Impact of different fermentation tank outlets on product quality

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Abstract

After filling of fermentation vessels, product remains in the long outlet pipes of the vessel during the whole fermentation period. The processes taking place in these pipes were observed. Different developments can be observed in the pipe compared to the tank. After a much faster fermentation than in the tank, the residue in the line undergoes negative changes. The yeast autolyses and releases off-flavours. This can also affect the beer quality in the tank. A possible reason for this could be the separation of the pipe from the tank during fermentation and immediate cleaning. The ECO-MATRIX-system is a novel, patented tank connection concept.

Key words: tank connection pipe, yeast degradation, un-controlled zones in fermenters

Introduction

Modern cellar management includes large fermentation vessels up to several thousand hectolitres equipped with more or less long outlet pipes. Processes like filling or cleaning are carried out mainly through valve blocks or pipe fences. Product frequently remains in the pipes after filling and during fermentation. Different process parameters compared to the tank (like temperature, pressure) have an influence on the changes of these residues in the pipe. The goal of this study was to investigate differences between the processes in the tank and the pipe. Different process parameters should lead to a different development in tank and pipe. Consequences of the distinct processes on fermentation management and the final beer quality should be determined.
In addition, an alternative design, the ECO-MATRIX®-tank outlet was evaluated to look for possible advantages.
The trials were carried out during the regular fermentation process in a large-scale brewery. To compare the processes, samples were taken out of the pipe and from the tank during fermentation. These samples were analyzed for conventional fermentation parameters like temperature, extract, and pH, and yeast activity was determined using live/dead cell staining. Additionally, the samples which showed the biggest differences were examined in detail by GC analyses.

Material and Methods

Cellar equipment

The investigated tanks were conventional cylindro-conical tanks connected via an outlet pipe to a pipe fence. Each tank was individually cooled.
Tanks equipped with the ECO-MATRIX system are directly connected to the pipe system by valves right under the cone. The remaining outlet is only a short pipe (less than 1 m). So the pipe system can be operated (cleaned) separately from the tank.

Sampling

The samples were taken out of five different tanks. Three tanks were equipped with a longer tank outlet (9.6 m, pipe volume 75.8 l) and two tanks with a shorter outlet of 3.1 m (pipe volume 23.7 l). The length describes the distance between the tank cone and the connection

to the pipe fence. In addition, four tanks equipped with the ECO-MATRIX system were also investigated (pipe length 0.8 m, pipe volume 6.3 l).
Daily samples were taken after trub removal (approximately 18 h after filling) and before the first yeast crop.

Results and Discussion

By comparison of the results from the tank samples and the samples taken out of the pipe it was to be determined how the fermentation process develops in both reaction spaces. The conventionally equipped tanks were looked at first.

Conventionally equipped tanks

The temperature development was strongly dependent on the ambient room temperature. The desired fermentation temperature was maintained in the tank by cooling. The opposite could be detected in the pipe. Immediately at the end of the cooling area of the cone the temperature began to rise and adjust to room temperature very soon (figure 1). Thus the temperature in the pipe is much higher than in the tank. This should lead to different fermentation behaviour.

Figure 1: temperature distribution in the pipe in comparison (left: conventional tank outlet, right: ECO-MATRIX)

Figure 2 shows the degradation of extract in the tanks and in the corresponding pipes. A regular course of fermentation can be determined. The values of extract in the pipe are totally different from the tank. Because of a higher yeast-to-wort ratio and the higher temperatures the extract was already fermented after a couple of hours and before the first sample was taken. This implies that for the rest of the fermentation time the yeast remains in the pipe without any nutrition at very high temperatures. A poor yeast physiology and autolysis of the cells can be the result.

