Creating a stir

How novel mixing technology increases capacity

Carlsberg UK at Northampton is the first major brewery to make a significant plant-wide investment in novel liquid mixing technology during fermentation. Using equipment developed by Alfa Laval, the plant has dramatically cut fermentation time and this has helped the company meet higher production targets. The success of the technology could well have implications for the whole of the brewing industry.

Co-author Thomas Paludan-Müller with an ISO-MIX unit as supplied by Alfa Laval.

by ***John Lazar*** and
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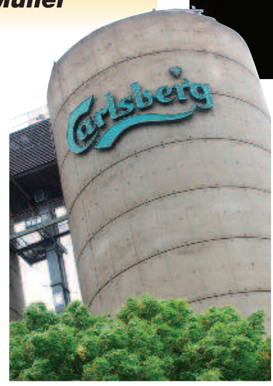

Left: Carlsberg at Northampton.

While embarking on a multimillion pound upgrade at its Northampton plant to expand production capacity, Carlsberg assessed the use of Alfa Laval ISO-MIX rotary jet mixing technology for its fermentation process. Carlsberg has increased its beer-making capability from 4.5 to 6.5 mhl and the changes to production were made while continuing to make beer without interruption. The ability to increase production has been achieved, in part, thanks to the introduction of mixing technology for its fermentation process.

Following a technical presentation by Alfa Laval, the company saw the potential of the technology and immediately embarked on a rigorous testing of the system at Northampton in collaboration with the Alfa Laval team and Tank Cleaning Technologies, UK. Trials were carried out over a period of three to four months using a 4800 hl treatment tank which was converted to a fermenter with the IsoMix technology, which is the largest capacity vessel used at the plant. As the plant produces variety of brands including Tuborg, Holsten and Skol as well its leading Carlsberg brands, the testing involved fermenting all these brands using a variety of yeast strains and over multiple yeast generations. Parameters studied also included yeast viability, foam stability, RDF and taste.

Having demonstrated and quantified the potential savings in fermentation time to its satisfaction and without compromise to the quality of its beers, Carlsberg decided that it would not only install the ISO-MIX equipment in its larger capacity fermentation tanks but also in ten storage/maturation tanks – each with a 4800 hl capacity - and converted these for fermentation by installing additional cooling using a heat exchanger in a circulation loop to ensure sufficient cooling capacity to maintain the correct process temperature during fermentation and ensure fast crash cooling. In all, 27 tanks of various types and sizes from 2,400 to 6,000 hl in capacity have now been fitted and there remains the potential to convert other tanks, if required. The brewery has also removed 57 smaller capacity fermentation vessels that are now surplus to requirements due to the increased capacity provided by this new technology.

Limits of conventional fermentation

In conventional fermentation tanks, there is no forced mixing of the wort and yeast. It is generally assumed in the industry that sufficient mixing in the vessel is provided by convection currents due to cooling near the tank wall, arising from temperature differentials generated by the cooling jackets, plus additional mixing introduced by nucleated rising CO_2 bubbles. However, as the capacity of tanks has increased dramatically over the years, there is the risk that yeast contact with the fermentable sugars is reduced and fermentation is less effective.

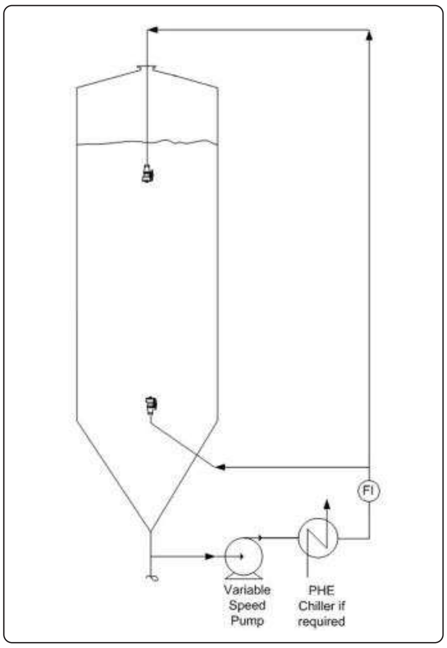

Figure 1: ISO-MIX concept.
The ISO-MIX is brought into operation once the jet head becomes submerged in the liquid and the speed of the rotation is gradually increased. When the ISO-MIX machine is in operation the content of the tank is gently mixed and the concentration of yeast will be kept uniform throughout the tank and temperature gradients are avoided. Generally the contents of a tank would be recirculated over a period of 24 hours.
As the yeast is constantly kept evenly mixed with the wort in the fermentation tanks, the contact between yeast and fermentable sugars is improved this means that the conversion of sugars to alcohol is more effective.

