A Novel Mash Filtration Process (Part 2)

FRACTIONAL WORT BOILING | In the first article of this series, published in BRAUWELT International No. 3, 2017, equipment and the Nessie by Ziemann mash filtration procedure were presented. Part 2 considers the effects of the novel wort composition on hop dosing. For this purpose, individual wort parameters and their effects on hop yield, an experimental test series of the disperse system and alternative wort treatment processes are described in more detail.

HOPS ARE AN ESSENTIAL raw material in beer production. Hops contribute to the character of beer. Secondary metabolites, such as bitter substances, essential oils or polyphenols in particular, are of prime importance. Bitter substances, especially isomerised α-acids, give beer its typical bitter flavour, promote and stabilise beer foam and act as a natural preservative. In the brewing process, it is not possible to make optimal use of these bittering agents. As a result, the amount of hops to be added for obtaining the desired bitterness units – giving information about overall bittering yield in boiled wort – is higher than the actual yield of isomerised α-acids. The "Green Gold" therefore accounts for a significant proportion of production costs of beer. This means that it is desirable to increase yield of isomerised α-acids in order to reduce costs required to produce a hectolitre of beer.

Isomerisation Is a Must!

Several aspects are involved in improving yield. In boiling wort, α-acids (humulones) and their homologues are limited in terms of solubility due to the pH value of the wort. When pH goes up, solubility also improves. Thermal energy brings about changes in the optical active hexacyclic compounds of α-acids, transforming them into a five-ring structure [1]. As a result, more advantageous cis- and trans-iso-α-acids are formed. In view of polarity increase caused by the new arrangement, these acids have a higher affinity for water. They are thus soluble in water and have the maximum potential for producing beer bitters. During this process, β-acids oxidise to hulupones which – in contrast to their original form – can make only a limited contribution to bitterness in beer. They are thus of no consequence.

Losses During Brewing

Loss of bitter acids during beer production is a problem. Bitter acids decrease from hops to cold wort by some 50 per cent. First of all, they isomerise incompletely, remaining as α-acids in the wort. Secondly, losses occur via trub. Bitter substances may play a role in trub formation via ionic interactions or can be carried along by coagulated proteins. In the continuous process (cold area), another 20 per cent (approx.) of this initial 50 per cent are lost from cold wort to finished beer as a result of a drop in pH, absorption or precipitation. In total, only less than 40 per cent of the initial amount of α-acids remains available for the bitters in finished beer [2]. This is not profitable but is still done.

The question arises which parameters can increase hop yield. The following paragraphs mainly focus on the hot section. Fermentation is not considered in detail.

Parameters That Influence Hop Yield

Given a yield of around 50 per cent up to the cold wort [2], isomerisation does not take place to the desired degree. There are many reasons for this.

On the one hand, influencing factors can be found in the hops as such. In other words, variety, hop product, ageing of hops and

Fig. 1: Novel mash filtration system – wheel 1 (left) to wheel 4 (right)

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amount added have an effect on isomerisation. On the other hand, wort composition, pH value and original gravity, as well as boiling parameters, play a decisive role. During boiling, hop dosing time, boiling time and temperature are important. Generally speaking, one should aim at achieving isomerisation over a long boiling time and at a high temperature of up to 106 °C [2, 3]. Degradation of α-acids already isomerised at high boiling temperatures has to be taken into account [4].

An alkaline pH value in the wort promotes isomerisation due to better solubility. The disadvantage of alkaline transformation is to be seen in the continuation of isomerisation via isohumulones, resulting in undesirable compounds. In addition, Maillard products intensify colouration of wort and bitterness takes on an unpleasant note [3, 5].

Another effect arises as the result of the combination of the factors temperature and pH value. Lowering temperature at a constant pH of 5 leads to a reduction in solubility of α-acids [2]. In terms of original gravity, the following rule applies: the lower, the better isomerisation.

Calcium and magnesium in particular are natural catalysts for isomerisation due to their toxicological inertness. They act as a catalyst directly in transformation to isohumulones between pH 4 and 8. According to *Koller* et al. [5], magnesium should be added at pH 7 to raise isomerisation rate. According to the German Purity Law, addition is, however, not allowed. Consequently, wort containing a higher amount of these minerals without requiring additives is desirable for the beer production process. Given the above optimisation potentials (temperature, time, pH, minerals, etc.), the challenge is to integrate them into the brewing process in order to achieve a higher isomerisation rate. The problem is that, in a standard brewing process, original gravity is between 13 °P and 14 °P, with a pH of approx. 5.40. A compromise concerning optimum temperature has also to be found between increasing isomerisation and preventing degradation of α-acids already isomerised.

Wort – A Disperse System

Wort is a disperse system consisting of a large number of individual particles (solid particles), the disperse phase and the surrounding medium – the continuous phase [6]. Nessie by Ziemann, the novel mash filtration system (Fig. 1), produces wort that can be classified as a coarse disperse system. As the tests listed below demonstrate, particles above 1 µm predominate.

