11	8	8
Minimum	78.5	79.2	84.6	79.7
Maximum	88.6	85.0	88.2	84.2
Range	10.1	5.8	3.6	4.5

On a commercial scale, high AAL results provide valuable information to the brewer and allow corrective action to be taken. However, when results are typical and the range is small then AAL is not accurate enough to provide correlation with plant performance (data not shown). The alternative to measuring AAL, is to measure the individual DP enzymes (alpha amylase, beta amylase and limit

dextrinase). Across a range of commercial malt samples Evans et al. (1) have shown a good relationship between the DP enzymes, Kolbach Index and beta amylase thermostability, and laboratory AAL analysis with an r^2 of up to 0.91. More recently commercial examples demonstrating the accuracy of his method have been described (2). This approach may provide more accurate and timely results and the adoption of his methodology warrants careful consideration.

References

1. Evans, D.E., Collins, H.M., Eglinton, J.K., and Wilhelmson, A., (2005) Assessing the impact of the level of diastatic power enzymes and their thermostability on the hydrolysis of starch during wort production to predict malt fermentability. *J. Am. Soc. Brew. Chem.*, **63**: 185-198.
2. Evans, D.E., Chenda Li, Eglinton, J. K., (2007) A superior prediction of malt attenuation. EBC Congress, Venice.