Some reflections on mashing – Part 1

HIGHLY FLEXIBLE | Despite the fact that malt quality can undergo fluctuations from year to year, brewers are very reluctant to change their mash schedules for fear of the inscrutable consequences this might have on the quality of their beer. But this is precisely what the process of mashing is all about. Mashing is a highly flexible instrument which affords a brewer the capacity to effectively overcome the challenges of contending with difficult malt. Thus, it offers a brewer the means to effectively compensate for the shortcomings of a particular year's crop and, in turn, helps to ensure a consistently high quality product even if the quality of the raw materials does not always remain the same. The mashing process also provides a brewer with a great deal of creative control, which can be harnessed in the development of novel and unique beers – a boon for brewers looking to alleviate monotony in their products. Through a clever combination of rests, the performance of the enzymes derived from the malt can be made to rival any supplemental technical enzymes, and the malt's own enzymes are, of course, fully in compliance with the German Purity Law for Beer.

THE MOST COMMON mashing process for pale lagers and pilsners is known in German as the Hoch-Kurz Maischverfahren (literally "high-short mashing process") [1]. Originally, it was conceived as a double decoction mashing process with the two decoctions being quite short. In brewing, decoction refers to an interval when a portion of the mash is boiled. Nowadays, it is mostly carried out as an infusion mashing procedure (fig. 1). And as the name implies, the procedure is of a relatively brief duration (sometimes less than 60 minutes). The strike water and the grist are mixed so that they come to rest at a relatively high mash-in temperature (62 °C). The high level of acceptance for this mashing procedure in breweries is due to two recent developments: First, technological advances have enabled brewers to conduct mashing with very little, if no, oxygen uptake with the advent of wet milling. A wet mill is essentially a modern mechanical pre-masher of sorts. The mash enters modern mash vessels from below, and with energy-saving measures, an infusion procedure is generally preferred, thus pumping the mash between vessels has little relevance today. Second, the advances in breeding malting barley have fostered the development of high levels of enzyme activity in the malt. One goal of breeding programs with malting barley based on the variety Diamant and its successors, such as Triumph, Alexis, Arena, Dorett, Gimpel, Scarlett, Grace, etc., has been to increase the soluble nitrogen content. This objective, however, seemed to take little heed of the effects this might have on beer foam. Behind this very extensive degradation of raw protein are enzyme potentials (endopeptidases active in the weakly acidic range), whose behavior is attributable to the presence of a sulfhydryl group at the active site. These enzymes are very sensitive to oxidation, and by limiting the influx of oxygen, their activity is preserved, thus leading to an increase in the degradation of protein during mashing. This is apparent in the reduction of nitrogen values as determined with $MgSO_4$ to significantly less than 200 mg/l. The advances made in barley breeding have also found expression in significant increases in grain yield, which resulted in a change in the response to nitrogen fertilization and yield-motivated "protein dilution", which occurs even in years of severe summer drought as long as the precipitation in spring is sufficient to promote tillering. The consequences of this change have been a decline in the formation and stability of foam and high levels of residual FAN after fermentation is complete. These high residual FAN levels compromise flavor stability and also increase susceptibility to infection.

The "high-short" mashing process

The "high-short" mashing process was implemented in order to restrict the activity of the endopeptidases and thus increase the percentage of high molecular weight nitrogen while retaining sufficient FAN formation through the activity of the more thermostable carboxypeptidases. However, the carboxypeptidases are somewhat inhibited, since the endopeptidases largely set the pace of protein degradation, and they have been

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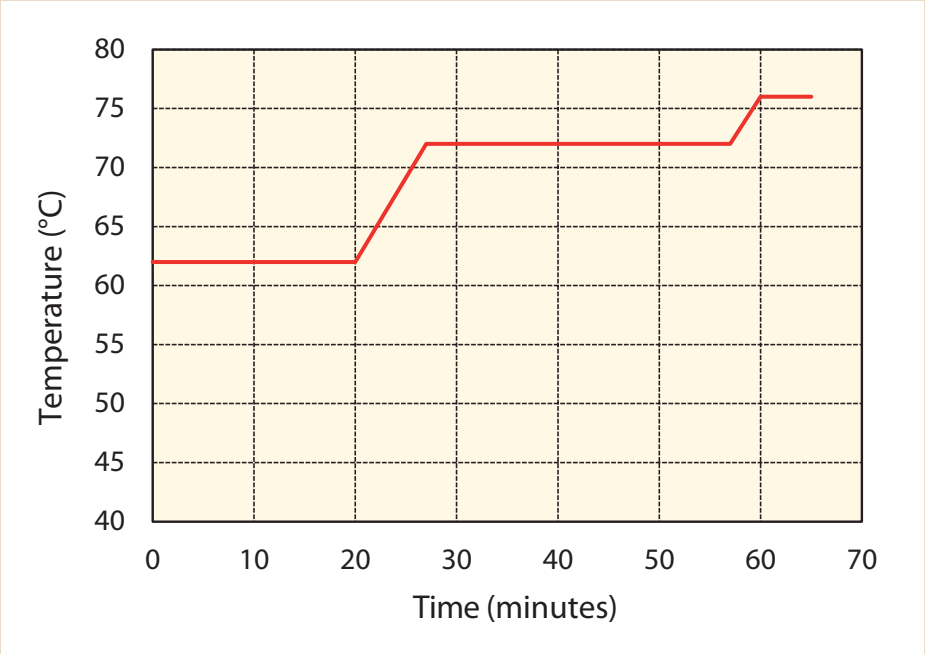