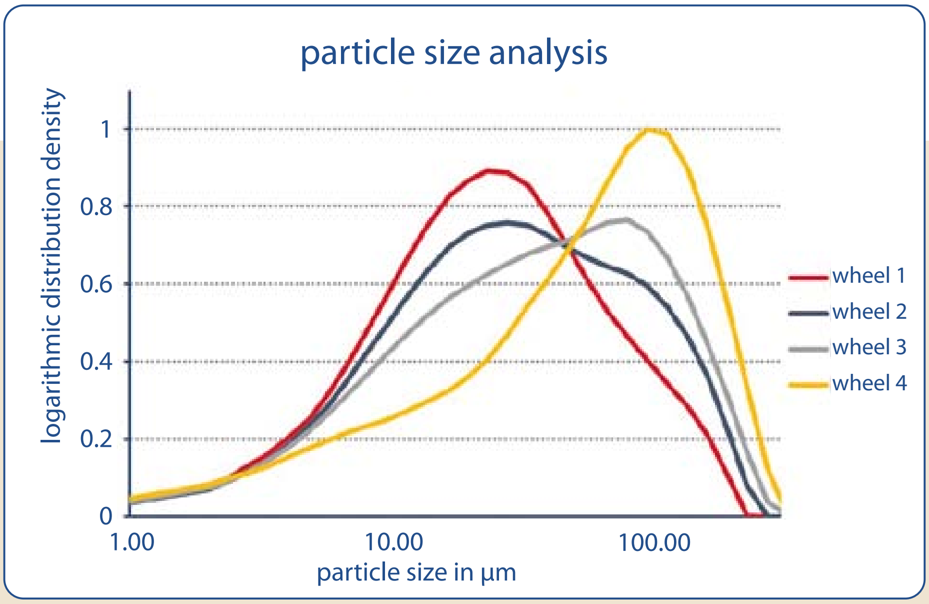

Fig. 2 Logarithmic distribution density of particle size analyses of the novel mash filtration system – wheel 1 to wheel 4

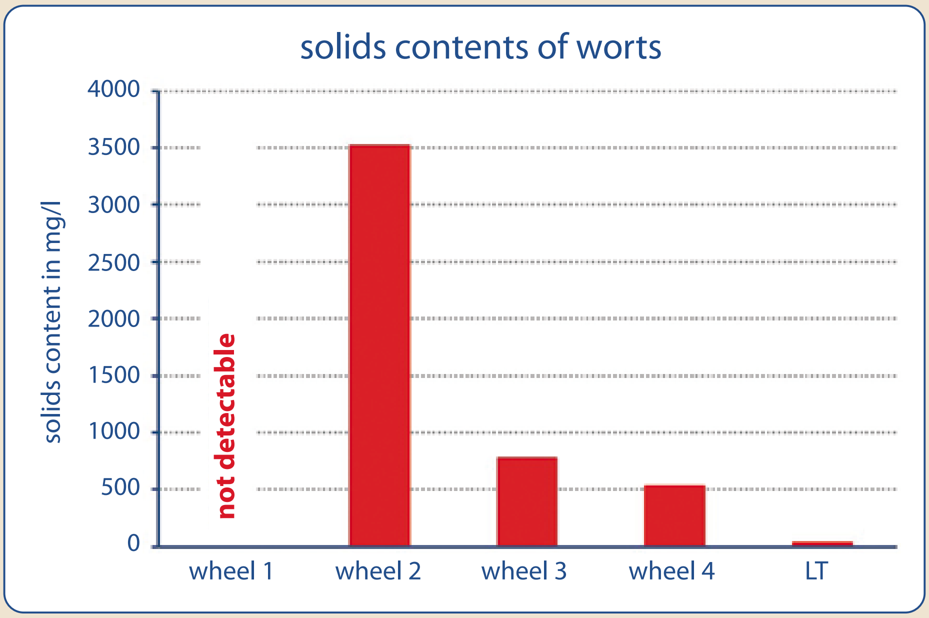

Fig. 3 Solids content of the individual rotary disk filter worts compared to the pfannevoll wort of a lauter tun

Preliminary tests with the novel mashing system have shown that worts contain a higher amount of particles and are thus cloudier compared to a lauter tun brew. This is desirable as wort with a higher mineral content and more fatty acids has a positive effect on the downstream process. The particle richness of the wort was taken as an opportunity to carry out tests which focus on these particles and compare hop yields.

In order to be able to estimate the size of the various particles in the cloudy rotary disk filter worts, particle size analysis is required using a laser diffraction spectrometer. A newly developed method was used for the Sympatec Helos system with the Sucell dispersing unit.

