The Influence of Novel Brewing Raw Materials on Beer Membrane Filtration

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Since the introduction of Beer Membrane Filtration (BMF) a lot of information has been gathered about the influence of the malt quality on filterability. All of the constituents in the beer which influence filterability, find their origins in the used ingredients and the brewing process. During the process, the raw materials undergo several transitions, all depending on the process conditions such as time and temperatures. The end product of these reactions determines not only the taste of the beer, but the filterability as well. Common components, like yeast and ß-glucans seem to be of less importance as people think. Filterability is primarily affected by the interaction of multiple components in the beer. New challenges are emerging, like adding a certain amount of barley to malt during brewing or even using 100% barley in combination with enzymes. The effect on beer membrane filterability of these raw materials is investigated.

Already in some breweries, small amounts of barley are added to the malt prior to mashing. The main driving forces for this are the lower costs and carbon footprint and the better availability of the barley. The amount of barley that can be added is limited by the reduced enzymatic activity of the un-germinated barley. To overcome this problem, *exogenous* activity can be obtained by adding extra enzymes during mashing. With the correct enzyme mixture, beer can even be made from 100% barley. It has already been shown, that the product results in a good drinkable beer with enhanced stability [1, 2]. A question that remains is however, how does this affect the filterability of the beer?

For this research, several beers were brewed with different ratios of barley and malt. For malting, the same barley was used as for brewing. In the case of 20% barley and 80% malt, a cytolytic enzyme mixture was used, comprising of xylanase and glucanase (Ultraflo® Max). When the amount of barley is increased, a more complex enzyme mixture (Ondea® Pro) should be used due to the reduced amount of endogenous enzymes. Next to xylanase and glucanase, other enzymes that are present are pullulanase, amylase, lipase and protease. The amount of enzyme used is relative to the amount of barley in the beer. Except for the barley to malt ratio, all other brewing conditions were the same in all the trial beers.

All filtrations were done on an 1 hl pilot plant with 1" modules. All filtration-process conditions are comparable to full-scale operation. Filtration is done in a tangential flow at 1.5 m/s, at 0° centigrade, with a permeate flux of 80 $lm^{-2}h^{-1}$. The pressure over the membrane is expressed as the Trans-Membrane Pressure (TMP), an is calculated with equation 1.

$$\overline{TMP} = \frac{P_{feed} + P_{ret}}{2} - P_{perm} \quad (1)$$

During the filtration, the TMP gradually increases due to the fouling of the membrane. If the TMP reaches 1.2 bars, a period ends and a backwash is applied. The filterability of the beers was measured as the length of the first period.

Results

In figure 1, the first period of a 100% malt and a 100% barley is given. In both cases, the same barley was used. It can be clearly seen that the filterability increases significantly. In the case of 100% barley, the TMP does not reach 1.2 bar, due to insufficient amount of beer available. In figure 1, the first period of a blend of both 100% malt and 100% barley is given as well. Blending after fermentation is an option for the brewer to tune the taste and

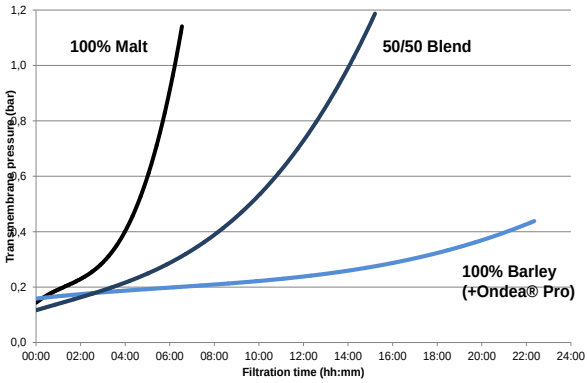

Figure 1: Filtration data from a 1 hl BMF pilot plant of 100% malt, 100% barley and a 50/50 blend of the two.

body of a beer. It can be said that the fouling rate for blends, is depended on the fouling rate of both the beer used for blending.

In figure 2, all the data of the first comparison trials is given. The first periods are normalized to the first period of 100% malt. What can be clearly seen is that the fouling rate reduces with higher barley loading, resulting in an increase in filterability.

Discussion

All beers were intensively analyzed, in order to get a better understanding of the different components that result in the reduced fouling rate of the barley beers. The most interesting results are discussed here. These results include the beer presented in figure 2 and additional tests.

