The Impact of Malt Steeping Regime on Beer Filtration Efficiency

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Introduction

Investigations to optimise beer filtration have seen the development of small scale methods to assess membrane filtration (Esser, 1972; Eyben and Duthoy, 1979; Siebert *et al*., 1984; Sudarmana *et al*., 1996). These methods, based on micro-filtration, have been suggested to predict keiselghur filtration efficiency in the brewery. Historically, reduced beer filtration efficiency has been largely attributed to β-glucan (Fincher and Stone, 1986; Leedham *et al*., 1975; Muts *et al*., 1984; Siebert *et al*., 1996). β-Glucan has the tendency to increase the viscosity of beer by forming gels, consisting primarily of large β-glucan molecules (Kruger, 1989; Sudarmana *et al*., 1996). More recently the adsorption of other large molecules such as arabinoxylan, protein and polyphenol have also been associated with reduced beer filtration, in particular micro-filtration (Meier *et al*., 1995; Sudarmana *et al*., 1996).

Brewing with malt that is over modified (ie. high KI), may alleviate the impact of β-glucan and arabinoxylan on beer filtration. In this case, non-starch polysaccharides from endosperm cell walls and the aleurone layer have been subject to prolonged β-glucanase and xylanase attack, substantially reducing their size and subsequently their ability to form viscous gels. However, using conventional malting regimes, over modifying malt is undesirable and results in high malting losses, changes in beer flavour and colour, increased potential for haze formation and reduced levels of foam promoting proteins.

In this investigation we examine the effect of different malting regimes on beer micro-filtration efficiency. Furthermore, we examine the potential for manipulating malting process to more completely degrade non-starch polysaccharides (β-glucan and arabinoxylan) without over modification of proteins, effectively "uncoupling" protein modification and cell wall polysaccharide degradation.

Materials and methods

Eight barley variety samples (5 Australian, 1 European and 2 Canadian) were malted using different steeping regimes, consisting of long (12 hours) and short (6 hours) steeps at high (22°C) and low (16°C) temperatures (Table 1). A small scale brewing method (Stewart *et al*., 1998) and V_{max} test (Esser, 1972; Stewart *et al*., 1998) were used to brew the malt samples and assess the micro-filtration efficiency (MFE) of the beer produced. A range of malt and beer parameters were measured, including Kolbach index, malt β-glucan and β-glucanase activity, beer β-glucan content and molecular weight, beer arabinoxylan and protein content as described by Stewart *et al*. (1998).

Table 1. Malting regimes. Each of the eight barley varieties were subject to each of the four different malting regimes producing a total of 32 malt, and subsequently, beer samples.

Malting regime	Steep temperature (°C)	1st Immersion (hours)	Air rest (hours)	2nd Immersion (hours)
I	22	12	6	12
II	22	6	6	6
III	16	12	6	12
IV	16	6	6	6

Results and discussion

Micro-filtration efficiency for beer brewed from malt samples produced by the steeping regimes described previously (Table 1), varied considerably (Table 2). V_{max} values ranged from 59 to 357 mL, with an average value of 190 mL (Table 2). Longer steep times, that is malting regimes 1 and 3, generally resulted in malt that produced beer that filtered more efficiently as indicated by the membrane filtration (V_{max}) test (Figure 1). Malting steep length had more of an impact on MFE than temperature, though beer brewed from malt produced by the warmer of the two long steep regimes (22°C) out performed that steeped at the lower temperature of 16°C. A similar relationship was observed between the higher and lower temperature for the short steep malting regimes (II and IV, Figure 1).

Table 2. V_{max}, Rudin head retention value (HRV) and a summary of the level of some malt derived beer constituents with the potential to influence micro-filtration efficiency. These include β-glucan, arabinoxylan, protein, β-glucan molecular weight, beer viscosity and malt Kolbach index.

Parameter	Value Range	Average	Standard deviation
V_{max} (mL)	59 to 357	190	73
Beer β-glucan molecular weight (kDa)	<10 to 211	95	64
Malt Kolbach index	30.2 to 52.9	40.3	5.8
Beer β-glucan (mg/L beer)	2 to 1346	271	283
Beer arabinoxylan (mg/L beer)	1.42 to 122	48	34
Beer viscosity ($mPa.s^{-1}$)	1.32 to 2.20	1.57	0.18
Beer protein (mg/L beer)	122 to 235	190	34
Head retention value (s)	94.7 to 125.7	107	6.1

Regression analysis was performed to ascertain which aspects of malt and beer quality were predictive of the observed variation in beer MFE (Table 3).

