High Gravity Brewing

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ABSTRACT

Right after the second world war the High Gravity Brewing was applied in America. It then became popular in Europe and Africa as well. The system of High Gravity Brewing has been subject to increased attention in the recent past. This is due on the one hand to the altered legislature for beer duty in the EC and in Germany which now allows for possibilities of brewing beer according to this system, and on the other hand, to the fact that Eastern Europe and Asia are experiencing a strong boom on their beer markets calling for a rapid increase in brewing capacity. This coincides with improvements and further developments on the plant engineering sector. In the following article, individual production steps are elaborated on, mechanical and technical plant equipment for High Gravity Brewing is introduced and economic aspects are examined.

PART 1: REFLECTIONS TO HIGH GRAVITY BREWING

Brewhouse Area

Naturally, all raw material (water, malt, blending agents, hop, yeast) is subject to meet the same high standards applicable in conventional beer production. It is advantageous, however, to use malts containing particularly high amounts of amyloid enzymes.

Mashing

For an equal brew number, the mill room must feature higher capacities in order to be in a position to process the higher grist. In the mashing process, the mash system is responsible for the mash concentration. For this reason ratios of grist to mash liquor of less than 1 part to 2.5 parts can hardly be illustrated; a value of 1:3 should be aimed at. When using a slightly modified mash program (shorter peptonizing rest at a slightly higher temperature, longer time of saccharification) no problems have to be expected.

Lautering

There are special requirements on lautering, but the lautering capacity actually causes a bottleneck. Thus, a higher grist needs to be processed on the one hand while using the same quantity of mash liquor on the other, whereby the yield should be right as well. In the lauter tun the grains resistance rises, there are smaller proportions of sparging liquors due to the higher mash liquor, for which reasons a comparable yield can be produced only if the (higher concentrated) last runnings are reused in the single mash process. Here it could be advisable to filter the last runnings prior to further processing via activated carbon in order to remove unfavorable substances (1). By means of a modified lautering process (e.g. continuous raking and sparging) the same net lautering time can be reached as in the conventional process. Certainly highest attention has to be paid to the quality of the grist to receive equally bright wort.

The older kinds of mash filters are less suitable for the production of High Gravity Worts; the new generation, however, is particularly suitable for this purpose (1).

Independent of the lautering system it is essential that strict attention be paid to the lautering process when producing High Gravity Worts. Here it proves favorable for the quality of beer if the oxygen pick-up in the lautering process is kept at a minimum level by using deaerated water for the spargings. Measurements of oxygen in brewing and sparging liquor have shown oxygen contents of 0.9 to 2.5 mg/l. Thus, oxygenic water influences the color of beer, e.g. a content of 0.2 mg/l O₂ in the water results in a beer color of 5.5 EBC units, 1.0 mg/l O₂ results in 6.0 EBC units and a content of 3.0 mg/l O₂ in the water results in a beer color of 7.0 EBC units.

Furthermore, negative effects are given by foam, bitterness and stability.

Boiling

While boiling is preferable to reach the same evaporation rate as in the conventional process, it should be as intensive as pos-
sible to receive a good protein flocculation. Provided, if permitted, syrup or liquid sugar can be added towards the end of the boiling period. The advantage here is that the wort from the lauter does not need to be as strong and, accordingly, the lauter process may proceed in a "more normal" fashion. In lieu of the higher dose of approx. 50% the yield of bitter substances is worse. When applying hopping of the first wort (up to 50% of the total dose) and/or cold hopping (iso-extract-dosage after fermentation) the hop addition may turn out to be normal; the yield will improve accordingly.

Cooling

The trub separation can be improved by the geometry of the vessel or whirlpool installations (1). As more and extract richer trub results, it proves favorable to feed this with the sparging liquors when lautering, as long as the lauter system will cause no restrictions here.

