CUT YOUR LOSSES

What's your best guess as to how much a million hectolitre brewery can add to its bottom line by reducing beer losses one per cent? The figure is certainly more than you might imagine, large enough to make it well worth clipping and saving this best practice overview. Report by *Ian Smith* and *David Quain*

Only those cooped up 24 hours a day, seven days a week in yet another 'reality' TV programme will be unaware that worldwide things are a bit tricky financially. Daily we are subject to multimedia nudges to get our finances sorted so we – individuals, families, business and organisations – can ride out the impending storm.

Brewery operations are not immune from such pressures. Indeed, costs need to be cut and losses need to be minimised irrespective of whether you are a craft brewer, a company that operates nationally or on the consolidating global stage. The drivers are universal, with hikes in the cost of raw materials; energy and effluent together with the squeeze on volumes and margins in the off- and on-trade.

A periodic focus on minimising process losses from start to finish can make a telling difference to the bottom line. Indeed, for a one million hectolitre brewery a 1% reduction in process losses is worth around £80,000. This is not new thinking! Not so very long ago, when the world was a little different, the head brewer could turn to a loss control brewer, in addition to the other brewers on his team.

Measureable benefits

It is vital that the loss performance is continually measured to determine variation to budgets so that timely action can be taken, but it is also essential to compare the performance with the industry benchmark. It is easy to become complacent with the historical performance and yet be uncompetitive in terms of cost. As a guide, production of a well attenuated lager-type beer can achieve losses below 0% whereas in a traditional ale brewery they are typically around 3%.

Process losses are a good indication of a well-run process and a change in performance can flag up potential problems. Contrary to popular belief, low losses run hand in hand with good beer quality, as both benefit from a process under control. A reduction in process losses also gives a direct increase in capacity that in turn reduces capital expenditure by deferring (or postponing) investment in new vessels. Further, there can be other external pressures to monitor and identify sources of process losses such as taxation, trading standards and quality accreditation.

Measurement systems must be robust, accurate and – where appropriate – subject to traceable calibration. Inaccurate information will undermine the validity of loss control and can result in investigations being focused in the wrong part of the process.

Although measurement systems should be 'potency' based, volume can be used with 'sales gravity' brewing but there will still be a small dilution through the process. If volume alone is used it is possible to transfer beer from one tank to another and have the same volume in the receiving tank as the supplying tank but still have a loss if the original gravity or alcohol by volume is lower. This reflects the difficulty in the control of the beer/water interfaces, with beer going to drain and water being collected in the receiving tank.

Original gravity is often used with volume to record 'potency' through the process as hectolitre per degree (hl.degree), measured as degree Sacch. or degree Plato. Some breweries use OG prior to fermentation and ABV after fermentation. In this case, a system to measure and account for the relationship between OG and ABV is required. This is achieved by measuring the specific gravity of the beer to give the 'apparent degree of fermentability' or the total fermentable extract (via a rapid fermentation procedure) to give the 'real degree of fermentability' and comparing this to the recipe standard.

Measurement should be timely to allow the rapid identification of an unusual result, prompting an immediate investigation. Such measurements should be by transaction (beer movement or process) and should be reviewed once complete. If this is not done then key evidence may be lost, and the audit trail will be compromised. It is also important that every movement in the brewery is accounted for, and this is particularly relevant when beer is reworked/blended or recycled. The starting point for each transaction must be the closing point for the previous movement to ensure that there are no 'black holes'.

Typical measurements include meter volumes, tank contents and volume of additions. All of these measurements have inaccuracies, and it is difficult to measure more accurately than ± 0.5%. This can result in some movement of apparent losses between batches and within the process – for example, where one batch follows another through a process such as a beer transfer, filtration or packaging. Here it is important to record the end/start of each batch and allow for the beer in process, whether in pipework, buffer tanks or in the process plant. The overall loss may be more accurate than the individual transactions and this should be considered when reviewing the losses.

