2020: The future brewery – Part 1

IDEAS FOR THE FUTURE | They don't often build large scale modern breweries in Western Europe anymore. Nevertheless, the authors of this article, both teaching at The Scandinavian School of Brewing in Copenhagen, submitted this two-part article in collaboration with their Diploma Master Brewer Class 2010/2011. In this series they present their idea of how the next generation of breweries larger than 200 000 hl/month could look like. The first part introduces the subject, reviews the developments in brewing over the last 70 years and describes the core issues for the future brewing industry, focusing on raw materials, brewhouse, yeast and fermentation. The second part will cover the issues stabilisation, filtration, energy and environmental aspects, waste water, storage and packaging.

THE BASIC MANUFACTURING PROCESS for international lager beers will not change much, but brewers will continue to take steps to shorten processes and reduce losses and energy consumption – and thereby cut costs. It is already technically possible to make the shift from classical batch processes to continuous brewing and beer processing, but there is little evidence that the leading brewers and equipment suppliers feel prepared for this step, even though this technology may be economically attractive and take up less space.

Small brewers and micro-brewers often produce niche products at relatively high sales value, and they may require special equipment for brewing, but at the same time not a fully developed beer recovery and utilities function. Large brewers producing more than 1 mio hl/month may operate their own power plants, water plants, glass working and can making facilities, malthouses and railways.

This article series focuses on brewers producing international lagers at 200 000 – 500 000 hl/month. These brewers will be equipped with beer- and yeast recovery systems, have a complete range of small packaging lines and all utility supplies.

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The story so far

Several papers have since 2005 covered the evolution of modern brewing from a technological perspective: In 2005, on the occasion of opening the Ziemann Academy, *Prof. emeritus Dr. Ludwig Narziss*, Germany, gave an outline of technological brewing advances since 1938, when the norm was 4 brews in 24 hours, each max 6 t grists [1]. Since 1958 malt was conditioned with steam, and the following 40 years the lautertun was improved to more than 12 brews in 24 hours (fig. 1), competing since the 1990s with modern mash filters, which offered more than 12 brews in 24 hours.

A trailblazing work on the real function and design of the whirlpool was published by *Prof. Viktor Denk* in 1992, and advances with reduced evaporation rates through the 1990s gradually improved the brewhouse, while warm fermentation and cold storage reduced cellar processes from 4 to 2 weeks.

In 2006 *Lionel Maule*, South Africa, gave a Horace Brown Lecture outlining significant raw materials advances [2], including understanding the malt germination process and the development of new barley- and hops varieties. He ended by outlining the modern world class manufacturing while taking performance management systems into account.

Fig. 1 Classic copper lauter tun

Also in 2006, *Paul Buttick*, UK, outlined the choices for investment in a modern brewhouse [3], with three milling systems (six roller mills, a hammer mill and wet conditioning), two distinctly different lautering systems (mash filter and lautertun) and either internal or external wort boiling. Buttick deals with energy conservation by vapour condensation and wort stripping, and also compares the energy costs of evaporating 5 percent and 10 percent of the boiled wort.

While most papers discussing modern brewing advances focus on brewhouse advances, advances simultaneously evolved in all areas of the brewery, as described by *Axel Kristiansen* [9], for example: kieselguhr filters have become common since the 1940s, and since the 1950s, warm fermentation using the understanding of the creation and removal of diacetyl have been the norm. Since the 1960s chemical stabilisation with PVPP and silicagel has become standard. At the same time copper was replaced by stainless steel in most brewhouses (costs!), and large cylindroconical tanks (CCTs) gradually have been implemented in most breweries since the 1970s – some might say this happened surprisingly slow, considering that much capital can be saved on tank installations [4, 5].

Even fewer papers focus on packaging line advances – packaging as a discipline continues not to attract many brewers' attention, although some 60 percent of a brewery's operational expenses fall upon packaging operations. Two of several landmarks in packaging disserve special attention [9]: The introduction of a reliable Empty Bottle Inspector (EBI) since the 1970s and the introduction of PET bottles with gas barriers in 2000.