Variations

To avoid an oxalate turbidity in the bottled beer, calcium chloride can be added to the brewing liquor. For more unfavorable pH-ratios it may be also necessary to take corrective action by means of biological acidification or phosphoric acid additions (if permitted). By using special malts (e.g. "Cara-malts") and/or special syrups/sugar, the taste of beer can be influenced greatly. Due to the different results it is, therefore, possible to use one "original" beer for making a number of beers differing in strength and flavor.

Functional scheme

A possible functional scheme for a 10-ton brewhouse could be the mashing of the 10 tons grist with a mash liquor of 255.6 bbl(US). For 340.8 bbl(US) of sparging liquors and an evaporation of 10% while boiling, a wort quantity of 481.4 bbl(US) with 13.3% of original wort results. When adding sugar (1.500 kg) the pitching concentration could be increased to 16% (481.4 bbl(US)).

Fermentation / Maturation / Storage Area

Aerating, Pitching

As usual in beer production aerating and pitching of the High Gravity Worts require utmost attention. Here it is recommendable to use the latest machinery developed so that a dispersement of air and yeast in the wort may be obtained. The corresponding quantity of yeast is to be dosed as exact as possible. This is to ensure that a sufficient propagation of yeast and fermentation can be obtained.

Fermentation

With the corresponding pitching technology the High Gravity Wort ferments in the same time as in the conventional process. It can prove to be advantageous to aerate again in the fermentation tank after 3 - 4 days (approx. 1/3 reduction of extract). Thus, the spectrum of the fermentation by-products can be influenced positively (1).

Storage

There is no difference in maturation and storage between High Gravity Green Beer and the conventional process. It is recommendable to pay attention to a clean yeast crop to avoid the autolysation of the yeast with the corresponding amino nitrogen involvement in the beer. For this reason, the yeast should be racked very carefully at the end of the fermentation, maturation and chill-stabilization phases.

Functional scheme

A possible process scheme could be the pitching with 20 - 25 million yeast cells per ml of wort, aeration with 8 - 10 mg of oxygen per liter of wort, a fermentation period of 7 days at approx. 10°C, yeast cropping for pitching again, 7 days of maturing at approx. 5°C (possibly in the same tank), yeast cropping, chilling in a deep cooler to about -1.5°C, 7 days storage, yeast cropping, filtration.

If the above-mentioned requirements are observed, then it is possible to have the High Gravity Beer ready for filtration about 3 weeks later.

Filtration, Dilution

This is the phase of the beer production where the dilution of the High Gravity Beer to a sales beer is performed. The dilution can take place before or after the filtration.

The dilution takes place with water which is subject to special requirements. Thus, it needs to meet brewing liquor quality and should be softened if required. It must be absolutely free of dirt, odor and germs, i.e. it must be sterile filtered or UV-radiated. The oxygen content has to be below 0.1mg/l, for which reason it has to be deaerated.

For the dilution prior to filtration the filter capacity must be large enough accordingly. It proves to be disadvantageous here that the blending ratio cannot be set exactly, as the content of original gravity in hazy beer cannot be measured in-line and a corresponding measurement by the filter cannot be used for controlling the blending because of the lengthy control distance. On the other hand, biological safety increases should the dilution water prove not to be okay.

The dilution after filtration poses a second possibility. In comparison, a smaller filter capacity is needed here. It is not smaller, however in the same ratio as the quantity of High Gravity Beer to be filtrated to the quantity of pre-diluted beer. This is simply due to the fact that stronger beers are more difficult to filtrate respectively that the ratio bbl of filtered beer to m² of filter area with higher beer concentration becomes worse. In a sense this may be compensated by a modified kieselguhr mixture and, if legally permitted, by addition of enzymes. The clear advantage featured in dilution after filtration is that the beer concentration can be set quite exactly via an automatic in-line-original-gravity-measuring system.

As is the case so often, a further possibility lies in between. It utilizes the advantages of the above versions leaving the disadvantages to dwindle. By means of a simple ratio control, part of the dilution water as well as the first and the last runnings are added to the High Gravity Beer prior to filtration. As dilution water is already used for the pre-coating and the start of the filters, the first first and last last runnings can thus be used also.