Fig. 1 A modern Hoch-Kurz mashing process performed as infusion

incapacitated by the higher mash-in temperatures. The positive effects are evident in enhanced foam formation and stability, a more pleasant mouthfeel, less residual FAN resulting in a more robust color and improved flavor stability. The latter is also ultimately a consequence of eliminating the lipoxygenase activity (temperature optimum approx. 45 °C), which causes fewer carbonyl compounds to arise from fatty acid oxidation. At 62 °C, the phosphatase activity is very limited. This, in turn, lowers the buffering capacity, resulting in a more rapid drop in pH, a lighter color and greater precipitation of prolamins, a fraction of proteins known to cause haze. Extended amylolytic rests, especially a long dextrin rest, releases glycoproteins in greater numbers, improves foam quality and produces a better mouthfeel in the finished beer. However, since essentially no β-glucan degradation occurs, and conversely, high molecular weight β-glucans are released by β-glucan solubilase at 62 °C, problems can develop during filtration when working with malt with less cytolytic modification. Conducting mashing operations as oxygen-free as possible, notwithstanding the comments above, and adjusting the pH to between 5.4 and 5.5, continues to be considered beneficial.

Mashing performs the task of continuing and correcting the degradation processes which occurred during malting. It also serves to fine-tune the quality of the wort to the style of beer being brewed. The enzyme activity desired during mashing should be encouraged, if possible, while that of undesirable enzymes should either be halted or at the very least slowed. Naturally, the method is also designed to be economical and produce the best possible extract yields. The rate at which enzymatic reactions occur doubles with a temperature increase of 10 K (according to the so-called Van t'Hoff equation). Therefore, at 60 °C, based on a factor with an average doubling of the temperature, the expected reaction rate will be approximately 16-fold compared to the same reaction at a temperature of 20 °C (24 = 16), though synergies, such as gelatinization and enzymes that help determine the rate of the reactions, have not been considered. This explains why correcting or otherwise intervening with mash enzymes is so effective.

RELATION BETWEEN GRIST QUANTITY AND MASH PH

Grist quantity	Mash ph
1 : 2.5	5.39
1 : 3.0	5.48
1 : 3.5	5.54
1 : 4.0	5.60
1 : 4.5	5.65
1 : 5.0	5.70
1 : 5.5	5.74

Table 1

Mash parameters

Adjustment of the mash parameters provides a means for regulating enzyme activity during mashing [2]. Controlling the temperature is of the greatest importance during mashing – both the temperature when mashing-in and during the rests. The former involves bringing the enzymes into solution in the mash at a temperature far below their temperature optima prior to commencing the mashing process. After reaching the actual temperature of the rest, more active molecules of the desired enzymes are available without having been damaged by heat as a result of this gentle procedure. This should increase the rate of enzymatic degradation during mashing. Maintaining the temperature during the rests also aims to directly foster enzyme activity by remaining at the so-called temperature optimum of the enzyme in question. This is defined as the temperature at which the maximum value on the curve of enzymatic activity reaches equilibrium. This equilibrium comprises, on one side, the increase in the rate of the enzymatic reaction as the temperature of the medium increases and, on the other, the decline in the same rate through ever progressing denaturation. Both processes strike a balance at the temperature optimum. Enzymatic degradation, however, depends not only on the activity of the enzyme and the reaction time, but also on the stability of the enzyme under the conditions in the medium. This is called the half-life of the enzyme and refers to the period in which the activity is reduced by thermal denaturation, oxidation and proteolytic degradation to half of its original activity. At the temperature optimum, this is very short, rarely more than 20 minutes. For this reason, the duration of a rest at the enzyme's temperature optimum extending over half an hour makes sense from neither a biological nor an economic standpoint. Attempting to save time during one particular rest, however, should be avoided. In fact, speaking of the economic aspects of mashing, the time saved in curtailing other rests should be "reinvested" in the dextrin rest. At this temperature, starch liquefaction through the action of α-amylase is important for downstream processes, as is the formation of glycoproteins through reactions involving the degradation prod-

ucts of proteins with dextrins. As this rest progresses, there is an added benefit for foam and mouthfeel. This notion should be taken into account when devising mashing procedures of a particularly short duration (due to extremely high malt quality at high levels of enzymatic activity, mash filter flour).