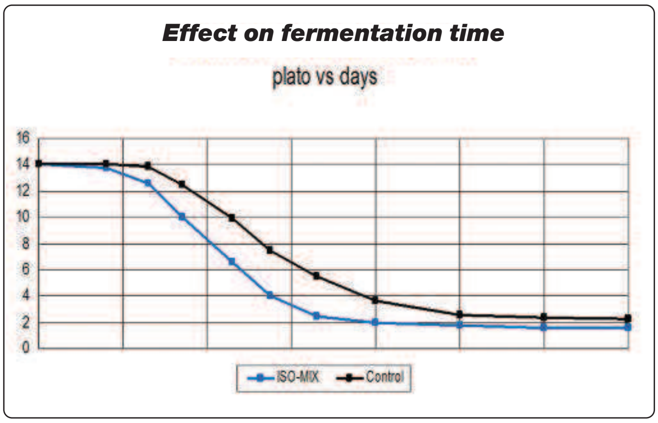

Figure 2: Typical example of the effect on the fermentation profile. In this case, unmixed (black line, control) end fermentation is reached after 5 days whereas mixed (blue line, ISO-MIX) end fermentation is reached after 3.5 days.

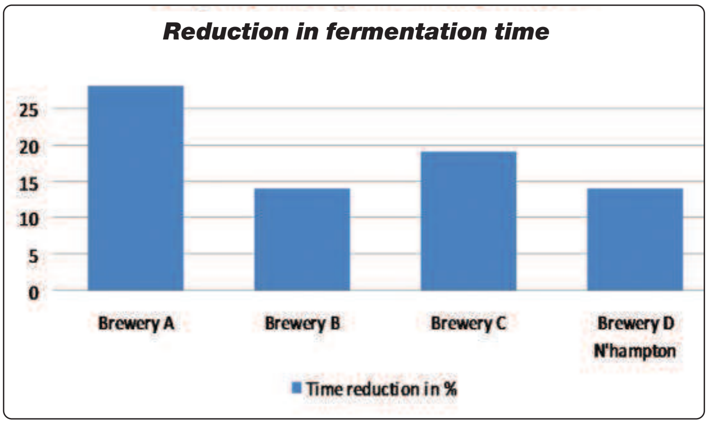

Figure 3: Reduction of fermentation time (fill complete to end fermentation) by introducing mixing in CCTs in four different breweries. Northampton is Brewery D.

Work presented by Chris Boulton *et al* [1] clearly documented for the first time in a full scale (1800 hl) CCT fermenter that inadequate mixing leads to premature settling of yeast in the cone.

How the mixing technology works

Alfa Laval ISO-MIX rotary jet mixer system consists of four rotating jet nozzles installed at a distance from the bottom of the tank. The jet head is positioned under the liquid surface and supported on the end of a pipe. The mixer head can either be inserted from the bottom or from the top as shown in Figure 1. The mixing is achieved with the four nozzles rotating around both the vertical and horizontal axes. This double rotation gives excellent coverage of the tank and results in efficient mixing. An external pump in the recirculating loop ensures that the contents at the bottom of the tank are recirculated to the jet heads.

Impact of mixing on key fermenting parameters

Introducing mixing in a fermenter influences three process phases; fermentation, diacetyl conversion and crash cooling. Alfa Laval has carried out tests to assess the contribution of ISO-MIX system in improving each of these phases. For fermentation, mixing leads to a shorter lag phase as the pitched in yeast is being distributed more homogenously. End fermentation is reached faster as settling of yeast in the cone is prevented thereby ensuring optimal contact between the yeast and fermentable sugars. The result is that fermentation lag phase is shortened i.e. the fermentation 'starts' earlier and the fermentation takes place faster which is illustrated in Figure 2. Figure 3 shows a typical example of what can be achieved in tests carried out by Alfa Laval in four different breweries.