ß-glucan has often been identified as a major fouling component in beer filtration [3, 4]. ß-glucan concentration as function of the normalized first period is given in figure 3. The data shows that high ß-glucan levels in beer may be detrimental, but low levels do not result in a good filterability per se. Reason for this can be that when looking at only the concentration of ß-glucan, the size and size distribution is neglected. It has been suggested that the (in)homogeneity of ß-glucans may influence brewhouse performance [5] and indeed higher molecular weight ß-glucan have been shown to result in increased fouling rates [3].

In all cases, the ß-glucan gel levels were below the limit of detection (<10 mg/l). It is unlikely that gelation takes places during the filtration test. Research has shown that shear induced gelation with low levels of ß-glucan takes much longer than a typical filtration run [6]. However, the nature and homogeneity of the ß-glucans important in the gelation process as well, gelation rate has been shown to be dependent to the ß-glucan molecular weight [6].

Another carbohydrate that is present in beer is arabinoxylan. It consists of a linear backbone of ß-(1-4)-linked D-xylopyranosyl units to which α-L-arabinofuranosyl units are attached [7, 8]. To these arabinose substituents, ferulic acid is often covalently bound (see figure 4a).

Although it is usually present in higher quantities than ß-glucans, it is often neglected with respect to brewhouse performance. It has however been shown, that it may cause problems during filtration [9], even more so than ß-glucans [10]. Reason for the lack of attendance may be that in standard analytical methods

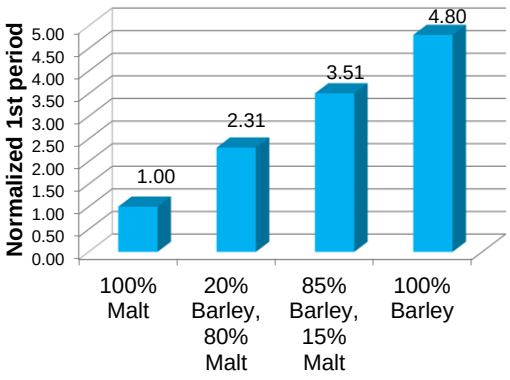

Figure 2: Normalized filterability of the different trials. In the case of 100% barley, the 1st period is estimated to 32 hours.

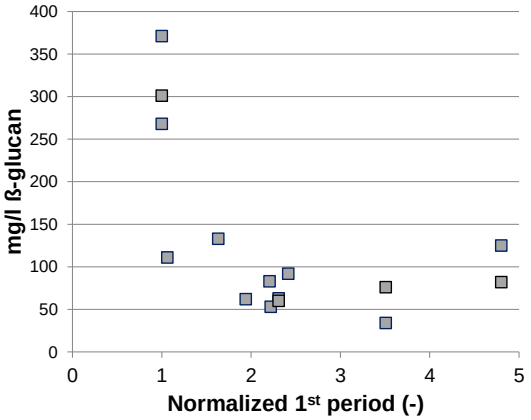

Figure 3: ß-glucan content (mg/l) vs. the normalized 1st period of all tests.