Since the financial crisis in 2008 much attention is given to energy savings and environmental issues, driven mainly by rising fossil fuel costs and also by Corporate Social Responsibility (CSR), which has become an important issue for all large brewing groups. *Eric Candy*, UK, outlines the environmental targets for the three biggest brewers AB-InBev, SABMiller and Heineken as well as the Total Cost of Operation for a modern brewery using the example of the Martens brewery from Bocholt, Belgium [6]. This brewery opened in 2007 and is characterised by continuous brewing, very low utility consumption and low manning levels. It is, however, also limited to a very basic product mix and all beers are being filled into large PET bottles. The Martens brewery, so far, appears not ready to brew the normal full range of beer styles. *Larry Nelson*, UK, has prepared a short outline of this new brewery [7].

Following this review of 70 years of brewing development, let us now look to the future in a logical order, following the process flow through the brewery.

Raw materials

Barley, malt and other adjuncts

In 1980 it was still considered normal that a farmer harvested 4 t malting grade barley per ha.

This figure has improved quietly, through remarkable barley breeding programmes, to now 7 t/ha. The breeding programmes in the barley growing countries France, England or Denmark – to mention but a few – will continue, and, according to the forecasts, 8.5 t/ha will become achievable for two-row spring barley varieties by 2020. Six-row barley varieties will still be grown, as will winter barley varieties, both driven by farmers pushing for high yielding feed barley, which still accounts for some 90 percent of the global barley production.

Brewing with 100 percent barley malt will continue in Europe, North America, Australia and the former Soviet Countries, in particular for premium, global brands. In Africa, parts of South America, Asia, China and India it will become attractive to look for other extract yielders, barley being less available and other types of adjuncts becoming developed to quality and economical status, i.e. sorghum, cassava, millet and various glucose syrups.

Three other options will have to be explored:

- malt partly replaced by unmalted barley: 30 percent barley and 70 percent good quality malt without external enzymes for many brands. This is possible as long as the malt used carries enough alpha- and beta-amylases to degrade also the barley part of the mash;
- malt 100 percent replaced by unmalted barley: Barley brewing incl. external enzymes: When the price for malt becomes higher than 1.5 x the price for barley, it will become attractive to use 100 percent barley helped by external alpha- and beta-amylases, perhaps also supplemented with limit dextrinases to ensure a sufficient high Real Degree of Fermentation (RDF) [12];

- routine change of adjunct source: Prices for barley, malt and adjunct fluctuate, sometimes fast. We expect that brewers will start to become flexible, i.e. they will brew and process the same beer, but made from a range of recipes depending upon availability and costs of different adjuncts. This will include also the proportion of barley/malt.

Hops

The alpha-acid content in raw hops has also seen a rise, supported by intensive hops breeding in Germany, Czech Republic and England, to mention a few. The alpha-acid content in raw hops has risen from 10 percent to currently 15 percent, and may well achieve 18 percent by 2020.

The global trend of reduced bitterness in international lagers has not ended yet, and lower bitterness combined with a reduced beer volume in some markets has already led to reductions of acreage in the hops growing areas.

The hops growers compensate partly by developing more sophisticated types of hops offering additional properties, which are also more expensive.

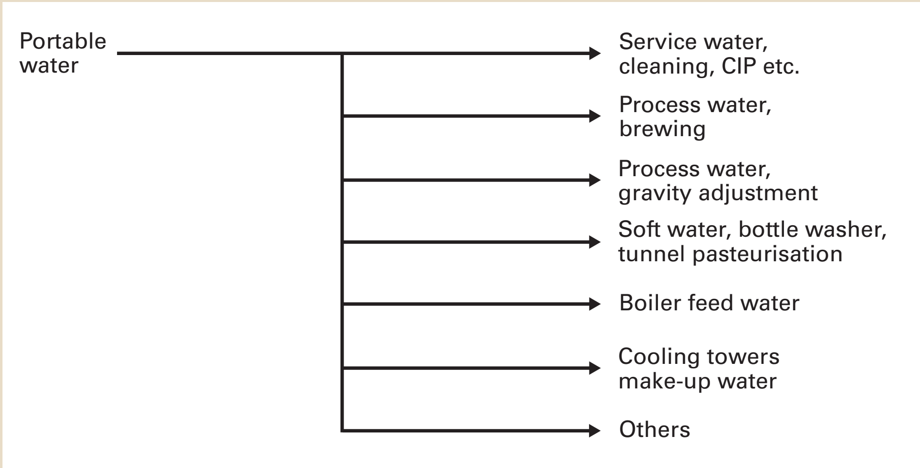

Fig. 2 Distribution of incoming potable water to the brewery for further purification

