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The Impact of Wort Production on the Flavour Quality and Stability of Pale Lager Beer

Fine milling in combination with thinbed mash filters has been introduced into the brewing industry more than 20 years ago. Although clearest worts can be obtained at highest gravity, in combination with high extract yield and improved starch conversion, a majority of brewers still use the conventional coarse milling in combination with lautertuns. Brewers seem still afraid having a negative impact of fine milling on wort and beer quality especially with regard to over extraction of polyphenols, proteins and oxidative enzymes. A lack of detailed data comparing both wort production methods could be a reason. In this study, the faster wort filtration as well as higher extract yield has been confirmed when using fine milling and a thin bed filter. A higher concentration of fermentable sugar led to this increased yield and not an increased level of proteins and polyphenols. On the contrary, fine milling in combination with thicker mash and thin bed filtration results in a lower level of haze sensitive protein in the pitching wort in comparison to coarse grist and the use of a lautertun. No striking differences have been found comparing analyses of fresh beer. Also during forced ageing of the beers at 30 °C, no difference in the formation of flavour negative compounds or degradation of bitterness has been noticed. Both wort production methods result in highly comparable beers with equal flavour stability.

Descriptors: milling, mashing, mash filter, wort production, flavour stability

1 Introduction

Driven by the objective to increase throughput and to reduce wort production costs in the brewing industry, many innovations have been introduced, especially with regard to the cost efficient mash filtration and extract recovery. Among them, a combination of fine milling and thinbed filtration as an alternative for coarse milling and traditional lautertuns is available [29]. Using an automated thinbed mash filter, including membranes for filter cake compression, clearest and highest gravity worts, as well as higher extract yields have been obtained in pilot operations. Soon after their introduction, the same results were reached under industrial conditions [4, 71].

In thinbed filters the depth of the vertical filter bed is approximately 4 cm, whereas in lautertuns a horizontal filter bed of 25-50 cm (depending on the malt load and the milling system) is obtained [23, 40]. In contrast with coarse milling, whereby the husks preferably remain intact, the husks in case of thinbed filtration have to be finely milled. Another point of difference is that when using thinbed filters, the filter cake produced during heavy wort filtration is compressed prior to sparging by an expandable membrane and again compressed after sparging. In lautertun operations however all is done to avoid compression of the filter cake or compensate by knifing of the filter bed. Knifing can result in an increased risk of turbidity, polyphenols and O_2-ingression which affect lauter performance and wort quality. Compression of the filter cake in thinbed filter operations prior to sparging allows the highest extract yields at the expense of lowest sparge rates (<2.5 hl/100 kg instead of <4 hl/100 kg in case of lautertun operations) [4, 51] or even very low sparge rates of 1.5 hl/100kg with optimized industrial conditions [28]. With fine milling, preferably under anti-oxidative conditions, starch free worts can be obtained with short infusion mashing and even after mashing-off and mash filtration at 95 °C [20].

Although a growing number of brewers nowadays have invested in thinbed filter brew lines, a majority still adopt the traditional combination of coarse milling and lautertuns [4, 51, 52]. Compared with traditional brewhouses, the higher extract yield frequently has been reported when using fine milling and thin bed filters [4, 51, 52, 55, 67] in combination with an increased starch conversion [55]. The total filtration cycle time is reduced by 60 min according to industrial results [4, 71]. Concerning the impact of milling on beer flavour quality and beer flavour stability, highly comparable results have been reported, but detailed analytical results have not been presented [19, 51].

Another important topic is the oxygen management in case of thinbed filter operations since excess of oxygen negatively affects lauter performance in practice [8, 12, 50, 63, 68, 70]. Indeed, excess oxygen leads to oxidative gelation and the formation of disulfide bounds that negatively affect mash filtration. The effect of O_2-entrainment can be corrected by the addition of anti-oxidants, such as SO_2 or gallotannins [1, 2, 8]. Anti-oxidative operations during

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wort production are preset conditions for improved flavour stability of final beer [1, 2, 6, 30, 33, 50, 56, 63, 65, 70]. However neutral findings were also found when oxygen entrainment was minimized at the early stages of mashing regarding flavour stability of beer [50]. Because of lowest mash rates and sparge rates, thinbed filters are best fit for cost efficient high gravity brewing [4, 29, 51]. Another exploitable issue is that with fine milling and thinbed filters, clearest worts can be obtained independent of whether husk material is present, as long as there is sufficient coagulated high molecular weight (HW) protein material to quickly form a filter bed [3, 11, 23, 24, 71]. With clearest worts, lowest levels of non-oxidized lipids can be obtained [4, 29, 51]. Lipids, fatty acids and also oxidized fatty acids (trihydroxy acids) negatively affect foam stability [38, 39]. Turbidity of pitching wort and accompanying unsaturated fatty acids affect ester formation during fermentation. Especially the middle chain fatty acid esters are influenced by the fatty acid concentration [26, 47]. When trub potential of the filtered wort is too low with a mash filter (< 2 ml/l Imhoff), it is easy to manage by eliminating turbid wort recirculation. A critical point with regard to thinbed filters is that loading is crucial for efficient extract recovery by sparging whereas with lautertuns the load flexibility is somewhat higher [4]. A flexibility of 30 % of the malt loading however is possible with a membrane assisted thin bed filter. On the other hand, a lautertun also performs best at a distinct load. Brew sizes exceeding these loadings will affect the operation of the lautertun in reduced extraction efficiency, an extended run off time, and also higher turbidity, because of the low knifing of the chopping device or a combination of all [13]. Beside the standard flexibility on the nominal throw, it is technically possible to get increased load flexibility with a mash filter by a blind plate [4].