Diacetyl conversion is a complicated process involving several breakdown steps. However it has been ascertained that improved mixing in the tank has a positive effect on diacetyl breakdown. Figure 4 shows how diacetyl levels vary through the fermentation process and how mixing increases the speed of diacetyl breakdown.

Figure 5 shows reduction in process time from fill complete to diacetyl acceptance. The large reduction recorded for Brewery A is due to the fact that mixing has improved yeast flocculation and settling thereby enabling a warm diacetyl conversion rather than previously where cooling was necessary before yeast could be harvested.

Crash cooling

When diacetyl acceptance is reached the beer is typically cooled down to approximately 0°C. Crash cooling is normally carried out using the cooling jackets on the fermenter where convection currents will ensure a down flow near the wall, thereby leading to some mixing of the fermenter content. It has been shown that introducing forced convection using the rotary jet mixer during crash cooling will improve the overall cooling effect. This has latest been documented as shown in Figure 6 by Alexander Poreda *et al* [2] demonstrating 18 hours, corresponding to a 23% reduction in cooling time in a 3200hl fermenter to 0.7°C using the rotary jet mixer with a recirculation flow of 300 hl/hr. This reduction in cooling time is obtained by introducing forced convection alone and the effect by doing this is dependent on target temperature and tank dimensions (see figure 7 showing results of different breweries), in particular aspect ratio where a low ratio entails larger time reduction than a high ratio. Similarly the time reduction is higher the lower the end temperature.

It should in addition to this be noted that even further cooling time reduction is possible when a chiller is installed in the recirculation loop. Crash cooling time can in such cases be reduced by more than 50%.

Other benefits of mixing

Finally the mixing technology also offers other benefits to the process. Mixing leads to uniform repeatable process conditions which ensure that the real degree of fermentation fluctuates less and is always low. If dilution of

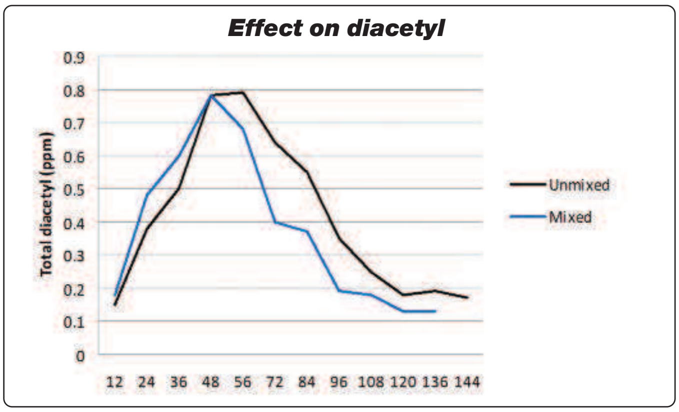

Figure 4: Diacetyl formation and break down with and without mixing.

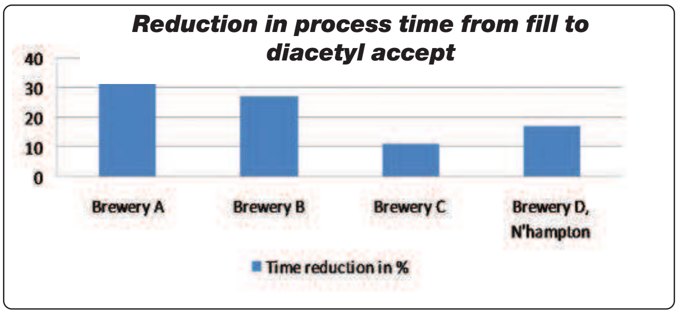

Figure 5: Time reduction in reaching diacetyl acceptance in different breweries. Northampton is Brewery D.

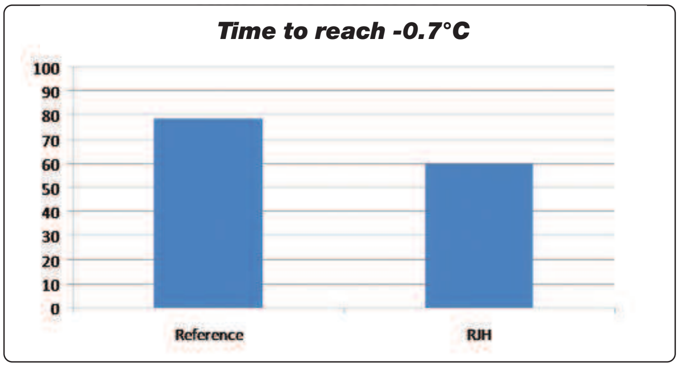

Figure 6: the effect of applying forced convection in a 3200hl fermenter during crash cooling[2].

