NEW SCANDINAVIAN SCHOOL OF BREWING CONCEPT: 'FUTURE BREWERY – 2020', PART ONE

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In two articles in the SBR, Axel G. Kristiansen describes the recent SSB concept of outlining the state of the art of a large sized brewery anno 2020 and the most important technological achievements resulting in this state of the art. This is the first article covering the process from raw materials to beer stabilisation. The second part of this paper, covering the process from filtration and downstream, will be featured in a later issue of the SBR.

The scope for the present paper is breweries producing international lagers of 200,000-500,000 hl/month, few SKUs, i.e. less than five worts in the brewhouse and one or two yeast strains only. These breweries will be equipped with beer- and yeast recovery systems, have a complete range of small pack packaging lines and all utilities supplies including a waste water treatment plant.

HISTORY FIRST: EIGHTY YEARS OF BREWING ADVANCES

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, where the norm was four brews in 24 hours, each max six ton grists. Since 1958, malt was conditioned with steam, and the following 40 years the lautertun was improved to more than 12 brews in 24 hours, competing since the 1990s with the modern mash filters, which offered more than 12 brews in 24 hours. Breakthrough understanding of 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 four to two weeks.

In 2006, Paul Buttrick*, UK, outlines the choices for investment in a modern brewhouse, as we have now three milling systems (six roller mill, hammer mill and wet conditioning), two ➜

Classic copper lautertun

Modern stainless steel lautertun

distinctly different lautering systems (mash filter and lautertun) and wort can be boiled by either internal or external boiling. Energy conservation by steam condensation and wort stripping is covered, and Paul Buttrick presents the energy costs of evaporating five per cent versus 10 per cent of the boiled wort.

While most papers discussing modern brewing advances favour the brewhouse advances, advances simultaneously evolved in all of the brewery as described by this author, here a few examples: Since the 1940s, kieselguhr filters became common, and since the 1950s, warm fermentation using the understanding of the creation and removal of diacetyl. Since the 1960s, chemical stabilisation with PVPP and silica gel became standard. Also in the 1960s, copper was replaced by stainless steel for most brewhouses (cost!), and large cylindroconical tanks (CCTs) gradually became implemented in most breweries since the 1970s – some will note surprisingly slowly, as much capital is to be saved on tank installations. Even fewer papers focus on packaging line advances – packaging as a discipline continues not to attract many brewers' attention, although some 60 per cent of the brewery operational expenses are tied up in packaging operations. Two of several landmarks in packaging deserve attention: The introduction of a reliable Empty Bottle Inspector (EBI) since the 1970s and the introduction of PET bottles with gas barriers since year 2000.

Since the 2008 financial crisis, much attention is now given to energy savings and environmental issues, driven mainly by rising fossil fuel costs and also by Corporate Social Responsibility (CSR) now becoming trendy in 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 compared with the Martens Brewery at Bocholt, Belgium. This brewery opened in 2007 and is characterised by continuous brewing, very low utilities consumption and low manning levels, however, also limited to a very basic product mix and all beer packaging 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.

Following the above review of 80 years of brewing advances, let us now look to the future in a logical order, following the process flow through the brewery:

AGRICULTURE AND FARMING

In 1980, it was still normal that the farmer harvested four ton malting grade barley per hectare. This figure has improved quietly – through remarkable barley breeding programmes, to now seven ton per hectare. The breeding programmes in the barley growing countries France, England and Denmark, to mention a few, will continue, and it is foreseen that by year 2020, 8.5 ton per hectare will become achievable for 2-row spring barley varieties. 6-row barley varieties will still be grown, as will winter barley varieties, both driven by farmers pushing for high yielding feed barley, which is still some 90 per cent of the global barley production.

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

RAW MATERIALS

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

But three other options will be explored:

A) Malt partly replaced by barley:
30 per cent barley and 70 per cent good quality malt without external enzymes for many brands. This is becoming possible, as long as the malt used carries enough alpha and beta amylases to degrade also the barley part of the mash.