The MFE value for beer brewed from the malt samples was negatively correlated with beer viscosity ($r = -0.75$, $P<0.005$, Table 3). Beer viscosity values ranged from 1.32 to 2.20 $mPa.s^{-1}$, with an average value of 1.57 $mPa.s^{-1}$. This suggested that the viscosity of particle free beer may provide a good measure of beer MFE (Stewart *et al.*, 1998). Beer viscosity is primarily influenced by non-starch polysaccharides, mainly β-glucan, and to a lesser extent arabinoxylan (Stewart *et al.*, 1998) as these polysaccharides have the ability to form inter-molecular hydrogen bonds between extended sequences of β-1,4 linkages (Narziss, 1993; Wainwright, 1990). It was not surprising that the relationship observed between V_{max} and the various malting regimes, also existed between malting regimes I to IV and viscosity (data not shown).

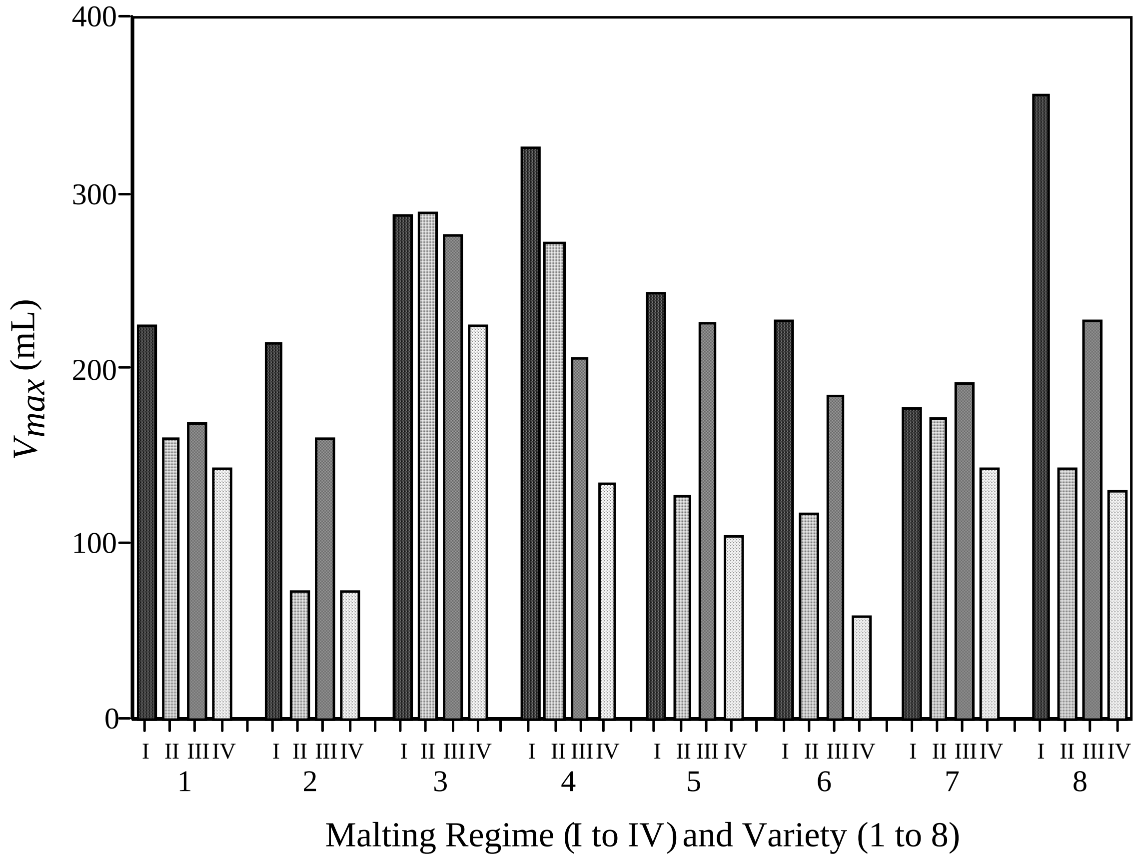

Figure 1. The micro-filtration efficiency of beer brewed from eight varieties of barley subject to four different malting regimes with variation in steep length and temperature.