Regular stock counts allow a picture of overall losses to be accounted for since the last stock count. Ideally this should be done when production has stopped. Where this is not possible care is needed to ensure that the beer is accounted for accurately and is not missed or double counted. Stock counts should be scheduled regularly as is appropriate. The closing stock from one count is used as the opening stock for the next count. Further, it is useful to carry out a regular 'mass balance' over the entire process, over a defined period of time. This will provide an overview of the materials purchased, finished beer produced and stock in process.

Another excellent check for physical losses is to monitor the effluent leaving the site. This opportunity can equate to a serious saving. Indeed, it has been suggested that a 10% saving in effluent costs is equivalent to improving the extract yield of malt by 1.5% (see Charlie Bamforth's *Brewers' Guardian* article, November 2008).

By measuring the volume and ABV, the equivalent volume of beer can be calculated. If this is done by a continuous or intermittent sampler, peaks can be identified and investigated. This can act as a 'sleeping policeman' that can flag sloppy practices and reduce losses. Further real time insight can be gained from the installation of TOC (total organic carbon) meter in the effluent drains.

Raw materials

All materials that have an extract value should be carefully measured as inputs to the process. Key to this is the extract specification is agreed with the supplier and is part of the purchasing contract. The competitiveness of the extract value should also be considered when agreeing the price of the material. The analysis of each batch should then be compared with the contractual specification, and monitored using 'control charts' (see textbox). If the material is vendor certified, it is advisable to have the occasional batch independently analysed. With malt it is important to review the 'as is' extract value, but if the 'dry' extract is used then it is also necessary for moisture levels to be accounted for. The levels of screenings and stones should also be monitored.

The measurement of material deliveries is ideally via a weighbridge and is the basis for the commercial transaction. All batches should be recorded and the vehicles weighed gross and tare with the same unit. Also ensure that you are not paying for the weight of the driver!

Material stock counts in silos are not easy, only correctly measured when the silo is empty. However, the stock loss or gain must be accounted for when producing the process loss figures. It is also best practice not to top up silos, as this makes stock control difficult as well as having quality and batch traceability implications. If it is impractical to avoid topping up, then the silo should be periodically emptied to allow the cumulative loss or gain to be accounted for.

Brewhouse

The brewhouse is one area where optimisation can have a large impact and should be reviewed as and when raw materials change, particularly between seasons and between suppliers.

When measuring extract recovery efficiency in the brewhouse, the performance is measured against the standard contractual extract as well as the actual extract. The former is used to calculate performance against budget and is the

Control charts and SPC

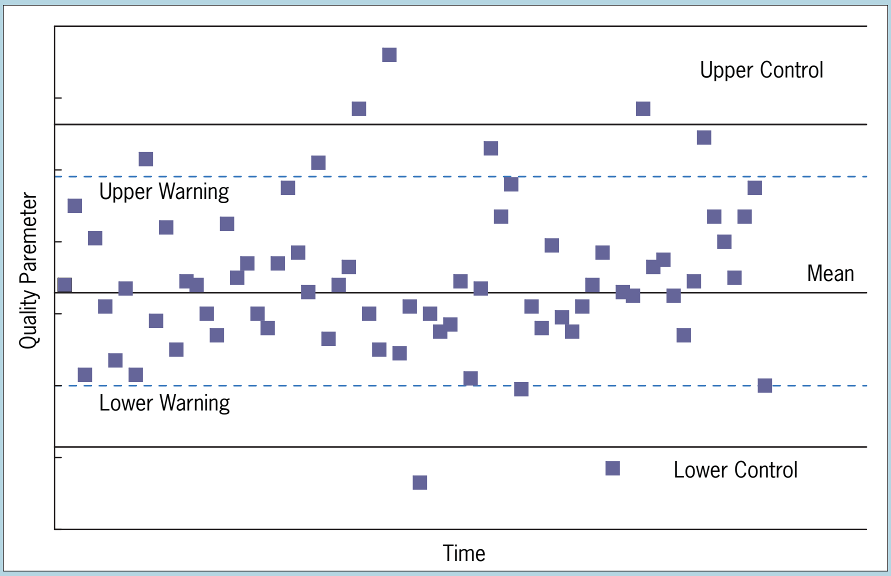
Statistical process control using a 'control chart' or 'process-behaviour chart' is a basic tool of quality control that operates alone or within a wider business strategy such as Lean/Six Sigma. It is not new; it dates back to 1924 when the control chart SPC was developed by Walter Shewart working at Bell Laboratories and then championed by quality guru W Edwards Deming. Whilst straightforward on paper, control charts and other quality tools are readily available these days as Excel software extensions.