B) Malt entirely replaced by barley:
Barley brewing including external enzymes: When price for malt becomes higher than 1.5 times the price for barley, the incentive to use 100 per cent barley helped by external alpha and beta amylases, perhaps supplemented also with limit dextrinases to ensure a sufficiently high Real Degree of Fermentation (RDF), as documented by Sven Schönberg* from Novozymes.

C) Routine change of adjunct source:
Prices for barley, malt and adjunct fluctuate, sometimes fast. We expect that brewers start to become flexible, i.e. being able to 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.

For hops, the global trend of reduced bitterness in international lagers has not ended, and lower bitterness combined with a reduced beer volume in some markets have already led to reductions in the hop growing areas. The hop growers compensate partly by developing more sophisticated types of hops offering additional properties, and costing more.

Hence, we will see more IKE (Isomerised Kettle Extracts) and PIKE type hops for bittering added at filtration: Yes, they cost more, but not after including the reduced isomerisation losses in the calculations. More brewers will start to boil wort and add small contents of water with hops separately boiled to achieve isomerisation before mixing with the wort – as does already Asahi in Japan*.

Other types of hops will also develop further, in particular the Rho type hops show a growing demand for light stable lagers sold in clear bottles.

Brewing water will increasingly have to become purified at arrival to the breweries, as the public water supplies, unfortunately, cannot always be relied upon to fulfil agreed WHO demands and the EU water directive 98/93/EU (1998).

In particular, challenges with heavy metals and organic solvents from industrial pollution plus nitrates and microorganisms from agricultural pollution are now increasingly demanding extra purifications at the breweries of incoming potable water. Some areas and some brewing groups take the ultimate consequence and have already as a routine implemented Reversed Osmosis (RO) treatment of all incoming brewery water.

A less dogmatic approach suggests individual treatment of the incoming potable brewery water according to needs in the various brewery departments: ➜

Potable water →
- → Service water, cleaning, CIP, etc.
- → Process water, brewing
- → Process water, gravity adjustment
- → Soft water, bottle washer, tunnel pasteurisation
- → Boiler feed water
- → Cooling towers, make-up water
- → Others

Figure 1: Distribution of incoming potable water to the brewery for further purification

BREWING

The brewhouse process is perhaps the most studied and tuned of all brewery processes, both by universities, breweries and the brewhouse equipment suppliers. Nevertheless, more can still be done, and here is a list of expected further brewhouse evolutions:

Higher HGB-degree:	Already, most breweries de-brew 25 per cent, and large brewing groups are expected not to stop there, but increase to 40 per cent, some to 50 per cent, as potential negative quality impacts like reduced head retention, bland flavour and yeast stress is being watched.
Reduced no. of worts:	As simplification work in large breweries drives creation of final beer styles late in the process, the future brewhouse may only need to produce less than five wort types.
Thicker mash:	Water to grist ratio will move from some 3:1 to 2.2:1 where malt quality is high and value of maximum amount of sparging liquor is wanted 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 six per cent to perhaps below four per cent, as much heat energy is to be saved here, and isomerisation of hops can be otherwise achieved.
Part boil:	Only the first wort off lautertun may need a full boil, leaving the sparged part of the brew with less or no boil. This activity will save heat energy.
Continuous brewing:	Martens Meura designed brewhouse will become more widespread, in particular for breweries making only one or two wort types and keen on heat energy savings.

In short: Many process improvements can still be achieved before investing in new equipment becomes necessary!

YEAST STRAINS

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

Scientists have for 130 years, since the days of Louis Pasteur and Emil Christian Hansen, continued to develop better yeast strains, modified classically or genetically. Recent advances now allow bottom fermented lager yeast strains to ferment at 20 °C, remove extract in four to six days, remove diacetyl at the end of the extract removal and show 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 cylindroconical unitanks (CCTs) were.