After filtration, the desired concentration of the beer is then set exactly in an automatic blending unit via an in-line measurement...
of the original gravity. It should be noted in this procedure, that the dilution water added prior to filtration as well as the filter first and last runnings should be rather cold. The dilution water added after the filtration can be warmer. After blending the CO₂-content in the beer is adjusted exactly in an automatic carbonation unit. Then, the diluted, carbonated beer is cooled down rather low (-1.5°C). It is now ready for filling.

Second lagering

It is recommendable to restore the deep-cooled beer in the bright beer tanks for another 2 or 3 days. Especially where high rates of dilution are applied, this has a favorable effect on the enhancement of taste, odor and sparkle. The storage in bright beer tanks is of practical importance insofar as the fermentation and storage periods are fixed via the production scheme which is exactly preset. The function of the storage tank farm as a buffer in case of variations in the output is thus eliminated, it is now taken over by the bright beer tank farm. Thus, superior and unfailing qualities of beer can be produced.

Variations

Attention must be paid to the fact that the pH-value of the beer should be in the normal range of pH 4.2 - 4.6. The buffer capacity of the High Gravity Beer can decrease depending on the raw materials used and their relation to each other, so that in case of heavy dilution, effects on the beer-pH can not be excluded. In this case, as already mentioned earlier, corrective action (acidification in the brewhouse) is in order.

Functional scheme

The practical procedure in filtration could be as follows: Dilution of the unfiltered beer from about 16% of original gravity to about 13% of original gravity with cold filter first and last runnings and dilution water by means of a simple ratio control. Filtration of the pre-diluted beer by a kieselguhr-filter, possibly a PVPP-filter and a final filter. An additional stabilization could take place by adding silica gel to kieselguhr. After filtration addition of further dilution water in an automatic blending unit with an in-line measuring-system for original gravity, while precisely adjusting the original gravity in the beer to 10.5% for example. Afterwards automatic carbonization to 5.5 g CO₂/l and cooling down of the beer to approx. -1.5°C.

PART 2: MECHANICAL AND PROCESS SYSTEM EQUIPMENT FOR HGB

Independent of the High Gravity Brewing, the application of deaerated water for the sparging liquors for lautering is advisable at all times, so that except for the capacity relations, there will be no differences in the brewhouse area.

In the fermentation / maturation / storage area there are also no differences in process technology. It is advisable, however, to verify the yeast dosage and wort aeration system and possibly replace by newly developed systems, as deficiencies in the working manner do result in strong (and negative) consequences for the quality of the beer.

In the filtration area, however, there will be several changes compared with the conventional brewing technology.

For the production of the dilution water a water deaeration unit with a sterile filter or a combined UV-sterilizing-system should be used.

There are different deaeration systems on the market, i.e. a 2-stage cold or hot spray deaeration under vacuum and slight CO₂-aeration. Others are a 1-stage hot drizzle deaeration with CO₂-injection or a 2-stage warm rinse deaeration in a packed column.

They all should work in such a manner that with a water temperature of 10°C and up, the remaining CO₂-content in the water measures less than 0.05 mg/l.
For pre-dilution of the beer a simple blending device with ratio control is used. It can be equipped additionally with a manually adjustable carbonizing nozzle for pre-carbonization of the precoating and the dilution water.

The dilution of the bright beer takes place in an automatic blending unit with an in-line gravity measuring system. The unit could be combined with a carbonation unit. In the blending route, the beer should be carbonated additionally up to the setpoint value. This step ensures also that the subsequent measurement of the original gravity is not influenced by varying CO₂-contents.

The original gravity should be determined by means of ultrasonic measurement. It works with an accuracy of +/- 0.05% of original gravity. For this reason it is possible to precisely adjust the original gravity content of the beer ready for filling. The CO₂-content should also be measured automatically in a CO₂-analyzer by processing the measured values for pressure and temperature.