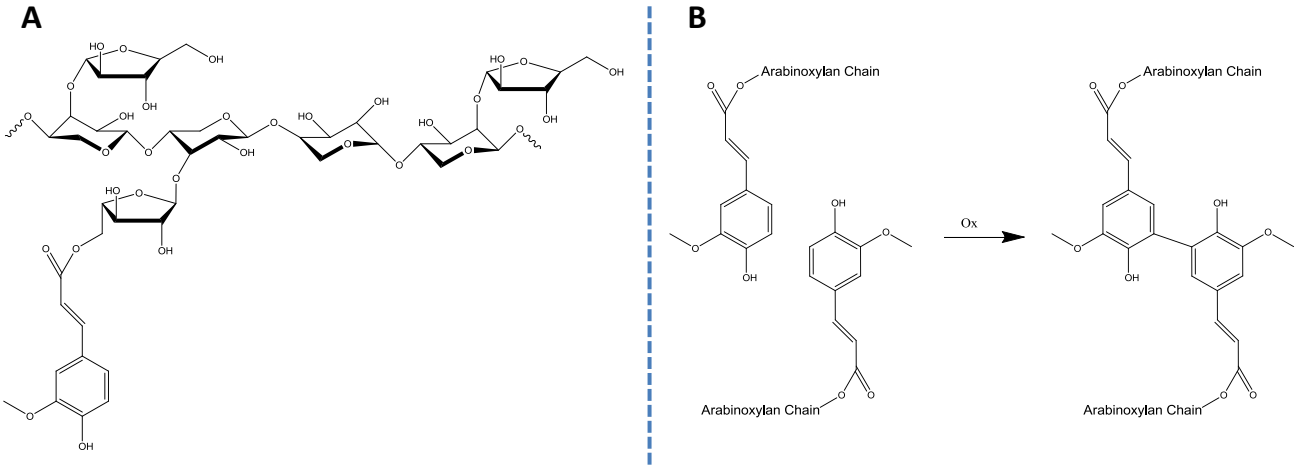

Figure 4: A, typical structure of an arabinoxlan with ferulic acid attached on a arabinose side chain. B, mechanism of ferulic acid cross-linking, in this case with another arabinose chain.

(acid hydrolysis) all arabinoxylan content is regarded, whereas only the high molecular weight fraction may pose problems. This can also been seen in figure 5, where there is no apparent influence in total arabinoxylan content on filterability (5a), but increased filterability is found with lower levels of high molecular weight arabinoxylan (5b). The high molecular weight content was measured via size exclusion chromatography. The xylanase used in the enzyme mixture has specific activity towards the xylose units that are substituted with arabinose. This higher activity towards substituted arabinoxylan in comparison to the enzymes present in malted barley, is likely to result in the lower amounts of high molecular weight fractions in the barley beers.

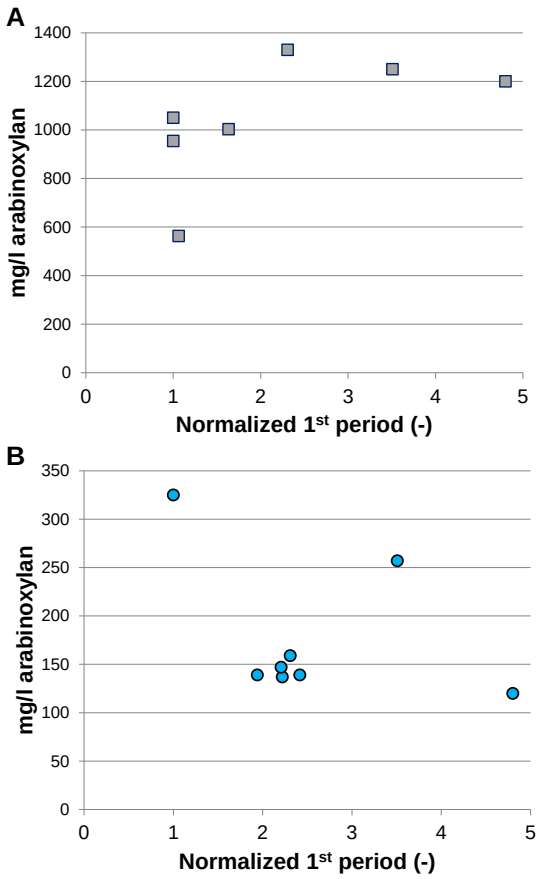

Figure 5: A, total arabinoxylan content vs. normalized 1st period. B, high molecular weight arabinoxylan content vs. normalized 1st period.

Next to the size of the arabinoxylan, the substitution ratio of the arabinoxylan may influence the fouling rate as well. It is know that ferulic acid substituted arabinoxylan are prone to crosslinking with other components in the beer such proteins, polyphenols and carbohydrates [7, 11]. In figure 4b, a typical mechanism is shown. These crosslinked networks can easily form gels and may impede filtration. Again, the specific xylanases present in the enzyme mixture for barley beers, will reduce these networks by the reduction of the substituted xyloses.

Besides carbohydrates, difference has also been found in the amino acid composition of the barley beers. Lower levels of proline are found in the barley beer [1], suggesting a different peptide composition as well. This shift may result in changes in the protein-polyphenol interactions during filtration (comparable to the well-known haze interactions). How and to what extend this influences the fouling rate, needs to be further investigated.

Conclusion

The results presented here clearly show that substituting barley for malt has a positive effect on the filterability of the product. Barley beer proved to be even more suited for membrane filtration as malt beers. The enhanced filterability is most probably due to the better conversion of the raw materials during brewing. It has also been shown that the fouling rate does not depend solely on the concentration of some specific components, but much more on the nature and specific interactions of the different components. For future research on beer membrane filterability, it is therefore necessary to focus more profoundly on certain ingredients. Especially, the homogeneity and size of ß-glucans should be addressed and the levels of high molecular weight fractions of arabinoxylan and there extend of crosslinking.

Acknowledgments

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