Table 3. Regression analysis of potential predictors of micro-filtration efficiency from malt and beer.

	β-Glucan Mol. Wt.	Beer Viscosity	Total β-Glucan	Arabino-xylan	Malt β-Glucanase	KI	HRV
V_{max}	-0.62***	-0.75***	-0.72***	-0.50**	0.42*	0.37*	-0.57***
β-Glucan Mol. Wt.	-	0.70***	0.55**	0.24	-0.70***	-0.69***	0.59***
Viscosity	-	-	0.83***	0.42*	-0.48**	-0.50**	0.86***
Total β-Glucan	-	-	-	0.17	-0.36*	-0.50**	0.72***
Arabinoxylan	-	-	-	-	-0.17	-0.047	0.39*
Malt β-Glucanase	-	-	-	-	-	0.75***	-0.40*
KI						-	-0.57***

Abbreviations: Mol. Wt., molecular weight; KI, Kolbach index; HRV, head retention value

Total beer β-glucan ranged from 1346 mg/L to negligible levels, with an average value of 271 mg/L of beer (Table 2). Similarly, average beer β-glucan molecular weight was of a considerable range, 211 to <10 kDa, for beer brewed from malt produced by the various malting regimes. Both total beer β-glucan and molecular weight correlated with V_{max} ($r = -0.72$, $P<0.005$ and $r = -0.62$, $P<0.005$, respectively) and beer viscosity ($r = 0.83$, $P<0.005$ and $r = 0.70$, $P<0.005$, respectively), suggesting that both beer β-glucan content and the molecular weight of β-glucan greatly effect beer MFE. However, there have been reports that the total β-glucan content of beer may not always be an accurate indicator of beer MFE, with the size of the β-glucan providing better insight into filtration performance (Esslinger and Narziss, 1985; Narziss, 1993; Stewart *et al*., 1998).

Lengthening the steeping time during malting consistently produced an improvement in the MFE of beer, irrespective of the steep temperature used. This improvement was most likely related to grain moisture levels and subsequently non-starch polysaccharide degradation as it is accompanied in all cases by a decrease in beer viscosity, β-glucan content and β-glucan molecular weight. This hypothesis is supported by the positive correlation of malt β-glucanase with V_{max} (r = 0.42, P<0.05), and negative correlation between β-glucanase and beer viscosity (r = -0.48, P<0.005), total β-glucan (r = -0.36, P<0.05) and β-glucan molecular weight (r = -0.70, P<0.005). It appears likely that increased steeping times resulted in higher levels of β-glucanase during germination, therefore causing increased β-glucan degradation and a subsequent reduction viscosity and MFE as indicated by the micro-filtration test.

Although beer brewed from malt produced by longer steep times had superior filtration performance, beer head retention was reduced. There was a negative correlation between Rudin head retention value (HRV) and V_{max} (r = -0.57, P<0.005). Consistent with this result, HRV was negatively correlated with KI (r = -0.57, P<0.005) and positively correlated with viscosity (r = 0.86, P<0.005), total β-glucan (r = 0.72, P<0.005) and β-glucan molecular weight (r = 0.59, P<0.005) (Table 3). A relationship was also observed between indicators of protein modification (ie. HRV) and indicators of cell wall polysaccharide degradation (ie. V_{max}) for the total compliment of malt samples assessed (Fig. 2, as indicated by the dashed line). However, some individual varieties behaved differently over the range of steeping regimes (Fig. 2, as indicated by the arrows).

For example, one malt sample of each of the varieties one, three and four (as indicated in Fig. 2 by arrows) appear not to follow the overall trend of a reduction in HRV with an improved MFE (V_{max}). Specifically, as variety one showed an increased V_{max} value of 170 to 226 mL, HRV also increased, from 111 to 115.5 s. Similarly, the V_{max} for variety four increased from 273 to 327 mL, while HRV increased, from 106.5 to 110.5 s. A comparison for two of the samples of variety four showed a large increase in HRV of 95.7 to 100.7 s, without a decline in V_{max}.

The steeping conditions necessary for optimum beer quality changed for different varieties e.g. the variety 3 sample needed a long cool steep whereas the variety 4 sample required a long warm steep to optimise HRV and V_{max}. It may be speculated therefore, that by modifying malting regimes on a variety to variety basis, it may be possible to uncouple protein modification and cell wall degradation, to brew beer that filters well and will still have good head retention. This preliminary study has indicated that further research in this area may be rewarding.

