Novel Mash Filtration Process (Part 3)

WORT PREPARATION TECHNOLOGY | Development of the new Nessie by Ziemann® lautering system [1] for mash separation is an interesting innovation for the overall techniques and technology of beer production. This paper will present the technological contexts and impacts on surrounding unit operations as well as the effects on wort quality, the ultimate outcome of brewhouse work.

THE PRIMARY objective of a brewery is to produce beer at a consistently high quality in a cost-effective manner. Today's brewing technology can help to achieve this. This technology is characterised by a centuries-old tradition and has reached a high level of development to-date. High-quality raw materials such as homogeneous, enzyme-rich malts are available. New high-yield hop varieties provide high alpha-acid contents or a wide range of flavours. The objective is to optimise the brewing process using these raw materials. It is thus possible to shorten the mashing process. The trend is towards infusion processes. Lautering is the longest process step, representing the limiting factor in the brewhouse. Current wort boiling systems have a high level of technical sophistication, reflected in gentle boiling processes (very good foam, low TBI). Fermentation and conditioning are often accelerated processes. For capacity reasons, the trend is towards large tanks, using moderate pressures in combination with a suitable pitching technology.

Lautering is currently the process step that sets the pace in the brewhouse. Lauter tuns and mash filters are highly developed separation systems with almost exhausted potential. The idea thus emerged to optimise the lautering process by developing a novel separation system based on know-how and findings of process and brewing technology. The function and design of this system have already been described [1, 4].

These and the following papers describe the effects of this novel separation system on the surrounding process steps (milling, mashing, boiling, fermentation, filtration). The numerous findings presented are based on trials on a pilot and on industrial scales from ten to 140 hectolitres.

Milling

Size reduction of malt is of crucial importance for material conversion in the downstream mashing process and for extract recovery during lautering. Optimal milling should produce maximum extract together with high-quality wort composition. Lautering should take place quickly and produce maximum yields. First and second

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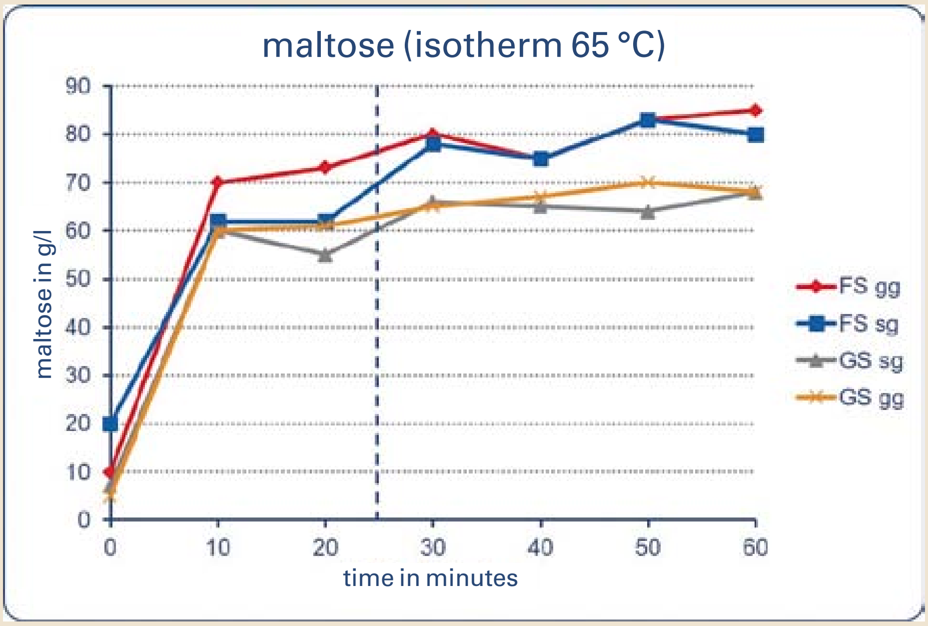

Fig. 1 Maltose formation is completed after 20 to 30 minutes, regardless of grist fineness (FS = fine grist, GS = coarse grist) and malt modification (gg = good modification, sg = poor modification)