Fig. 2 shows the logarithmic distribution densities for the particle size in µm. Note the logarithmic plot on the x-axis. The chart shows a clear distribution of particle sizes from the second wort from wheel 3 and wheel 4 towards larger particles. In comparison, tests in which isomerisation rates of hops in the individual worts were determined from wheel 1 to wheel 4 also showed an increase from wheel to wheel. In two of the four samples, hop yield was higher than that in a comparable brew produced with a lauter tun. Based on the findings from the two tests, particle ranges can be derived, which tend to have a rather positive or rather negative effect on hop yield. The size range between 1 µm

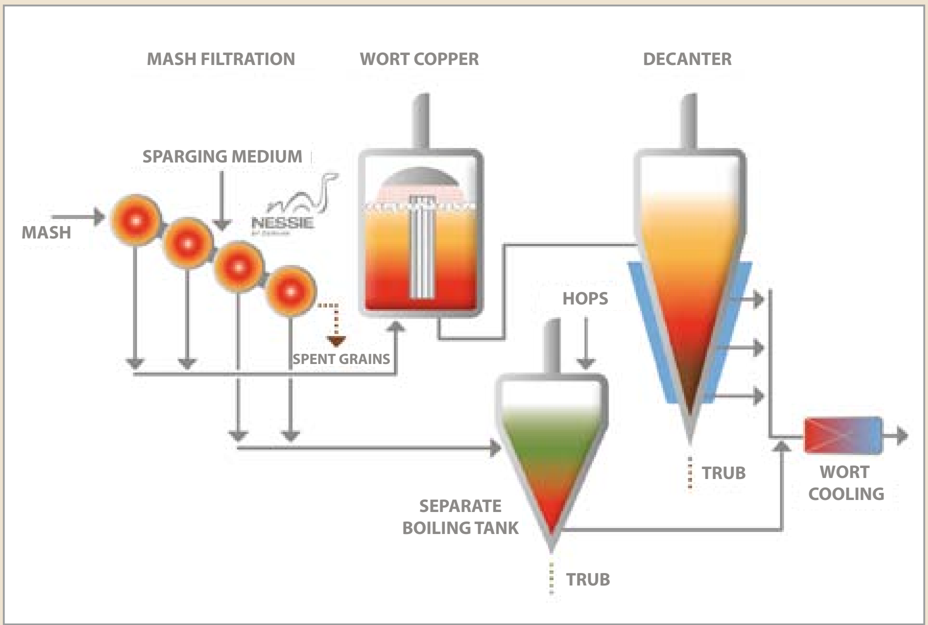

Fig. 4: Wort flow distribution of the novel mash filtration system for fractional wort boiling

and 40 µm (here referred to as fine particles) had a negative effect on isomerisation rate, whereas the range between 40 µm and 400 µm (here referred to as coarse particles) did not impair or even improve isomerisation.

A further analysis – determination of the solids content (field method) [7] – also showed that the mass of solids does not have a direct impact on isomerisation rate. Fig. 3 shows the results of solids determination in mg of solids per litre of sample volume. In percentage terms, the pfannevoll wort of a lauter tun brew (LT) has only seven per cent of the particles from the second wort from wheel 4, having the lowest particle load of all rotary disk filter worts. Yield of iso-α-acids, however, was more than double the amount in a particle-rich sample from wheel 4 than in a comparable lauter tun brew.

As the test series shows, specific ranges of particle sizes play a role in isomerisation of α-acids, in addition to the previously mentioned factors (temperature, pH value, minerals, etc.) and not the solids content.

Hops in the Brewing Process

It is well known that the efficiency of hop dosage can fundamentally be improved by adding hops that have been pre-isomerised into a hopping tank or by using a hop product already pre-isomerised [8]. At this point, these two variants are not considered in detail. Based on the tests described above with the novel mash filtration system, another opportunity to make optimal use of hops presents itself: fractional wort boiling. The fractions of the wort have to be separated and treated according to their chemical-physical properties and the respective tasks, as shown in Fig. 4. For hop isomerisation, the second worts can be used as fluids. They have benefits in terms of lower original gravity and a pH value which is in the slightly alkaline range due to additional sparging water. In addition, an increased level of positively acting minerals in the wort of the novel mash filtration system, such as magnesium and calcium, also contributes to raising isomerisation.

Extension of isomerisation time because unit operations run in parallel is a positive side effect of a separate tank with a cone (Fig. 4). For isomerisation of α-acids, not only boiling time of the remaining wort fractions (pfannevoll wort) but also sedimentation time in the whirlpool/settlement decanter is available. After the hop trub has settled in the cone of the separate boiling tank, wort fractions can be merged and cooled.

Conclusion

A hop yield of only up to 40 per cent [2] in beer is not economically acceptable. To-date, the literature describes many approaches for raising hop yield. However, opinions differ as to the parameters to be set during hop dosing, especially time of hop dosing [8].

In the near future, we are seeking to carry out targeted tests which will take into account all hop-influencing parameters of the boiling fluid used, such as boiling time, boiling temperature, pH value, original gravity, mineral content and distribution of particle sizes as new influencing factors, in order to be able to demonstrate a possible maximum hop yield.

The wort from Nessie has already laid the foundation for more beneficial wort to raise hop yields. In combination with fractional wort boiling, prospects for a higher hop yield look very promising. ■

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