Because of its influence on the structure of the catalyst molecules, the hydrogen ion concentration is almost as important as the temperature. It is affected by the quality of the brewing liquor, additions of acid and the mash concentration. The last parameter is often underestimated, as the accompanying table shows. The ratio of the quantity of grist to that of the mash liquor plays a major role in determining the ultimate pH of the mash through dilution of the acids in the malt (table 1). The choice of infusion or decoction (physical digestion) is an important mash parameter. Not only is the thermal disintegration of inaccessible structures in the endosperm important, but decoction also allows brewers to create new combinations of enzymatic rests – features not offered by infusion. In a true decoction process, substantial portions of the mash are boiled, and despite the partial destruction the enzymes, decoction processes produce beers with remarkably high degrees of attenuation. The reason for this is the staggering of the rests, an aspect of decoction that is impossible with an infusion process. With infusion, the α-amylase is used to set the pace for the enzymatic degradation of the starch only after the -amylase rest has occurred. However, with decoction, by performing a dextrin rest in the mash kettle, along with the associated pre-digestion of the starch, and a subsequent maltose rest with the entire mash in the mash tun (fig. 2), the enzyme activity is arranged in a more efficient sequence, resulting in a significantly higher quantity of fermentable sugars in the wort. Another beneficial feature of decoction is the inactivation of the polyphenol oxidases. This results in polyphenols with a lower polymerization index, thus increasing the antioxidant potential. This effect is even intensified in the second decoction. Furthermore, the inactivation of the endopeptidases in the decoction mash is advantageous for the foam. The lipoxygenases are damaged as well, and this is beneficial for the flavor stability. At this point, it should be noted that actually boiling the separated portion of the mash is not absolutely necessary in order to reap the benefits of decoction mashing. For the sake of energy savings, it is sufficient in most cases to heat the mash in the mash kettle up to 96 °C and hold it there for 5-10 minutes. Knowledge of the enzymatic activity in the mash as well as the targeted adjustment of the mash parameters and how to combine them allows brewers to elegantly resolve issues, which have been recent topics of discussion, such as malt quality, brewhouse processes and the composition of beer. This small contribution should provide some sense of how to confront these issues. These topics will be discussed in the second article appearing in BRAUWELT International no. 6, 2016. ■

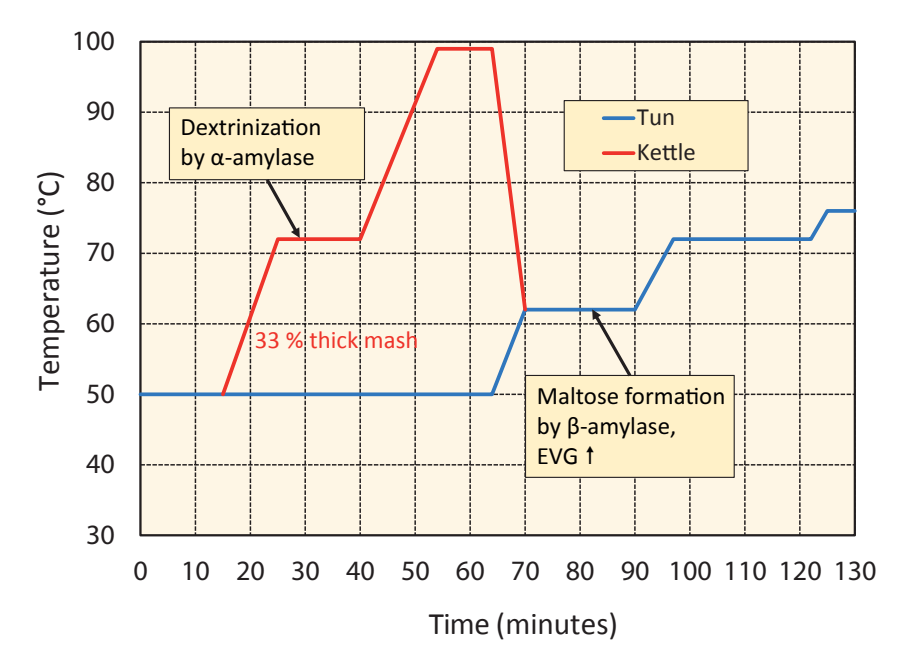

Fig. 2 A single decoction with a subsequent infusion mashing process

Literature

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