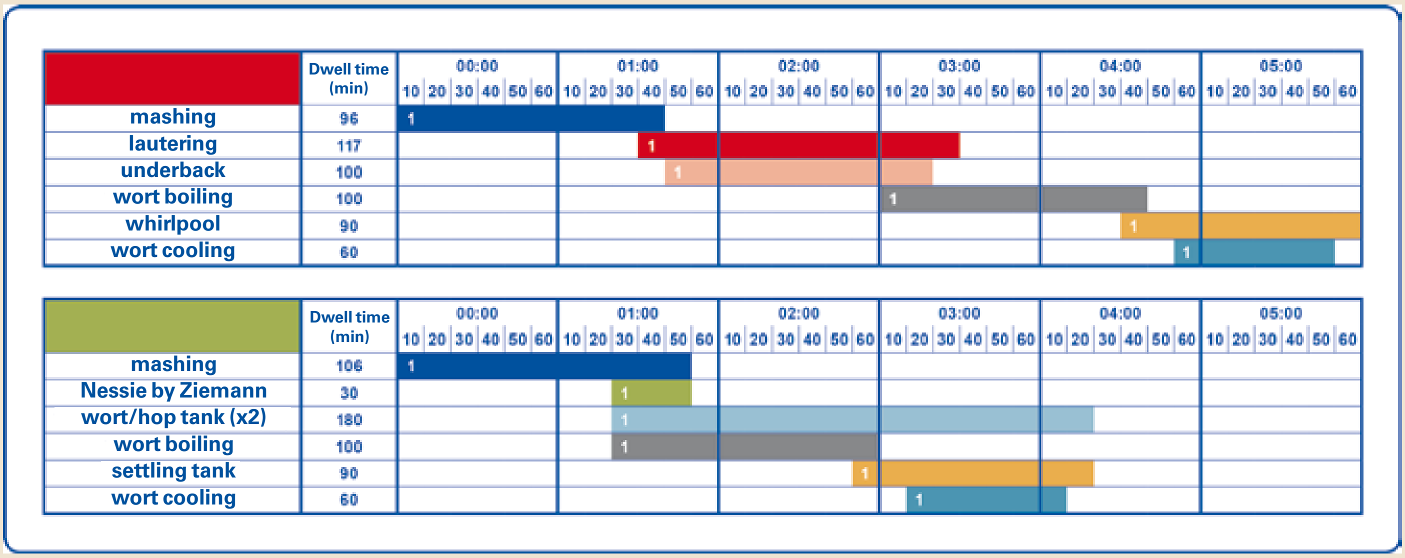

Fig. 2 By shortening overall process time in the brewhouse, the Nessie system (bottom) allows greater flexibility in brewhouse operation compared to the conventional system (top)

worts should be finished within less than two hours. Grist fineness and the lautering system are interlinked up to this day.

The lauter tun requires relatively coarse grist. Husks in the spent grains are responsible for formation of a porous and very permeable layer of spent grains. The finer the milling of husks, the less permeable will be the layer of spent grains. This is particularly important for high-performance lauter tuns (up to 14 brews in 24 hours). The basic requirement is to preserve a husk ratio of about 18 to 25 per cent. Not only are pure husks important but also a specific percentage of grits are required to act as "spacers". Preserved and well-ground husks result in a high husk volume (target > 700 ml/100 g). The powder flour fraction is important for grist composition.

Extensive grinding of the malt endosperm is conducive to providing enzymes with a point of attack during mashing but permeability of the layer of spent grains is reduced considerably. When grist is too fine, there is a risk of incomplete or at least impaired leaching. As a result, raking technique has to be optimised in the presence of a decreasing husk ratio or another separation procedure has to be used as an alternative to the lauter tun, such as a state-of-the-art mash filter (thin-layer filter) that can process powder grist passing 70 per cent < 150 µm. The novel Nessie filtration system operates independently of grist composition and malt modification due to its separation properties. Conventional limitations involving lauter tun and mash filter, such as choice of grinding system and type of raw material, do not affect the novel filtration system. Higher raw material ratios can also be processed (see other publications).

Well-modified barley malt crushed with a 6-roller mill gave rise to the results presented below. The tests were carried out in parallel to lauter tun operation.

Mashing

The mashing process is deemed very important in brewhouse operation. The main objective is to convert compounds already soluble into solution and to use enzymes to break down insoluble compounds. Fast modification of malt components and complete conversion are the basis for wort composition and thus for beer type and beer quality. Parameters are temperature, time, pH value and grist fineness. Reaction kinetic tests [2] have shown that maltose formation is completed after 20 to 30 minutes, regardless of grist fineness and malt modification (Fig. 1). Similar reaction times apply to proteolysis and – given good malt quality – also for cytolysis.

As a result, shorter mashing times can be achieved. In the present series of tests, a high-short mashing process (mashing-in temperature 62 °C, maltose rest at 65 °C) was used. Mashing with Nessie took 75 minutes, 15 minutes less than the brews produced in the lauter tun (90 minutes), as the latter were mashed off at 77 °C (Nessie system 72 °C).

Lautering

The process time for the Nessie system is 30 to 60 minutes. The lautering process using a lauter tun or mash filter includes two steps:

1. filtration;
2. sparging.

The objective is to separate the mash as quickly as possible into wort and spent grains while obtaining a high-quality wort with minimal residual extract in the spent grains.

