Prediction of Beer Foam Stability from Malt Components

Edyta KORDIALIK-BOGACKA and Natalia ANTCZAK

Institute of Fermentation Technology and Microbiology, Faculty of Biotechnology and Food Sciences, Technical University of Lodz, Lodz, Poland

Abstract

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Industrial unhopped worts produced from different batches of commercial malt were taken to analyse the contents of compounds related to beer foam stability, such as polypeptides, polyphenols, and β-glucan. Kolbach index of malts was also determined. Foam stability of beers produced from these wort batches was measured and the relationship between the foam stability and malt components was sought. The findings showed that the great variation in total and hydrophobic polypeptides as well as β-glucan contents among malt batches did not substantially influence the beer foam stability. None of the studied malt parameters correlated highly with the foam stability. The results showed that it is difficult to predict the foam performance relying on the polypeptides, β-glucan, or polyphenol contents in malt. It seems that the scope for the beer foam stability improvement by the malt selection is not considerable.

Keywords: beer; foam stability; malt; polypeptides

Brewers need to produce consistent quality products that will satisfy the consumers. Beer foam is one of the primary characteristics by which the consumers judge the beer quality. Therefore, it is a high priority for the brewers. Many methods of the foam quality assessment have been developed but the quality control is usually limited to the evaluation of the foam stability, mostly with the NIBEM or Rudin tests.

Beer foam formation and stability are influenced by both raw materials, namely malt, and brewing process. Thus, it would be desirable to use malt which has optimal levels of the foam-promoting components. Evans *et al*. (2003) demonstrated that the foam stability quite substantially depends on the malt source. In their studies, the differences in the foam stability between beers produced from the superior- and inferior-performing malts accounted for 5–20% (Evans *et al*. 2003). However, the head character cannot be predicted from the traditional quality parameters shown in the malt specification. Malt Kolbach Index (KI) and historical perception of varietal performance usually have been the only indicators of the beer foam quality (Nischwitz *et al*. 1999; Evans & Sheehan 2002; Evans *et al*. 2003). The increased malt modification, shown by a high value of KI, reduces the beer foam stability (Nischwitz *et al*. 1999). On the contrary, the use of malt from barley varieties with high contents of protein Z and LTP1 and, simultaneously, of low KI contributes to producing beer with stable foam (Evans & Sheehan 2002; Evans *et al*. 2003).

The beer foam stability depends on the interaction of a number of components, mainly proteins/polypeptides originated from malt and iso-α-acids from hop (Bamforth & Kanauchi 2003; Ferreira *et al*. 2005; Evans *et al*. 2008). Protein Z with a molecular weight of 40 kDa, lipid transfer protein 1 (LTP1), hordeins, and barley dimeric α-amylase inhibitor-1 (BDAI-1) have been identified as foam-positive proteins (Evans & Sheehan

2002; Hao *et al*. 2006; Iimure *et al*. 2008). It has also been accepted that hydrophobic polypeptides are the most effective in stabilising beer foam (Yokoi *et al*. 1989, 1994; Bamforth 1995; Ferreira *et al*. 2005). Furthermore, Bamforth and Milani (2004) demonstrated that the beer foam stability is dependant not only on the level of the individual foam-promoting polypeptides but also on the balance between the polypeptides derived from albumins and hordeins. However, malt is not the source of proteins, only but also of other foam-positive and foam-negative components, such as β-glucan, melanoidins, polyphenols, and lipids (Lusk *et al*. 1995; Dickie *et al*. 2001; Cooper *et al*. 2002; Evans & Sheehan 2002). It is commonly known that lipids damage the beer foam (Dickie *et al*. 2001; Cooper *et al*. 2002; Van Nierop *et al*. 2004). By now the data have not been conclusive in identifying the roles of other malt factors in producing stable beer foam. For example, many scientists did not observe the improvement of the beer foam stability by β-glucan (Roberts 1975; Stowell 1985; Lusk *et al*. 2001) while others did find a correlation between β-glucan and the foam stability (Lusk *et al*. 1995; Evans *et al*. 1999; Evans & Sheehan 2002).

Polyphenols have been reported to have a negative influence on the beer foam (Evans & Sheehan 2002). The use of malt with a low polyphenol content results in lower losses of the foam-positive proteins during wort boiling.