A quality parameter (e.g. CO_2, container contents, ABV) is plotted against time. Based on historical performance a control chart is established with a mean, upper and lower warning limits and upper and lower control limits. These are set at 2 ('warning') and 3 ('control') sigma/standard deviations from the mean. For a process that is normally distributed, measurements have a 2.5% chance of being outside the warning limit and 0.1% chance of being outside the control limit.

The purpose of the chart is to indicate if a process is behaving with the same variability as before or something has changed with the process. This is important as adjustments should only be made if the process has changed statistically or this will add to the variability.

There are various 'run rules' or 'rules for detecting signals' that are used to analyse the chart and to indicate when action is required. Typical rules are:

- a point lying beyond the control limits
- 2 consecutive points lying beyond the warning limits
- 7 or more consecutive points lying on one side of the mean
- 5 or more consecutive points going in the the same direction (indicates a trend)



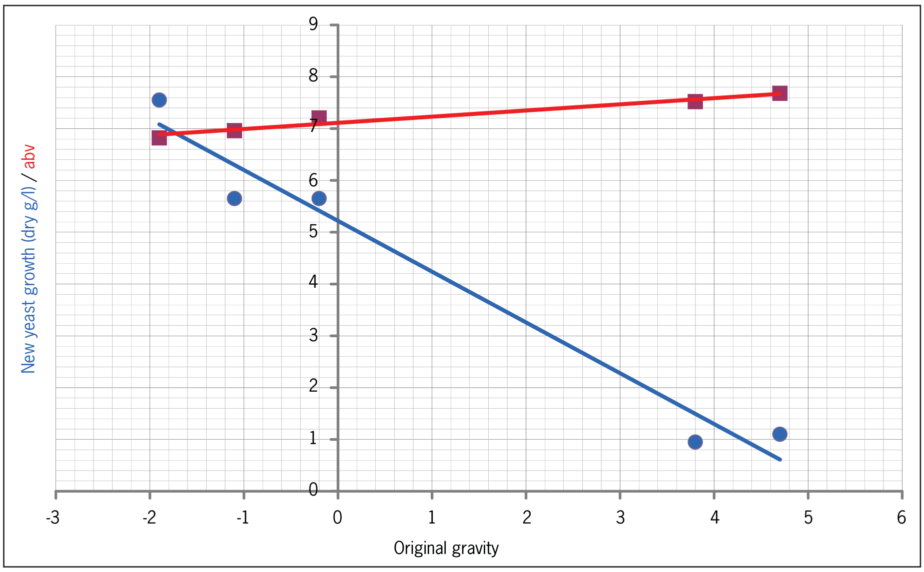


Figure 1: Relationship between OG and yeast growth/ABV

value that is important for variances to standard product costing. The latter figure gives a true indication of the plant performance, and is significant in the monitoring of process efficiency.

It is important that the materials used in each brew are accurately controlled, measured and accounted for. The conversion of starch should be completed and the mash temperatures adjusted to optimise the fermentability of the wort to achieve specification. The conversion should be checked (starch test) and the spent grains analysed ('total' minus 'soluble') for unconverted extract remaining in the grains.