Hence, we will see more IKE (isomerised kettle extract) and PIKE (potassium-form isomerised kettle extract) type hops for bittering added at filtration: Yes, they cost more, but not after including the reduced isomerisation losses into the calculations. More brewers will start to boil wort and add small amounts of water separately boiled with hops to achieve isomerisation before mixing with the wort – as Asahi already does in Japan [8].

Other types of hops will also develop further, in particular the Rho type hops required for light-stable lagers sold in transparent bottles (fig. 4).

Water

Brewing water will increasingly have to be purified at arrival to the breweries, as the municipal water supplies unfortunately cannot always be relied upon to fulfil agreed WHO demands and the EU water directive 98/93/EU (1998). This particularly concerns pollution with heavy metals and organic solvents from industrial plants and nitrates and microorganisms from agriculture. Some areas and some brewing groups take the ultimate consequence and have already implemented reversed osmosis (R.O.) treatment of all incoming brewery water as a routine.

A less dogmatic approach suggests individual treatment of the incoming potable brewery water according to needs in the various brewery departments (fig. 2).

Brewhouse

The brewhouse process is perhaps the most studied and coordinated of all brewery processes, both by universities, breweries and the brewhouse equipment suppliers. Nevertheless, more can still be done in a brewery of the future. The following list shows some of the expected further brewhouse developments:

- higher amount of high gravity brewing: Already a lot of breweries use HGB for roughly 25 percent of their products, and large brewing groups are not expected to stop there, but increase to 40 percent, some to 50 percent, while closely monitoring potential negative qual-

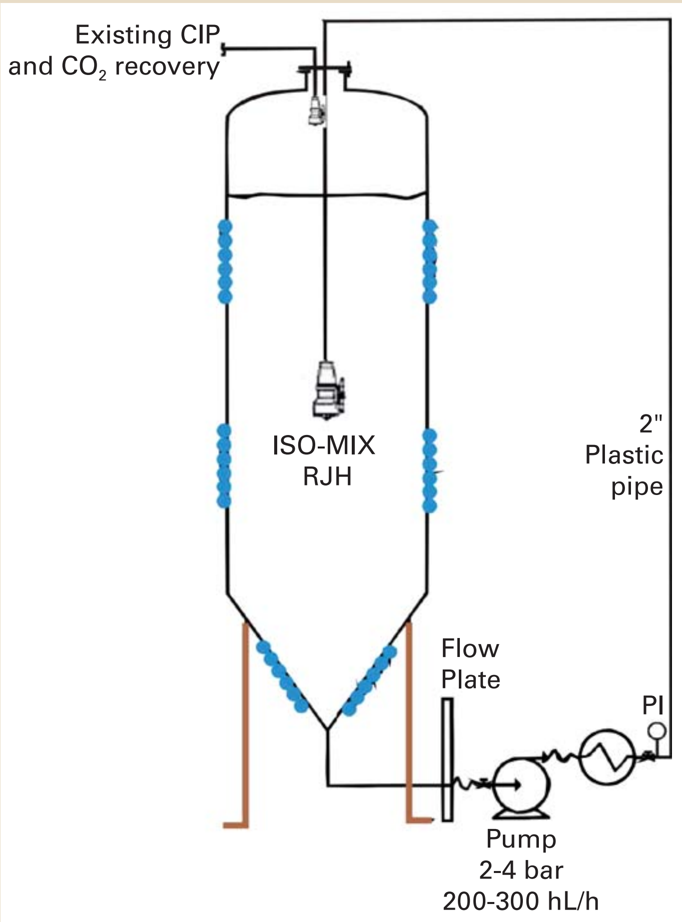

Fig. 3 Recirculation of fermenting beer; system: Iso-Mix from Alfa Laval

ity impacts like reduced head retention, bland flavour and yeast stress.