In this study, we decided to examine further the impact of polypeptides, β-glucan, polyphenols, as well as KI of malt on the beer foam stability. We carried out these investigations on industrial scale using commercial malt, which did not exhibit a high variability in KI. In previous studies addressing this issue, small- and pilot-scale brewing tests were performed and the range in malt KI was much greater than normally acceptable for commercial malt (Evans *et al*. 1999, 2003). Bearing in mind the fact that malt specifications in big commercial breweries are rigorous and malt quality quite consistent, we wanted to consider whether there is any scope for the beer foam stability improvement by an appropriate malt selection.

MATERIAL AND METHODS

Experimental design. Industrial all-malt unhopped worts produced from different batches of commercial malts were taken to analyse the contents of compounds related to the beer foam stability, such as polypeptides, polyphenols, and β-glucan. Additionally Kolbach index of malts was determined.

Eight malt blends were prepared from fourteen lots of malt originated from four Polish and Czech malthouses. Two lots were usually mixed to make one malt blend (Table 1). The malt amount for one brew was 9850 kg. Wort with a gravity of 12°Plato was obtained from each malt blend.

Hop products used for hopping came from the same batch. Every time beer of the same brand was produced.

Finally, the foam stability of the beers obtained from the studied wort batches was measured. The beer samples were also analysed for total and hydrophobic polypeptides, polyphenol, and β-glucan contents.

Malt, wort, and beer analyses. The Kolbach index of malts was determined using the EBC method (Analytica-EBC 1987).

Table 1. Malt blends prepared from lots originated from four malthouses (A–D)

Malt blend	Malt lot	Protein content (%)	Soluble nitrogen (%)	Kolbach index
1	A1/B1	10.5/10.1	0.720/0.640	43.0/40.0
2	B2/C1	10.1/10.8	0.645/0.708	40.0/40.9
3	C2	10.0	0.640	40.0
4	C3/C4	10.1/10.1	0.648/0.660	40.0/41.0
5	D1/B3	10.1/10.0	0.680/0.640	42.3/40.0
6	A2/B4	10.4/10.0	0.700/0.640	42.0/40.0
7	B5	10.1	0.645	40.0
8	B6/C5	10.1/10.3	0.645/0.719	40.0/43.4

The polypeptides contents of wort and beer were measured by the Bradford method using Pierce Coomassie Plus Protein Reagent (Bradford 1976). The hydrophobic polypeptides concentration was determined using the method developed by the Brewing Research International employing a 1 ml Hitrap Phenyl Sepharose, fast flow, low substitution column (HVD Vertriebs GmbH, Vienna, Austria) (Bamforth 1995). The hydrophobic polypeptides concentration was calculated as the difference between the total polypeptides concentrations measured before and after the passage through the column. Bovine serum albumin (BSA) was employed as the standard protein for calibration.

Polyphenols in wort and beer were analysed according to the EBC method (Analytica-EBC 1987).

β-glucan was measured in wort and beer according to the McCleary method with Megazyme kit (McCleary & Codd 1991).

For the evaluation of the beer foam stability the foam stability tester NIBEM-T (Haffmans B.V., Venlo, Holland) was applied (Klopper 1977).

All measurements were carried out in five replicates and the mean values are presented.

RESULTS

Total polypeptides

The concentration of total polypeptides in wort was in the range of 297–578 mg/l (Figure 1). Thus, a considerable variation in total polypeptide concentration in wort among batches was observed. The differences between total polypeptide concentrations were lower for beer than for wort. The variability in total polypeptides levels in beer accounted only for 14%.

There was a weak linear correlation between total polypeptides in wort and the beer foam stability (r = 0.35, P < 0.005). Total polypeptides in beer also correlated with the beer foam stability (r = 0.55, P < 0.001).

The analysed beers did not exhibit a high variability in the foam stability. Nibem values were between 249 s and 267 seconds. Thus, the differences between beers were not higher than 7%.

This relatively small range and a limited number of samples could have influenced the level of correlations between the malt components and the beer foam stability.