After diluting and carbonating, the beers are cooled down in a deep cooler to approx. -1.5°C.

All the units, used for deaeration, blending, etc., should be designed in such a way that they can be cleaned with hot water (up to 95°C) and all commercially available cleaning agents approved for the brewing and beverage industry can be used.

### PART 3: ECONOMIC ASPECTS

When examining the economic efficiency of the High Gravity Brewing, it is essential to differentiate between two types of costs, namely, fixed cost and variable cost.

When building a new brewery the cost savings amount to approx. 5 - 7.5% of the investment sum. For an extension of the capacity of an existing brewery the ideal value may be much higher, e.g. if limited space would cause a considerable jump in fixed costs.

But it is not the fixed cost only where high savings potentials are given. The variable (operating) cost can be reduced substantially upon application of High Gravity Brewing.

The result are energy savings in the brewhouse up to a third, allowing for the slightly bit higher cost of hop caused by the smaller yield to be absorbed, provided that that is the case. The cost of energy in the fermentation / maturation / storage areas remain almost unchanged as the same fermentation heat is to be dissipated and also the same quantity to be chilled (although less green beer but additionally also dilution water in the filtration area). In the filtration area there will be certain savings in the kieselguhr consumption, opposed to that, however, (low) costs for the deaeration of water are due.

Therefore, the first major cost advantage results from the savings of energy in the brewhouse. The loss ratios prove another advantage. By implementation of specific measures, the loss can be reduced to approx. 3% of the quantity of the beer to be sold without affecting the quality of beer. The water requirement, usually 3 - 6 bbl water per bbl of sales beer, is lowered by approximately a third as well.

Also the cost for waste water can be reduced substantially. On the one hand there is less waste water to start with and on the other, the filter waters as well as the first and last runnings can be reprocessed, resulting in a reduction of BSB and CSB as well.

Another advantage is in the savings of personnel expenses as a result of the increase in productivity.

Based on the circumstances and cost structures in Germany, the following calculation could be a working model:

For a brewery making 1 million hl (852,000 bbl [US]) sales beer annually, the cost for electric energy is quoted at Dpf 18.2 / kWh, for thermal energy at Dpf 3.94 / kWh with an energy consumption of 2.0 kWh / hl for electrical and 23.6 kWh / hl for thermal energy in the brewhouse (2). Thus, the cost of energy for the brew process works out to 129.38 Dpf / hl.

Excluding the cost of filling, the production cost (raw material, energy, Afa) amounts to approx. DM 25.00 / hl (14.2 US$ at 1 US$ = 1.5DM). The total cost for water is estimated at DM 2.69 / hl sales beer and the gross personnel expenses at DM 48.00 / hl (2).

With a saving of 30% brewhouse energy, 1% of loss, 30% of water and waste water plus 1% of the cost for personnel, the total annual cost savings for a 1 million hl brewery sums up to DM 1,925,140.00.

The cost for production of the dilution water amounts to about 21 Dpf / hl of water. For 300,000 hl of dilution water annually this works out to DM 63,000.00 / year.

Thus, an amortization period of approx. 0.6 years is arrived at for the mechanical installations of the High Gravity Brewing System. The savings as a result of decreased investment costs for extensions of brewing capacities were, however, not taken into consideration for this calculation.

### SUMMARY

Subject to some relevant points, beers of at least equal quality may be produced with the High Gravity Brewing System. Special attention should be paid to the lautering of the High Gravity Wort, the pitching of the yeast and the filtration. Also the quality of the dilution water is an essential point, which is highly dependent on its pre-treatment, amongst others the deaeration. Setting the correct blending ratio is also of importance. Some manufacturers offer a combined system for this purpose. Upon application of the High Gravity Brewing System definite production costs may be saved. The additional installations are amortized within 7 months, whereby the minor costs for investment for the gained capacity were not even considered. Consequently, High Gravity Beers are more favorable as far as production cost is concerned while the quality of the beer remains at least the same.

### CITED REFERENCES

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