Among brewers and scientists, there is still a debate about the impact of fine milling on the final beer quality. For many brewers, fine milling of the complete husk fraction as well as of the intact and viable seedling of pale lager malt, is a big step to take [71]. Fine milling results in higher extraction levels of all malt compounds if mash is free of clots by using appropriate mixing systems. The positive effect with regard to higher yield and starch conversion is already mentioned, but there's also the increased release and extraction of risk-compounds for beer quality, e.g. proteins and polyphenols [4], pentosans [45] and glucans [36], DMS precursor [21], and lipoxygenase (LOX) [19]. However, compensations, even within the context of clean-label technology, are possible.

Polyphenol extraction can be controlled by sparging with acidified water [15, 27]. Proteolysis can be limited by higher mashing-in temperature [30] and, especially in case of anti-oxidative mashing, proteins get coagulated during mashing and retained in the filter bed during lautering [14, 43, 61]. A more complete protein precipitation is found in thick mashes [44]. Reactions between haze active proteins and polyphenols are at their best at high and balanced concentration and when pH is near 5 [14, 61]. The combined effect of fine milling, thicker mash, thinbed filtration, and mashing at decreased pH should lead to the efficient removal of high molecular weight proteins and polyphenols.

Beta glucans indeed are more easily extracted in case of fine milling at the expense of a higher viscosity and poorer lauter performance. However, the solubilization of glucans and pentosans is limited in thicker mashes (mash rate of 1:2.5) [36, 45]. Malt modification has a greater impact on the lauter performance than milling or mash rate [37]. Microflora management during malting can have a positive effect on mash filtration and extract yields. The use of starter cultures during malting has been reviewed quite recently [32]. It leads to lower levels of β-glucans and arabinoxylans in malt and an improved lauter performance [9, 41, 46, 57]. However, there is the negative effect of excessive shear forces on industrial mash filtration due to badly designed stirrers, pumps, and pipeline layout. Short and high temperature mashing schemes and state of the art engineering of pipe lines, stirring, and transfer operations will definitely result in a decreased solubilization of glucans, arabinoxylans, and β-glucan gel formation resulting in an improved lauter performance [27, 35, 45, 63].

Pale lager malts are characterized by residual DMS precursor (DMSP), mainly present in the seedling. It has been observed that with fine milling slightly more DMSP is found than with coarse milling. However, this increased extraction did not result in a higher DMS-level after boiling and in the final beer [21].

LOX-activity, if still present in malt, risks being involved in the enzymatic oxidation of fatty acids during malting and mashing-in as well as on the production of precursors of stale flavour aldehydes [78, 79]. More LOX is extracted by fine milling [19], but when the grist is hydrated and mashed-in at pH 5.2, the LOX activity decreases already by 50 % [79]. Extracted LOX is also rapidly inactivated at 63 °C [34]. It was found that upon mashing, only one third of bound LOX is released, whereas LOX, bound in the spent grains is apparently more heat stable with more bound LOX in the spent grains after coarse milling compared with fine milling [1, 2, 80]. The lowest levels of hydroxy fatty acids, resulting from LOX activity, were found for the combination of mashing-in at 60 - 63 °C and under CO_2 atmosphere (anti-oxidative wort production) [16, 21, 77]. Addition of anti-oxidants to the brewing liquor also limits LOX activity [2, 42, 72, 73]. A completely different approach whereby milling and mashing has no effect on the LOX-reaction at mashing-in is to brew with low-LOX or LOX-free malt (barleys characterized by a zero to low LOX-peak-activity towards the end of germination, prior to drying) [22, 31, 62].

In this paper a detailed study of wort and beer characteristics is presented, comparing coarse milling-lautertun operations to fine milling-thinbed filter operations using the optimal conditions for both wort production methods. Beers brewed on pilot scale have been aged and evaluated both sensoryially and analytically.

2 Materials and methods

2.1 Wort production

Conventional wort production – coarse milling

From the same batch of malt, three Pilsner beers have been prepared in our pilot scale brewery of 2 hL (brewing line 2) under the following conditions: 40 kg coarse milled Pilsner malt (2-roller