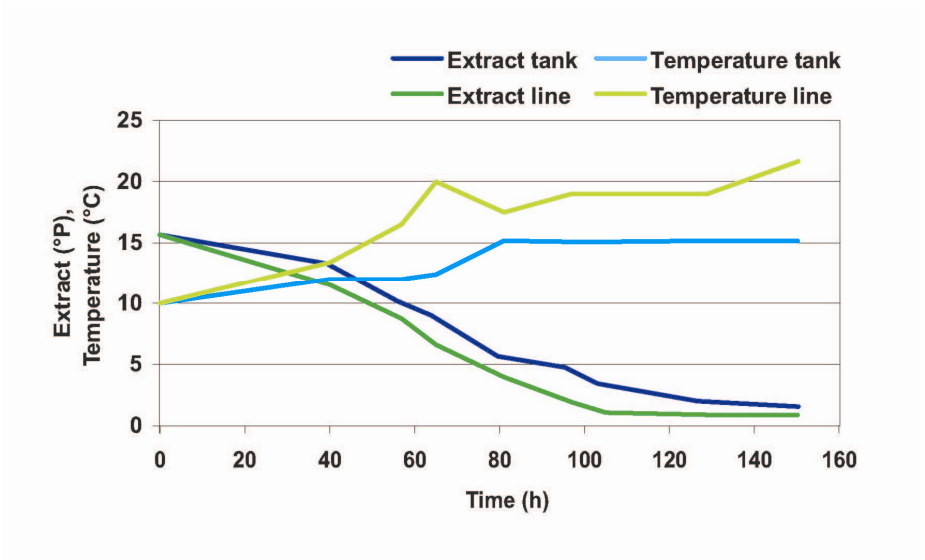

Figure 2: course of extract in tanks and pipes

The pH-values of the samples are an obvious indication for yeast starvation and autolysis. While the tank values also show a regular behaviour, the values of the samples taken out of the line increase over the fermentation period. A release of basic amino acids out of the autolysing cells is responsible for this development. The very high values, over pH=6, show the highly negative conditions for the yeast in the pipes.

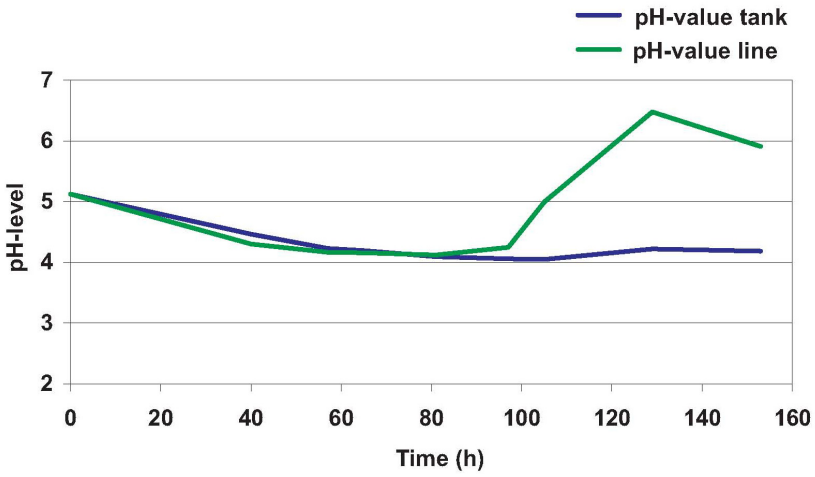

Figure 3: course of pH in tanks and pipes

These results are underlined by considering the yeast viability. Figure 4 depicts the living cells over the fermentation period. The samples taken from the tank show a good vitality. The values of the pipe samples show a constant decrease leading to almost 100 % dead cells. The strong degradation phase after approximately 100-120 h corresponds with the increase of pH. Because of a strong yeast settlement in the long outlet pipes no values could be gained.

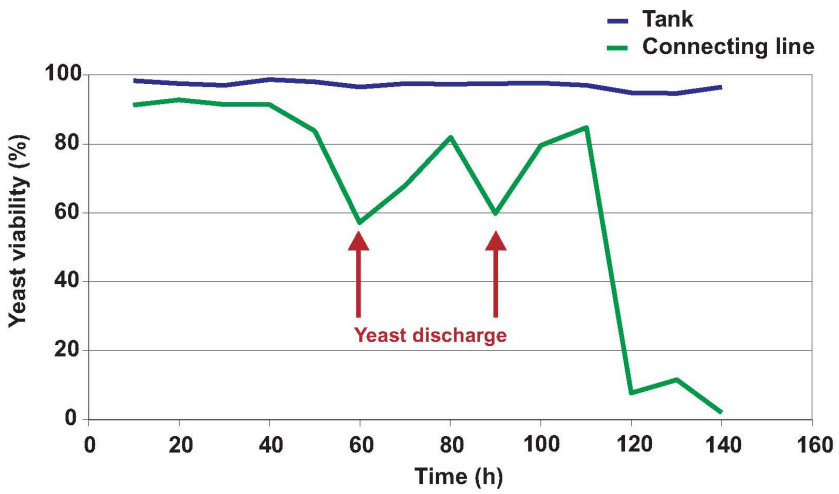

Figure 4: course of yeast viability in tanks and pipes

The samples from the pipes were also tested with an immunochemistry assay for the presence of proteinase A. The detected values were all higher than the effective range of the analysis. Unfortunately no sample material was left for a diluted assay. Thus only a qualitative statement can be made: Occurrence of proteinase A is detectable, in an undesired quantity. A visual and sensory analysis of the samples showed an increase in colour and a release of off-flavours. Over the fermentation period the smell becomes more and more unpleasant with rotten notes.