The soluble extract recovery should also be maximised. This requires that the wort separation processes are optimised around milling and grist composition, extraction and leaching efficiency, control of sparging, final running gravity and weak wort recycling where practised. As above, spent grains should be assessed for soluble extract remaining in the grains.

A modern mash filter (Meura 2001) can provide excellent extract yields and will easily exceed the laboratory extract. This is as a result of the very fine grind and the even, short sparge path. Further, high gravity wort may be produced, allowing high gravity brewing without weak worts recycling.

The separation of trub and hops in the whirlpool is also worthy of attention. Also, it is important that all of the material is removed for quality reasons but the volume of wort either entrained in the trub or present as a supernatant liquid is minimised. This requires a good compact trub cone followed by a well controlled separation process.

However, the move to use higher alpha hops, pre-isomerised hops or extracts has reduced the loading of 'vegetable material'. Under these circumstances, the take-off point from the whirlpool may need to be physically adjusted. Further, dependent on quality policy, trub may be recycled to the mashing vessel or lauter tun, which then requires the transfer of extract from one brew to another to be accounted for.

The operation of brewhouse is a trade off between speed and capacity versus efficiency. Accordingly, with the peaks and troughs of seasonal demand, it is beneficial to operate the plant for maximum output with a slight loss in efficiency for the 'peaks', but also to optimise it for maximum efficiency for the 'troughs'. It is not best practice to run the plant flat out and then finish the brewing programme early if this involves lower extract recovery.

Fermentation

Fermentation has a major influence on losses in determining the efficiency of sugar to alcohol conversion together with the need to control the physical separation of yeast from beer and attendant losses.

To minimise extract losses the conversion of extract to alcohol should be maximised in accord with the process specification. This is achieved by optimising the fermentability of the wort and ensuring the desired attenuation is achieved. This requires focusing the extent of yeast growth which involves the interplay of the 'usual suspects' – wort quality, optimised levels of dissolved oxygen and the controlled pitching of viable yeast. Of these oxygen has the most potential impact on losses through the over production of yeast mass at the expense of alcohol formation (*Figure 1*).

If the OG is calculated after fermentation and compared with the SG prior to fermentation, there is normally a rise – particularly with highly-attenuated and enzyme-assisted beers. This caused much consternation in the UK prior to 1993 with duty was paid at the wort collection stage and was often blamed on 'under declaration' by the brewer.

However, the real reason is twofold. The tables used to calculate OG were based on work carried out 100 years ago by Horace Brown. Modern fermentations are much more efficient with a greater yield. The other reason is 'hydrolysis gain'. When a maltose is broken down to two molecules of glucose, a molecule of water is incorporated which results in a 5% apparent gain. Similarly, hydrolysis of the trisaccharide maltotriose results in a 7% apparent gain as two molecules of water are incorporated.

Hydrolysis gain was behind the popularity of 'high maltose syrups' and techniques where the sugar was collected and declared separately. As the wort will contain a mixture of sugars, the gains in reality are not as high but can be considerable and need to be understood when analysing losses. Accordingly, the accurate measurement of extract prior to fermentation is critical.

Yeast cropping

The most significant physical loss during fermentation can occur during the recovery of yeast from the beer. Although sufficient healthy yeast is required for repitching, it is also important that the beer entrained in the yeast crop is minimised. With fermentations in cylindroconical vessels the controlled removal of the yeast crop is vital. The 'how' is dependent on the yeast strain (flocculation/sedimentation characteristics), fermenter size, zonal cooling and geometry. The rate of removal of the yeast plug from the vessel cone has to be controlled so that beer is not pulled through the centre of the cone.

Other embellishments can include 'warm' cropping, in-line cooling and centrifugation of less flocculent yeasts. With top-cropping ale fermentations in traditional open or closed (Yorkshire) Squares, yeast skimming requires careful timing and selection of only the thick yeast.