- reduced number of wort types: Due to process simplification in large breweries the creation of final beer styles happens late in the process; therefore less than 5 wort types might be sufficient for the future brewhouse.
- thicker mash: The water to grist ratio will move from some 3 : 1 to 2.2 : 1, where the malt quality is high and the maximum amount of sparging liquor is required for increased extract yields.
- mashing-in at 60 °C: Again, where malt quality is sufficiently high, mashing-in temperatures will increase to 60 °C, as this saves both energy and brewing cycle time.
- evaporation rate: Evaporation rates will further reduce from 6 percent to perhaps below 4 percent, as this will help saving a lot of heat energy, and isomerisation of hops can be otherwise achieved.
- continuous brewing: The Martens/Meura brewhouse type [7] will become widely-used, in particular by brewers who produce only one or two wort types and are keen on heat energy savings.

Yeast

Breweries will seek to reduce the number of yeast strains in the name of simplification. Ideally, the brewers will work with one yeast only, more realistically, they will use one yeast strain for their premium lager, another for regional or discount lagers and may be one top fermented yeast (if they have to) so they can supply ales.

For 130 years, since the days of Louis Pasteur and Emil Christian Hansen, scientists have continued to develop better yeast strains, modified either classically or genetically. Recent advances now make it possible to ferment bottom fermented lager yeast strains at 20 °C, remove extract in 5 – 6 days, remove diacetyl at the end of the extract removal and achieve good flocculation properties at the end of the primary fermentation. These improvements are just as significant to the fermentation process as the introduction of the CCTs (conical cylindrical tanks) were. Yeast propagation in the brewery may become replaced in future breweries by freeze – dried yeast supplies, as investment in and operation of a modern, well equipped propagation plant is very expensive and requires a certain amount of expertise. Breweries already equipped with a modern propagation plant able to deliver < one percent dead cells in newly propagated yeast are likely to continue to operate in-house propagation, since the investment has already been made.

Fig. 4
SSB students picking fresh hops

Fermentation

The primary fermentation process has nowadays already been shortened by use of CCTs, and warm fermentation (13 – 17 °C) and capacity improvements are obtained by the shortened process time as well as by HGB. The following options might help to reduce costs even further.

Batch process

The process in operation in CCTs today will be further adjusted. This particularly concerns yeast growth, as the breweries should produce beer, not yeast.

The yeast growth rate should not exceed 2–2.5. Further growth just results in increased extract losses.

Large CCTs take approx. two days to cool, and two days is becoming a significant proportion of the total process time. If not already installed, breweries will therefore wish to crash-cool the entire CCT contents at the end of primary fermentation through a flash cooler, mainly to save process time.

For new breweries, an interesting option is now available: a flash cooler linked to a centrifugal pump and a spray nozzle in the CCT. This system is able to shorten primary fermentation time by 10–30 percent by homogenizing the fermenting beer (according to Alfa Laval), and the CCT can be quickly cooled after fermentation, saving additional process time (fig. 3). Furthermore, new installations can save a lot of material, as the CCTs may be constructed using a plastic polymer and without cooling jackets.

Continuous process

In the 1990s, Finnish brewers have developed continuous primary fermentation in a reactor with immobilized yeast as described by *Esko Pajunen* [4].

The process is tested in industrial scale, and early challenges with high diacetyl levels, high pH of resulting beer and excess yeast production have been overcome. Passing the fermented beer flow through an immobilized yeast reactor during secondary fermentation / maturation has also been developed in Finland. This way, diacetyl can be removed within 2 hours, also tested in industrial scale [4]. The continuous fermentation and maturation is available, but – as far as the authors know – still not used outside Finland. Whether brewers will really move this direction remains to be seen – the CCT suppliers and traditional brewers are not likely to push this development.

Short maturation – external enzyme

Any brewery wishing to reduce the time for diacetyl reduction during fermentation may apply α-acetolactate decarboxylase, an external enzyme produced by a genetically modified strain of *Bacillus subtilis*, at the start of the primary fermentation. This enzyme, produced by Novozymes under the trade name Maturex, converts α-acetolactate to acetoin outside the yeast cell walls – and diacetyl is not produced at all. The process is used by many breweries that look for capacity increases or simply want to avoid ongoing challenges reducing diacetyl the natural way. ■

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