Hydrophobic polypeptides

Hydrophobic polypeptides contents in wort differed to a large extent depending on the malt batch used. Likewise it was with total polypeptides, the differences in hydrophobic polypeptides contents being higher in the case of wort than in that of beer. The differences in hydrophobic polypeptides concentrations accounted for 131% in wort and 59% in beer.

Hydrophobic polypeptides measured in both wort and beer were weakly correlated with the beer foam stability (r = 0.38, P < 0.001 and r = 0.34, P < 0.001) (Figure 2).

β-glucan

Malt exhibited a 2.9-fold variability in the content of β-glucan (Figure 3). The differences in the

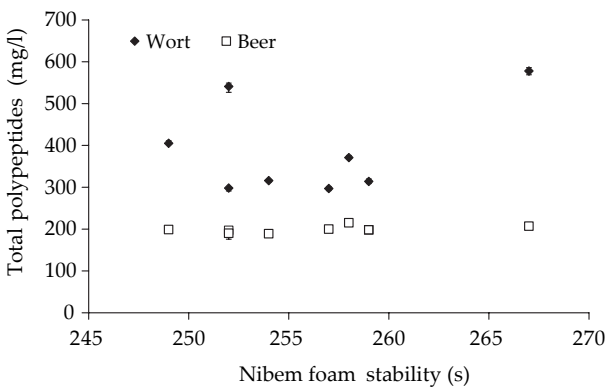

Figure 1. The relation between Nibem foam stability of beers produced from various malt blends and total polypeptide concentrations in wort and in beer

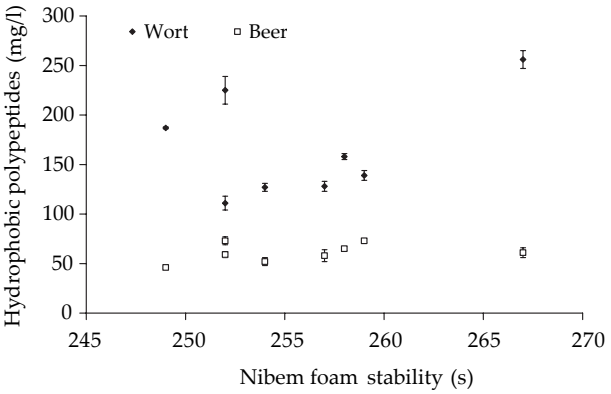

Figure 2. The relation between foam stability of beers produced from various malt blends and hydrophobic polypeptide concentration in wort and in beer

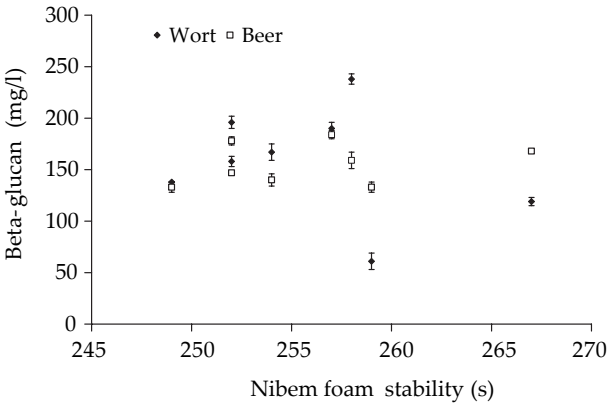

Figure 3. The relation between foam stability of beers produced from various malt blends and β-glucan content in wort and in beer

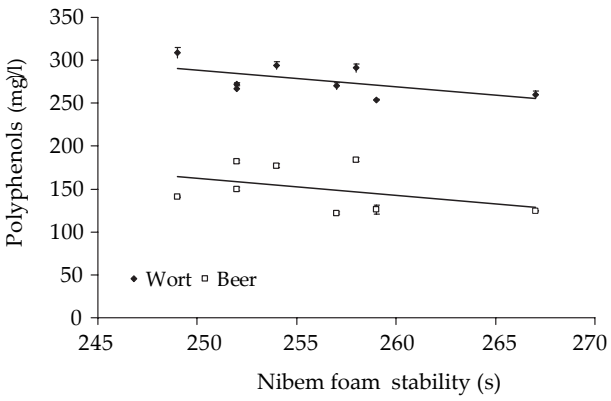

Figure 4. Relation between foam stability of beers produced from various malt blends and total polyphenol content in wort and in beer

content of β-glucan in beer were much lower and accounted for 38%. The level of β-glucan in wort remained uncorrelated with Nibem values (r = 0.26). Any correlation between β-glucan in beer and Nibem foam stability was not found either (r = –0.30).