Beer movements and interface management

All transfer pipework should be 'packed' with deaerated liquor prior to transfer so as to avoid picking up dissolved oxygen. At the end of the transfer the beer also needs to be chased out of the main unless a further transfer is to take place. The quantity of interface depends on whether high gravity brewing is being practised, as it is possible to collect the entire interface upstream of the filter. With sales gravity brewing it is not possible to collect the complete interface but a percentage can still be collected without causing excessive dilution.

There is a similar issue after the dilution point. When the interface is collected this will increase the volume in the receiving tank at the expense of ABV, and that layering may be an issue when the beer is sampled or further processed.

There are several ways of controlling the inter-

Process variability: best controlled by investing in the best available equipment backed by monitoring and controlling the operation

face, ranging from metering of the liquid flows, conductivity measurement, colour measurement, OG, PG or ABV measurement. There are advantages and disadvantages to all of these systems, and it is often a trade off between accuracy and cost. As ever, these systems must be set up correctly, maintained and fitted with an overrun volume facility in case of equipment failure. Where liquid flows are metered and there are many tanks and routes used, it is possible to programme every movement separately with the required chase volume.

The use of buffer tanks adds complexity in managing interface volumes. One option is to chase through the pipework to each tank in turn or the mains can be chased through the route prior to running into each of the tanks. Preferably the use of buffer tanks should be avoided, and only used where absolutely necessary (e.g., adjacent to a centrifuge, filter or pasteuriser). Any additions to the beer should be accounted for in terms of extract and volume.

Centrifugation

Optimisation of centrifuge operations can minimise beer losses. The solids content of the discharge should be maximised and the yeast count in the beer should be as low as possible to ease downstream processing. Modern centrifuges are capable of adjusting to variable beer infeed yeast counts by changing the discharge frequency and/or by varying the processing rate. However, these may struggle with excessive yeast counts.

Cold tank solids removal and processing

The settling and removal of solids ('grounds', 'bottoms', etc.) from maturation or conditioning vessels is arguably the key operation in reducing process losses, particularly with the trend to reduced storage times. The use of finings or silica gel can help to compact solids, but may cause complications when reprocessing them. The use of a turbidity meter to assist the operator in assessing the solids content is worthwhile, and the rate of removal should be controlled to allow the solids to reconsolidate without pulling a hole in the vessel outlet.

A filter operator will tend to remove excessive quantities of solids in order to protect the filter bed, and may be tempted to remove them too quickly to save time, so this operation should be monitored. One option is to transfer the medium solids to a divert tank and then dose these back throughout the filtration run. This is likely to affect the life of the filter bed and it may be better to process via a separate beer recovery operation.

There are many factors to consider, including the loading and capacity of the filtration plant, the risk to beer supply, and the beer recovery equipment available. A turbidity meter can facilitate the initial removal of solids and can be used to detect and divert any 'slugs' which may be pulled from the tank during the filter run. These 'slugs' can sit on the shoulder of the tank cone, a consequence of incomplete solids removal. Here a 'true' buffer tank (with separate inlet/outlets and mixing), is helpful as any slugs of yeast have a chance to be dispersed without blinding the filter.

Filtration

It is necessary to maximise the length of filter runs as the turnaround operation is a potential cause of large losses. A long filter run is achieved by optimising the bodyfeed dosing rate to the solids loading of the infeed beer. This is achieved by monitoring the increase of differential pressure across the filter and changing the powder dosing rate accordingly. It is also possible to make an assessment of the loading, and hence the required powder dosing rate, by measuring the yeast count, turbidity or solids content in the infeed beer.

The start and end of a tank typically result in higher solids and accordingly the powder dosing rate can be increased at these times. If the filter is precoated with deaerated liquor, it is possible to push the interface forward to the bright beer tank and similarly at the end of the filter run with the chase through liquor. The downstream dilution equipment may struggle to account for the large volumes of dilute beer. This can be managed by the use of a divert tank, where the interfaces are transferred and then dosed back in through the entire filter run.

A complex brand portfolio can increase losses because of the difficulty in blending the different beers due to their incompatibility, so scheduling filtration by similar beer types is beneficial.