In essence, all these results show that there are two different reaction spaces during fermentation, the tank and the pipe. It is shown that the processes in there vary extremely. The fermentation in the pipe is characterised by different process parameters like the yeast-to-wort ratio and higher temperatures. This leads to an immediately extensive degradation of extract with subsequent starvation and autolysis of the yeast cells in the line. An excretion of undesired off-flavours and proteinases are the consequence. Though the volume in the pipe is negiglibly small compared to the whole tank volume, quality losses for the finished beer cannot be excluded. The amount of off-flavours will not be detectable if diluted with the tank content, However, proteinase might still affect the foam stability negatively. The conditions in the pipe (high temperature/ high pH) may enable growth of bacteria. The conditions in the pipe mainly depend on ambient conditions. They will probably not differ that much in a cool cellar, but vary greatly in plants with outdoor tanks in hot areas. Thus it is recommended to discard one pipe volume at least, despite minor product losses. But also the cleaning of the pipes could be critical. Figure 5 shows pictures made with an endoscope camera. The cleaning of the pipe has to be carried out together with the tank cleaning. This leads to a very low flow velocity in the pipe and unfavourable fluid dynamic conditions. Only extended cleaning intervals, higher temperatures and/or a higher detergent concentration will give satisfying results.

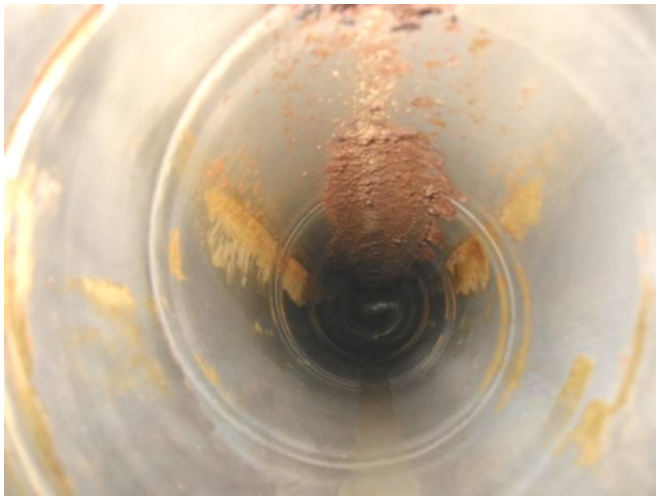

Figure 5: inner surface of the pipe after cleaning

To solve the above-mentioned problems, flushing of the pipe after filling should be possible.

Tanks with ECO-MATRIX-system

An alternative pipe system, the so-called ECO-MATRIX-system, was also installed in the brewery. The analyses carried out above were also carried out for this system.
The temperature distribution is like in the conventional system, right under the cooling zone the temperature in the pipe adjusts to room temperature.
The degradation of extract is different compared to the other system (figure 6). The tank values are comparable but the samples taken out of the pipe show a slower degradation of extract. Still faster compared to the tank but not that extreme in the conventional pipe. This indicates better intermixing of the contents of tank and pipe (ECO-MATRIX) in the first fermentation period.

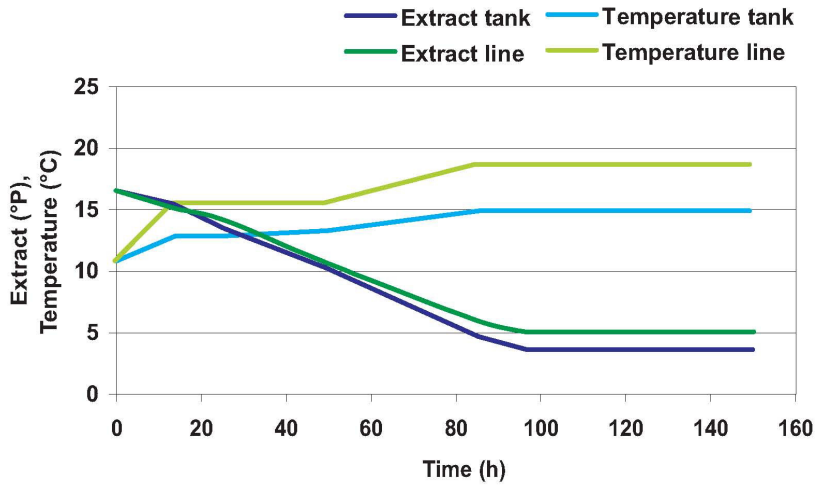

Figure 6: course of extract degradation in tanks and pipes (ECO-MATRIX)

Corresponding to this development, the pH-values and the yeast viability are shown in figure 7 and 8. The increase of pH in the pipes starts later than in the other system. Additionally, the values did not become that high. The same applies to yeast vitality. A later decrease in the pipe samples can be seen.