Total polyphenols

Total polyphenol contents both in wort and beer did not differ substantially in the dependence on the malt batch used for the beer production (Figure 4). The variation in polyphenol levels in wort was 22% and in beer 7%. A correlation was found between Nibem values and total polyphenols in wort (r = –0.58, P < 0.01) as well as in beer (r = –0.42, P < 0.001).

Kolbach index. Malt represented a very low variability in Kolbach index. Kolbach index was in the range of 40–42 (Figure 5). No relation was observed between Kolbach index and the beer foam stability (r = –0.25).

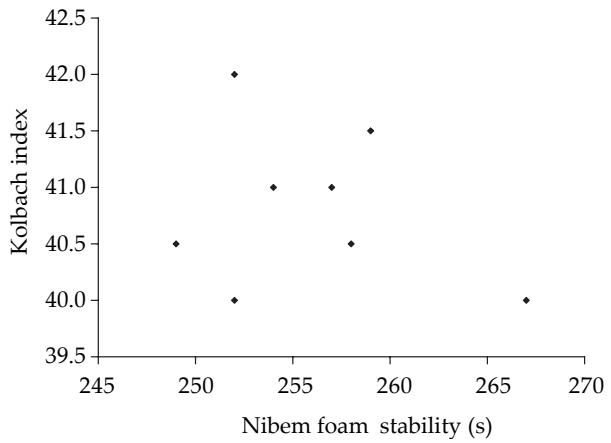

Figure 5. The relation between Kolbach index and beer foam stability

DISCUSSION

The small- and pilot-scale brewing tests made by Evans *et al*. (2003) showed that malt has a substantial impact on the beer foam stability. The use of malt with increased levels of foam-enhancing constituents would be a potentially viable strategy for improving the beer foam stability. However, malt specifications do not describe malt sufficiently to allow the brewer to predict the foam stability of the final product. It was in our interest to investigate the malt components that have been related to the beer foam stability and to consider whether they are reliable in predicting the beer foam stability. We aimed to evaluate whether additional malt parameters, not shown in the traditional malt specification but easy to measure in the factory laboratory, could enable to predict the beer foam stability in the commercial brewery.

Polypeptides play a crucial role in the foaming behaviour of beer (Evans & Sheehan 2002; Bamforth 2004). It was demonstrated that foam-positive polypeptides can be measured effectively by the Bradford Coomassie blue dye binding assay (Bradford 1976; Bamforth 1995; Siebert & Lynn 2005). This measurement has been mainly used for the trouble shooting of the foam problems in beer. But it was also postulated to apply this investigation for assessing the level of foam-active polypeptides in malt and, consequently, the

potential beer foam stability (Evans & Sheehan 2002). By now, this approach has been undertaken only by Evans *et al*. (2003), who found a correlation between the malt foam-positive polypeptides measured by the Bradford method and beer foam stability. In this study, a relation was also observed between total polypeptides measured in wort and the beer foam stability.

Since hydrophobic polypeptides were shown to determine the beer foam stability even to a larger extent (Yokoi *et al*. 1989, 1994; Bamforth 1995; Ferreira *et al*. 2005), the investigation of the level of hydrophobic polypeptides after the fractionation of wort hydrophilic/hydrophobic polypeptides by phenyl sepharose hydrophobic interaction chromatography seemed to contribute to a better evaluation of the foaming potential of malt polypeptides. However, a similar level of correlation with the beer foam stability was found for total and hydrophobic polypeptides in wort. Thus, hydrophobic polypeptides did not appear to be a very valuable indicator of the beer foam stability.

A close level of correlation with the foam stability was also observed for polypeptides determined in beer.

Although polypeptides are very important for stable foam generating, they are by no means the only factor involved. There are a number of malt constituents that can influence the beer foam stability (Evans & Sheehan 2002).