Dilution and ABV control

Most breweries brew and process at high gravity and then dilute post filter. This operation requires careful control as it can result in beer losses by running above final beer specification. If the specification for the finished beer is 4.0% ABV, and the average achieved is 4.2% ABV, this equates to a 5% beer loss even if the beer is within specification! There also may be tax/excise duty implications if the trend is not corrected and a surcharge may be levied.

All processes have variability, but it is worth the investment of installing the best available equipment, and then monitoring and controlling the operation to achieve the target ABV with the minimum of variability. Trends should be monitored using control charts, and the appropriate action taken if a significant change is detected. Although modern dilution equipment will compensate for changing ABV, it must do quickly particularly if several bright beer tanks are being produced.

It is also important that there is not excessive layering in the bright beer tanks. The laboratory and in-line instruments should be carefully calibrated and validated periodically through an inter-laboratory assurance scheme.

Beer recovery

The beer recovery operation is often a neglected area, but is a key operation in managing the cost of process losses. Whilst it is preferable to minimise recovered beer, its processing should be efficient, hygienic and dissolved oxygen levels should be kept as low as possible There is now a wide range of plant options available, and the choice is often a balance between capital costs versus higher quality recovered beer and lower losses. For example, for a modern crossflow filter, it is possible to add back high quality recovered beer later in the process, with the advantages of lower overall losses and also capacity gains.

The different types of input streams should be segregated, as they may need different processing regimes. Thick yeast and tank bottoms will require very different processing to recovered beer from packaging operations. If different types of beer are produced, again they should be segregated to allow separate addback. Some breweries do not add recovered beer to their premium products, and instead add larger quantities to discount brands. It is vital that the recovered beer is processed quickly, and that beer is removed from yeast slurries without delay to minimise yeast autolysis flavours. It is best practice to minimise the stock of recovered beer and to maintain a balance between its production and rates of add back.

Packaging

After the bright beer tank it is necessary only to monitor the beer volume, although QC checks need to be made to ensure that the beer is not diluted. To satisfy the appropriate authorities it is necessary to maintain records of the ABV in the final packages. As dilution is not acceptable at this stage, any interface has to be collected and reprocessed back upstream.

The volume filled into containers is important, as there are potential tax/duty and legislative requirements together with potential impact on beer losses. For small pack lines the volumes are recorded from every filling head on a regular frequency and tracked using control charts. This ensures adherence to container volumes guidelines.

For beer losses it is important that the degree of overfill is minimised through having a very tight fill tolerance and good process capability. In the case of cans (or bottles) with a 'widget' a degree of overfill may be necessary. This overfill should be identified separately in the accounts as part of the packaging cost for the widget cans, and not just part of the overall beer losses. Any short-filled containers rejected from the lines are a process loss.

Large pack lines such as keg and cask provide different challenges. In the UK the container population has to be checked to ensure that the contents are large enough to contain the nominal volume. As containers are damaged and dented with use they tend to shrink. Any undersize containers need to be identified and repaired or culled.

It is normal to meter-fill the containers and the volume checked by taking pre-weighed containers and weighing them full. The fill volumes are monitored using control charts to ensure that the differing requirements of the (UK) Excise and Trading Standards are satisfied. If the container population has a percentage of undersize containers it is possible to bring up the average by over metering the volume into the containers but this is very wasteful. Under filled containers may be decanted and the contents recycled.

Good brewing practice

Low process losses are a sign of a well-run, well-operated and well-maintained brewery. If the process is highly capable, then out-of-specification production should be minimal, resulting in low levels of rework which is a major factor in high process losses. An exercise to simplify the process will also assist in reducing process losses by reducing the number of products to be controlled and product changeovers.

With the current economic climate, a full review of process losses should be undertaken immediately - not only against historical performance but also by benchmarking against industry best practice. Most of what has been covered here is not new, but should stimulate some ideas which can easily be put into practice and, importantly, benefit the bottom line!

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