With the new filtration procedure, this objective is achieved in a single unit operation: solid-liquid separation of the mash is done by passing it through four rotary screen filters in cascade arrangement, by means of filtration and simultaneous extraction in counter-current flow.

To assess the Nessie system, three criteria are taken into account:

- capacity (hl/brew);
- quantity (yield);
- quality (wort/beer).

The capacity of the new lautering system (see hl/brew) corresponds to today's common sizes. The system can be extended by placing filters per shaft and stage in parallel.

Wort preparation, from mashing to wort cooling, normally takes six hours when using a lauter tun with twelve brews per day and a dwell time of 117 minutes. Thanks to the new brewhouse concept, the entire process can be reduced to four hours and 20 minutes, corresponding to savings of 100 minutes or almost 30 per cent achieved by shortening mashing and, in particular, separation time (Fig. 2). This results in a greater flexibility in brewhouse scheduling.

For assessment of quantity, spent grains analyses is suitable. As defined in DIN 8777

COMMERCIAL-SCALE VALUES FOR YIELD ACHIEVED WITH THE NESSIE SYSTEM – ANALYSES OF SPENT GRAINS COMPARED TO STANDARD VALUES

Parameter	Nessie	Standard values (LT)
Water content [%]	< 80	80
Total extract [%]	0.8	1.6
Extract rinsable air-dry [%]	0.6	0.8
Extract leachable air-dry [%]	0.2	0.8
Iodine value [dE578nm]	1.8	< 3

Table 1

COMMERCIAL-SCALE VALUES FOR WORT QUALITY (HALF-TIME COOLING) IN THE NESSIE SYSTEM – DIRECT COMPARISON WITH ADEQUATE LAUTER TUN OPERATION

Parameter	Nessie system	Lauter tun
Colour [EBC]	5.5	7.3
TBI [-]	38	50
TBI Increase [-]	18	30
Furfural [µg/l]	212	431
Viscosity [mPas]	1.80	2.10
Total N [mg/100 ml]	120	113
$MgSO_4$-N [mg/100ml]	25	26
FAN [mg/100 ml]	22	25
Coag. N [mg/100 ml]	1.6	1.1
Polyphenols [mg/l]	142	240
Anthocyanogens [mg/l]	58	92
Tannoids [mg/l]	22	85
Si-ions [mg/l]	9	14
Iodine value [dE 578 nm]	0.18	0.70
Zinc [mg/l]	0.63	0.01
C 18_1/2/3 [mg/100 ml]	2.00	0.12

Table 2

or the MEBAK Guidelines, it is indispensable to determine extract yield from loss of spent grains alone [3]. Nessie produces higher yields. This is evidenced in low extract yields of the spent grains (rinsable, digestible) which are considerably lower than standard MEBAK values (Tab 1).

Wort Boiling

The well-known tasks of wort boiling – evaporation of water to obtain the required wort concentration, precipitation of proteins, dissolution and isomerisation of hop bitter substances, inactivation of enzymes and stabilisation of wort, driving off volatile substances and formation of Maillard products – can be achieved with currently available boiling systems. Issues of minimum evaporation, thermal loads and homogeneity have also been largely solved.

In the trials covered, boiling time was 60 minutes (internal boiler) and evaporation four to five per cent. The trials were carried out under standard technological conditions.

The above tasks remain the same, also when using the Nessie system.

This novel separation procedure means moving in new technological directions. The following modules were added to the brewhouse (Fig. 3):

I. dosage of a malt extract (2 %) at 85 °C after boiling to ensure low iodine values;
II. separate external hop isomerisation (atmospheric, ≤100 °C) and dosage after trub removal to raise hop yield [4];
III. controlled trub removal in the settling tank to preserve physiologically important components (85 °C).

These three modules will be explained in more detail in a subsequent article.

Hot Break / Cold Break Removal

The amount of resulting hot break depends on factors such as malt modification, mashing procedure, lauter turbidity and boiling parameters. For years, the requirement of 100 per cent removal was considered a technological "must" (see "smudging" of yeast cell surfaces). Optimisations in lauter technology and hot break separation have resulted in low-lipid worts in recent years. On the one hand, the relevant fatty acids introduced by the mash (C16, C18, C18:1-3) are retained on the spent grains filter bed, especially by the upper dough [5, 6]. On the other hand, the trub (hot and cold break) adsorbs a large proportion of fatty acids still present after boiling [7]. As a result, fermentation slows down as long-chain unsaturated fatty acids – in the form of lipids in the yeast cell membrane – promote absorption and transport of nutrients, such as α-amino nitrogen (FAN) and phosphate. In the case of a negative balance, yeast multiplication requires an even greater synthesis of these fatty acids in the presence of oxygen. The same applies to zinc, an essential trace element for yeast metabolism. It promotes cell multiplication and protein synthesis and has a crucial role in the rate of sugar degradation. Malt contributes enough zinc into the mashing process, but a large proportion of this is adsorbed by spent grains or, subsequently, by the trub. It is no longer available to the yeast. This led to the idea of leaving a certain percentage of trub, which collected in the settling tank, in the wort.