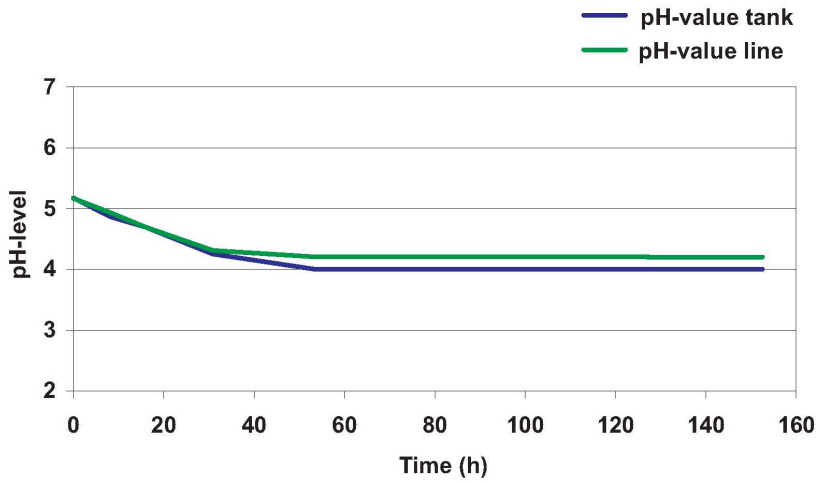

Figure 7: course of pH in tanks and pipes (ECO-MATRIX)

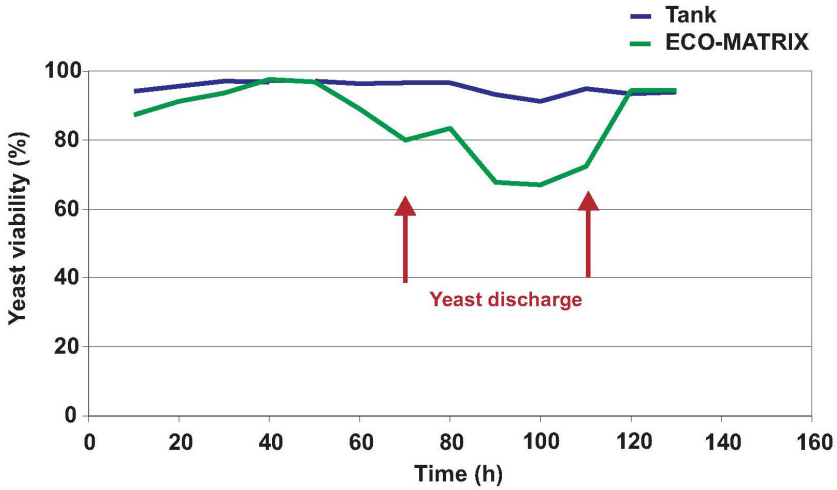

Figure 8: course of yeast viability in tanks and pipes (ECO-MATRIX)

Regarding the tanks equipped with ECO-MATRIX, the results are almost comparable to the results achieved with the conventional pipe system. But in detail the parameters observed do not show the extreme values. And the negative changes in the pipe occur later in the ECO-MATRIX tanks. Considering the minor volume in the small outlet, only about 6 litres, this could be considered as a short extension of the cone. Because of the ECO-MATRIX design the outlet pipe is no longer connected with the tank and can be cleaned individually. This should lead to lower product losses and less cleaning requirement.

Summary

It can be summarised that the connection of the tank with a long pipe system shows disadvantages if product remains in this pipe over the fermentation period. Because of different conditions in the tank and the pipe two different processes can be described. The tank as a matter of course shows regular fermentation, but in the pipe the fermentation process is finished very soon. This results in yeast starvation. Off-flavours and other quality reducing substances are released. In addition to complex cleaning of these pipes quality problems may be a consequence. Strategies of separating and cleaning the pipe after tank filling are recommended. One possibility is the employment of the ECO-MATRIX-system,

where the valves are directly connected with each tank. Thus no product remains in the pipe and can cause the problems discussed above.

Acknowledgements

The authors would like to thank the project partner in the brewery for his expert technical advice and his efforts in carrying out these experiments. Additionally Konrad Müller-Auffermann's efforts in taking and analyzing all samples and collecting data material are very much appreciated.