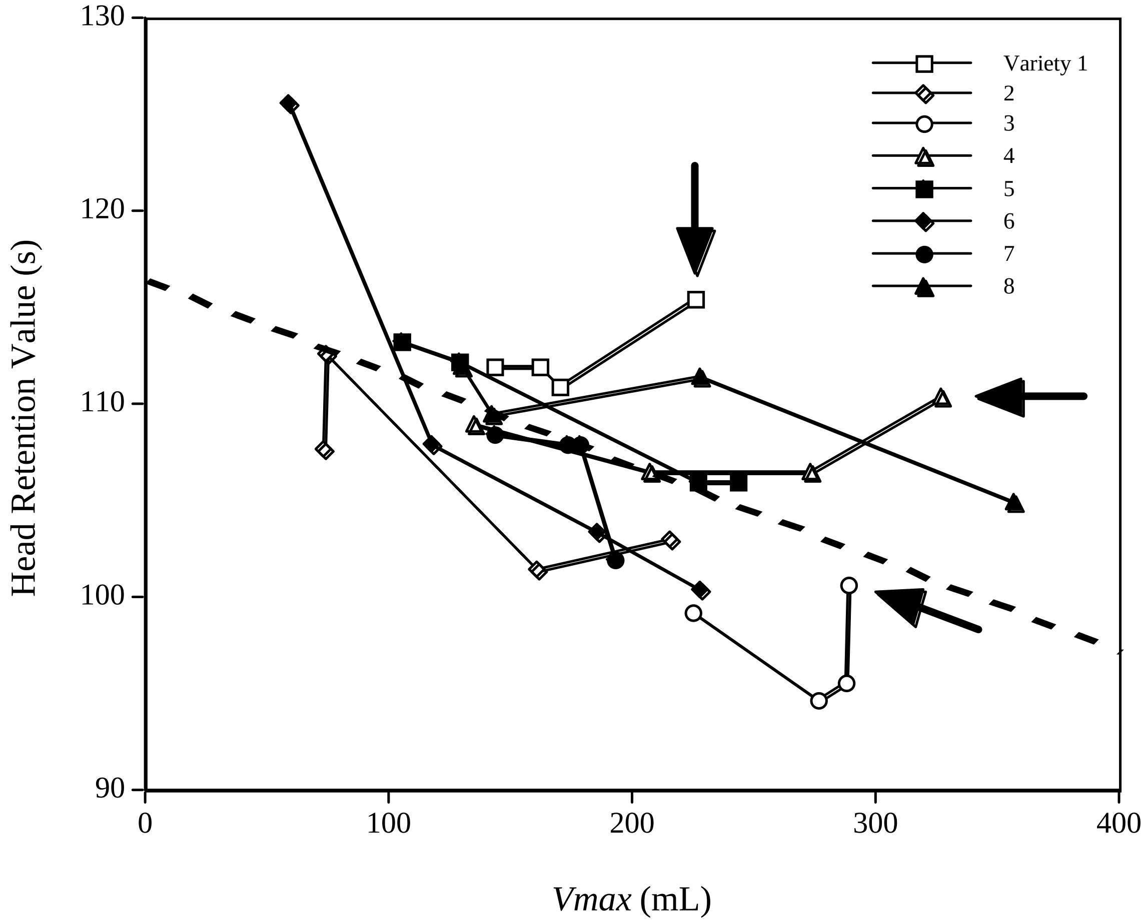

Figure 2. A measure of the relationship between protein modification as denoted by Rudin head retention value and cell wall polysaccharide degradation as denoted by V_{max}. Individual varieties are displayed. The overall trend indicated by the dashed line (r = -0.57, P<0.005), and those that do not follow the overall trend are indicated by arrows.

Conclusion

Modifying the steep length and temperature of malting regimes had a significant effect on cell wall polysaccharide degradation as indicated by beer MFE, and protein modification as exhibited by HRV. In general, longer steeps resulted in beer that filtered well due to increased β-glucanase activity and subsequent β-glucan degradation and viscosity reduction. Longer steeps also resulted in greater protein degradation as indicted by KI values and low Rudin HRV. There were however some barley varieties that did not follow the trend of decreased HRV with increased MFE, suggesting that by modifying steeping regimes, particularly steep length, it may be possible for some varieties to more fully degrade cell wall polysaccharides without incurring the negative effects of over modifying protein.

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