PROPAGATION

Yeast propagation in the brewery may cease and become replaced in new breweries by freeze-dried yeast supplies, as investment in and operation of a modern, well-equipped propagation plant is a significant cost demanding attention and skill.

Breweries already equipped with a modern propagation plant able to deliver less than one per cent dead cells in newly propagated yeast are likely to continue to operate in-house propagation, since the investment has already been made.

FERMENTATION

The primary fermentation process has already nowadays been shortened by use of CCTs, and warm fermentation (13-17 °C). Capacity improvements are obtained not only by the shortened process time but also by HGB.

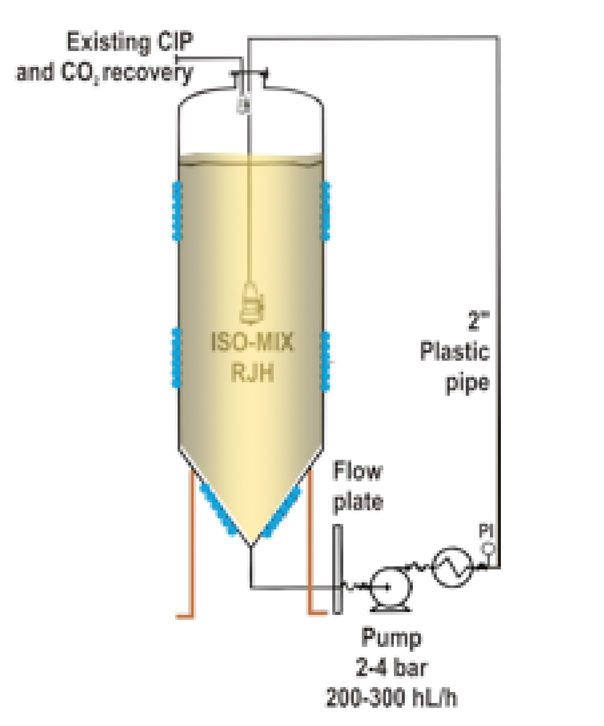
Therefore, the next phase of improvements (cost reductions) may come from three different options:

A) Batch Process:

The process now generally applied in CCTs will be further tuned: In particular yeast growth is in need of control, as the breweries should produce beer, not yeast. Yeast growth should not exceed a factor of 2-2.5. Further growth just results in increased extract losses.

Large CCTs take approximately 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 also available: To install a flash cooler linked to a centrifugal pump and a spray nozzle in the CCT. This system has demonstrated 10-30 per cent shortening of the primary fermentation time by homogenizing the fermenting beer (Alfa Laval statement), and the CCT can be quickly cooled at end of fermentation, saving additional process time. Furthermore, for new installations, there is much material to be saved as the CCTs may be constructed by a plastic polymer and without cooling jackets.



Recirculation of fermenting beer, system Iso-Mix from Alfa Laval

B) Continuous Process:
Since the 1990s, Finnish brewers have developed continuous primary fermentation in a reactor with immobilized yeast as described by Esko Pajunen*. The process is tested in large scale, and early challenges with high diacetyl levels, high pH of resulting beer and excess yeast production have been solved.

Secondary fermentation/maturation has also been developed in Finland by passing the end-fermented beer flow through an immobilized yeast reactor. This way, diacetyl can be removed in two hours, also practised in industrial scale*.

The continuous fermentation and maturation is available, but to our knowledge still not used outside Finland. Whether brewers will move in this direction remains to be seen – the CCT suppliers and traditional brewers are not likely to push this development.

C) Short maturation – external enzyme:
Any brewery wishing to reduce the time for diacetyl reduction during fermentation may apply external enzyme α-acetolactate decarboxylase, an enzyme produced by a genetically modified strain of *Bacillus subtilis*, at the start of the primary fermentation. This enzyme, produced by Novozymes under 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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REFERENCES

The author of this article has a complete list of references for the background statements and results referred to in the article (generally indicated by an asterisk (*) in the text). The list of references can be obtained by contacting the author via e-mail: agk@brewingschool.dk.