# Moving from batch to continuous fermentation systems

## In a nutshell

| Summary | | | | |
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| Best practice is to move from batch to continuous fermentation systems to save energy and water. One option is the use of a four-tank continuous system consisting of three stirred tanks and a fourth unstirred one, where the beer is separated from the yeast. From the last tank, the clarified beer flows to a warm maturation tank where the flavour is refined by yeast action. | | | | |
| **Target activities** | | | | |
| All food and beverage manufacturing | Processing of coffee | Manufacturing of olive oil | Manufacture of soft drinks | Manufacture of beer |
| Production of meat products | Manufacture of fruit juice | Cheese making | Manufacture of bread, biscuits and cakes | Manufacture of wine |
| **Applicability** | | | | |
| There are some limitations to the applicability of this best practice. The technique is mostly feasible for large-scale brewing operations. Moreover, switching to continuous brewing can have effects on the organoleptic characteristics of the final product and may not be suitable for all beer types. | | | | |
| **Environmental performance indicators** | | | | |
| • Overall energy use in the production process per hectolitre of beer produced (MJ/hl)<br>• Water consumption in the production process per hectolitre of beer produced (hl of water/hl of beer) | | | | |
| **Benchmarks of excellence** | | | | |
| N/A | | | | |

## Description

The reduction of energy and water consumption in breweries can be achieved by moving from batch to continuous beer production systems. The continuous fermentation system can consist of three stirred tanks and a fourth unstirred one where the beer is separated from the yeast. The system uses a flocculent yeast strain, which is precipitated and collected at the end of the fermentation. From the last (fourth) tank, the clarified beer flows to a warm maturation tank where the flavour is refined by yeast action. The total residence time is approximately from 40 to 120 hours, depending on production requirements. The whole process is illustrated in Figure 1.

The first vessel (hold-up vessel or HUV) is used to stimulate yeast growth and to ensure a steady flow of yeast and beer from later on in the fermentation process. The introduction of yeast into wort is stressful for the yeast because of the high nutrient levels. However, by mixing the wort with partially fermented beer, the concentration of nutrients is reduced and thus the fermentation starts faster. The residence time of the beer/wort mixture in the first vessel is about three to four hours.

In the first of the two fermenter vessels, the partially fermented beer is recycled back into the first hold-up vessel. The residence time is approximately 30 hours or more, depending on the production demands. In the second continuous fermenter vessel, a fine-tuning process is carried out, known as fine-tuning of the finished fermented beer. The duration of this stage is approximately 12 hours or even more. This is followed by the yeast separator, which is an unstirred vessel with a conical base. The beer flows into the vessel and most of the yeast settles at the bottom of the cone and is eventually piped back to the beginning of the fermentation system where it is mixed with the incoming wort. During the process, more yeast is produced than is required by the brewery process. Afterwards, the surplus yeast is washed/cleaned to recover as much beer as possible and the yeast can be sold.

**Figure 1:** The continuous fermentation plant

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In the maturation vessel, the beer is stored for two days in cold storage.

Continuous wort boiling is implemented under pressure where the wort passes through various heat exchangers and the pressure is reduced to atmospheric through a series of flash-off vessels. The wort residence time can be reduced to a few minutes and the system can be run at any evaporation time relatively independently of the prime energy input (Brilliant Beer Company, 2004). This process has the advantages of reducing the energy requirements, easier integration of the system, full use of energy to preheat the wort, variable evaporation rates and high energy savings. On the other hand, the main disadvantage is the possibility of slightly changing the quality of the final product and potential microbial infection if the wort is stored cold.

Continuous wort boiling is an efficient way of reducing the energy demands. In particular, the energy used for boiling is used for heating up the incoming wort in a multistage process. Initially, the wort feeds into a holding vessel where hop additions can be made. Afterwards, the wort runs through an appropriate heat exchanger where it is heated to approximately 135°C. This temperature is kept constant for 1.5 to 2 minutes in holding tubes. Therefore the wort is held constant at 135°C by regulating the flow rate at the inlet to the first of two adjoining separators. When the wort is flowing into the separator, the pressure is decreased up to a certain value and thus the wort is boiled and evaporated. The wort from the separator runs through a booster pump to one of three whirlpool casting vessels (which should be sized to be approximately equivalent to the capacity of one hour of throughput from the boiler).

An effective evaporation rate of approximately 7% is required to remove the undesired aroma components. Continuous wort boiling allows the steam demand of the brewhouse to be maintained at a constant level, thus avoiding the peaks resulting from batch heating or boiling of the wort. Heat recovery is very efficient, requiring only prime energy input to compensate for the difference between the wort inlet and outlet temperatures and minor heat losses from the heat exchangers (O'Rourke, 2002).

## Environmental benefits

The energy use, the water use, the steam consumption and the amount of waste generated are significantly less compared with the batch brew process. In particular, it has been reported that approximately 30-35% of energy savings are achieved by moving from batch to continuous production systems.

The $CO_2$ which is produced during the fermentation process is collected from the top of the fermenting vessels and thus it is not systematically released to the atmosphere. $CO_2$ recovery is therefore possible and it may be used for other processes (e.g. purified and compressed for later use in the brewery itself).

## Side effects

More equipment is employed in a continuous process than in batch processes, increasing the environmental footprint. However, this is compensated by the reduced energy and water consumption.

## Applicability

There are some limitations to the applicability of this best practice. Continuous wort boiling is difficult to manage with several different wort streams and a number of brewers still have reservations about the quality impacts of switching to continuous brewing. For example, the continuous production systems are noted to have an impact on the taste of the beer (Brányik et al., 2008).

Despite being applicable to all size of breweries, the technique might only be feasible for medium- to large-scale brewing operations.

Some key aspects that should be taken into account when moving from batch to continuous wort boiling there are (Brilliant Beer Company, 2004):

- If the wort is stored at temperatures higher than 85°C, then there are hazards associated with oxidation resulting in the pick-up of colour and flavour changes, which may have a potential impact on customers.
- If the wort is stored at temperatures below 35°C, then microbiological infection is a potential hazard.

## Economics

The labour and capital costs are reduced because all the steps for the fermentation process are simplified.

## Driving forces for implementation

In principle, the continuous processes are more energetically efficient, easier to control and consequently lead to a lower production cost. The main driving forces for implementation are listed below:

- Reduced peak consumption of utilities
- Reduced energy and extract losses
- Reduced waste disposal
- Limited space requirements
- Easy process control

## Literature


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