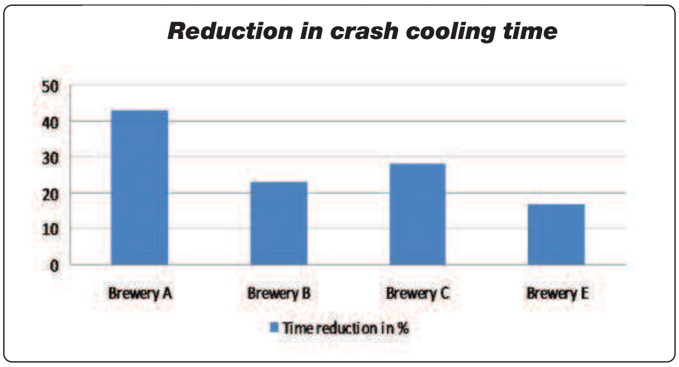

Figure 7: time reduction in crash cooling in four different breweries

high gravity beer is performed, based on alcohol content, even small improvements in the real degree of fermentation leads to considerable profit. If, for example, the average ethanol yield increases around 3% this leads to additional €450,000 profit per million hl annual capacity.

Since the Alfa Laval rotary jet mixer eliminates yeast sedimentation at the bottom of the tank by redistributing the yeast in the entire vessel, no hot spots and yeast autolysis occur in the cone which has a positive effect on yeast viability.

Having a mixer in the fermentation tank opens the potential to add stabilisers and fining agents directly in the fermenter which will maximise stabiliser performance, compared to addition during transfer. Best practice stabilisation can be achieved if the addition of the appropriate amount takes place directly in the fermenter and is combined with a haze precursor measurement like the PSS system developed by ISP. Such a set up will lead to a reduction in stabiliser consumption[3].

Another feature of the technology is its relative simplicity and ease of installation taking only a few days to carry out the mechanical tie in work and adding a pump as well as the mixing head in the beer lines. Retrofitting an existing brewery with rotary jet mixers will typically have a payback time of less than one year, depending on the type of brewery. Whereas installing the mixers in a greenfield brewery leads to reduced Capex due to a reduction in the number of fermentation vessels

Results at Carlsberg Northampton

For the Northampton plant, in quantitative terms, reaching the end fermentation is 14% faster with ISO MIX, there is a 23% faster gravity drop per day and the process is 17% faster to diacetyl acceptance. There has been a 4% improvement in harvested yeast viability and the real degree of fermentation (RDF) is improved by 3%. The benefits have been achieved with a Carlsberg yeast strain that has low flocculent properties so does not tend to clump together. For very flocculent yeast strains, the benefits could be expected to be even higher.

The fermentations now are more consistent, which means that it is possible to predict with greater accuracy when beer is ready to move to filtration, which is important for planning. The ability to determine the optimum time to crop has been improved, at which point the ISO-MIX equipment is switched off so that the yeast will settle. This supports better yeast viabilities as it avoids a long period where the yeast sediments in the cone of the fermentation vessel, warming up and being compressed.

Overall the fermentation process is faster, the quality, stability and fermentation capabilities of the yeast during fermentation is maintained and the final properties and taste of the beer is not affected by the introduction of the mixing technology.

For Carlsberg, some of the ISO-MIX installations were made in former storage/maturation tanks (converting them into fermentation vessels) which have made a contribution to increasing output capacity without the need for significant capital investment in new fermentation tanks and the cost of the investment was recouped immediately. The Alfa Laval ISO-MIX mixing technology helped the plant increase capacity in a limited plant space and also saved the company millions by avoiding the need to invest in new fermentation tanks. For the brewing industry in general, this mixing technology has broad application for beer production using bottom fermented lager beers. It enables a significant increase in production capacity achieved through reduction in fermentation time and without the need for costly capital investment in infrastructure.

More of these from the same number of fermenters after the introduction of ISO-MIX.

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