β-glucan has been suggested to enhance the beer foam stability (Lusk *et al*. 1995; Evans *et al*. 1999; Evans & Sheehan 2002), yet not much evidence is available for the positive role of β-glucan in the beer foam stability. In this study, no significant relationship was seen between β-glucan measured in wort or beer and the beer foam stability. Relatively few investigations addressed the impact of polyphenols on the beer foam quality. These findings showed a statistically significant relation between polyphenols measured in beer and the foam stability. Our results are consistent with the conclusions drawn by Evans and Sheehan (2002), who observed a negative correlation (r = –0.54) between polyphenols in beer and Rudin head retention values. However, this was not in agreement with the observations by Lewis and Lewis (2003). They found a high positive correlation (r = 0.62, $P < 0.001$) between total polyphenols in beer and the beer foam stability measured as Normalized Half-Life (NHL). This discrepancy can result partly from a different way of the foam stability measurement. The foam stability was assessed in their investigations by the method of Constant.

In this study, we focused not only on the evaluation of the role of polyphenols present in beer in stabilising beer foam but also on the examination of the relation between malt polyphenols determined in wort and the beer foam stability. And likewise as in the case of beer, a significant negative correlation between malt polyphenols and the beer foam stability was observed. It is noteworthy that the variability in the polyphenol levels among wort and especially beer samples was low in comparison with the other malt components analysed.

Polypeptides contents differed substantially between malt batches, with up to a 0.95-fold variability for total polypeptides and a 1.31-fold variability for hydrophobic polypeptides. Moreover, malt exhibited an almost threefold variability in the content of β-glucan. However, the beer foam stability varied only up to 0.07-fold. The foam stability appears to be barely affected by the quite high variations in total and hydrophobic polypeptids as well as β-glucan concentrations among malt batches.

Such great differences in β-glucan content, which certainly have an impact on wort and beer filtration, did not seem to have a considerable effect on the foam stability. Thus, the search for the improvement of the beer foam stability should not be based on the selection of malt with a high β-glucan content.

To sum up, we did not find factors that are highly correlated with the foam stability. However, these results need to be interpreted with caution, as the differences in the foam stability were not high and the number of samples was limited.

It has to be stressed that the differences in KI, which was widely postulated to be one of the two most important malt characteristics influencing the foam stability (Nischwitz *et al*. 1999; Evans & Sheehan 2002; Evans *et al*. 2003), were not great between the malt blends. The value of KI was about 40 (40–42), which can be classified as optimal taking into account the foam stability. It is tempting to speculate that, if KI values are correct, the other factors may be of minor importance.

The results of this work confirmed that the relation between the malt factors and beer foam stability is very complex and, having malts of the consistent value of KI, it is difficult to predict their potential foam performance relying additionally

on total and hydrophobic polypeptides, β-glucan, or polyphenol concentrations. In our studies, no substantial variation in the beer foam stability was observed, despite considerable differences in the contents of the malt constituents studied. However, the malt quality was much more consistent than in previous investigations where malt exhibited a high variability in the contents of foam-active proteins and β-glucan, and, also in Kolbach index (Evans *et al*. 1999). It is likely that, apart from the determination of KI, more sophisticated analytical methods focusing on the measurement of both the foam promoting proteins, such as Z4, Z7, LTP1 or BDAI-1, and the foam-negative malt components (e.g. free fatty acids), could be more useful to control the foaming potential of malts.

It has been suggested that the foam stability may be improved by the use of malt that has optimal levels of the foam-promoting components (Evans & Sheehan 2002; Evans *et al*. 2003). It seems that the visible improvement of the beer foam stability can be obtained when the selection of the superior-performing malt out of malts of considerably diversified quality takes place. At present, the variability in the content of the foam-active constituents among commercial malts is usually not so high as to affect substantially the beer foam stability. Thus, there is little scope for the beer foam stability improvement by the malt selection in commercial brewing.

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Corresponding author:

Dr. Ing. Edyta Kordialik-Bogacka, Technical University of Lodz, Faculty of Biotechnology and Food Sciences, Institute of Fermentation Technology and Microbiology, 171/173 Wólczańska Street, 90-924 Lodz, Poland
tel.: + 48 426 313 488, e-mail: bogacka@p.lodz.pl