To analyse wort quality, analysis data from half-time cooling worts (KM) (Tab. 2) can be used. Most analysis criteria have been met to date, e.g., the N contents (total N, $MgSO_4$ N, FAN). Coagulable N, DMS (dimethyl sulphide) are within the common range. The following characteristics are worth emphasising:

The KM worts in the Nessie brews are considerably brighter compared to the lauter tun worts (5.5/7.3 EBC). The TBI is strikingly lower, both in the increase from pfannevoll to half-time of wort cooling, as well as in absolute values (38/50). This means that thermal load could be further reduced during trub removal in the settling tank due to the short separation time and the low tem-

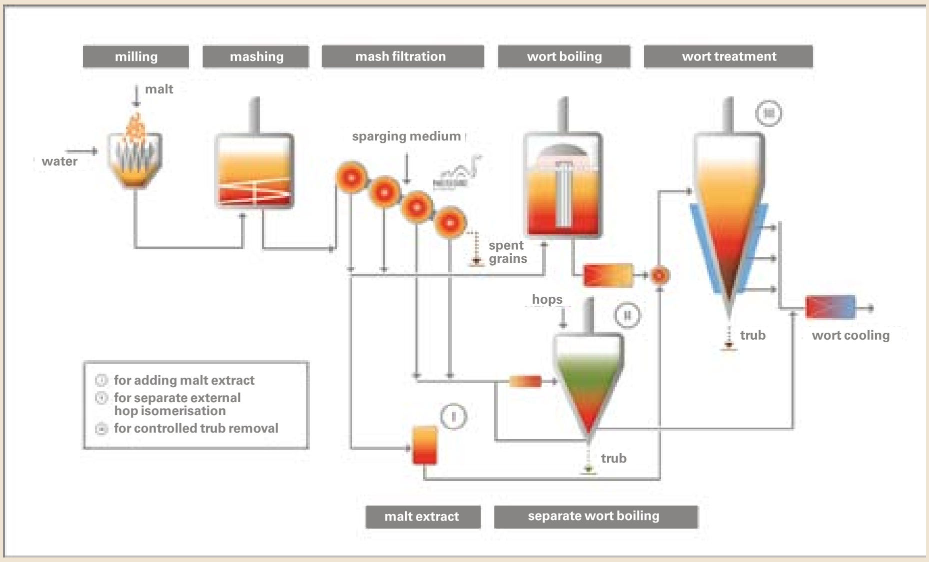

Fig. 3 The Nessie system is integrated in an extended brewhouse design

perature of 85 °C. This is also confirmed by the low furfural content and suggests a positive effect on flavour stability.

The favourable viscosity of 1.80 mPas compared to the lauter tun values of 2.10 mPas is presumably achieved by degradation of α-glucans still present, adding malt extract after boiling. This could improve filterability of beers even further.

Tannins are reduced by approx. 40 per cent. Silicon content in Nessie worts is also reduced. This can be attributed to the shorter contact time during mash separation and thus reduced leaching from the husks. Dwell time of a mash particle in the separation system is between three and five minutes. This has a positive effect on colour. The iodine value is kept very low by dosing malt extract after boiling. As a result, risks associated with a high iodine value (microbiological instability, turbidity, filtration problems and deterioration of flavour) [8] can be eliminated. The trace element zinc rises to a very high level of 0.63 mg/l, otherwise not possible in the brewhouse within the scope of the German Beer Purity Law. The target is to achieve a minimum concentration of 0.15 mg/l in the cast wort for rapid primary fermentation, good yeast multiplication and complete breakdown of diacetyl. Thanks to this new separation technique, zinc released during mashing is largely preserved as it is not retained by the spent grains layers. The same applies to long-chain unsaturated fatty acids (2.0/0.12 mg/100 ml). In addition, targeted trub adjustment after the settling tank makes it possible to preserve the amount of zinc and fatty acids desirable for yeast metabolism.

Conclusion

Development of the novel Nessie by Ziemann lautering system for mash separation opens up new possibilities for optimising the brewing process. The effects are reflected in a shortened process time for wort preparation, reduced thermal load, lower iodine values, increased hop yield and an optimised nutrient supply for yeast. The positive effects on beer quality are set out in the subsequent articles.

Sources

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