ABSTRACT

The protection of reducing substances derived from wort as well as the development of the antioxidant activity during fermentation are important factors for the flavor stability of beer. The antioxidant activity of beer is investigated by means of electron spin resonance spectroscopy in dependence on filling intervals and timing of aeration in cylindro-conical fermentation tanks. The development of the antioxidant activity shows an exponential correlation with the concentration of sulfur dioxide formed during fermentation. Removal of cold break by flotation or cold wort filtration results in considerable reduction of the antioxidant activity. In case of multi-filling of cylindro-conical fermentation tanks, the timing, when aerated wort is added to the already fermenting wort, leads to significant differences in the antioxidant activity of beer.

Keywords: Cylindro-conical fermenters, Multi-filling of cylindro-conical tanks, Topping-up, Antioxidant Activity

INTRODUCTION

Reducing substances of beer are strongly involved in the inhibition of reactions which cause a stale flavour in beer. These ‘natural antioxidants’ are responsible for the antioxidant activity of beer which shows a significant correlation with flavour stability.

The pitching and filling technique of cylindro-conical fermentation tanks has a great impact in the protection of reducing substances derived from wort, as well as on reducing compounds formed during fermentation by yeast. The antioxidant activity of the resulting beers is investigated in dependence on variations in filling intervals and aeration timing of cylindro-conical fermentation tanks besides other quality parameters of beer.
EXPERIMENTS

- Cylindro-conical fermentation tanks with 2 cooling jackets in 30 l scale
- Concentration of yeast in pitching wort: 10E+6/ml
- Bottom fermented yeast (strain W 34; 2nd propagation)
- Fermentation temperature: 8.5°C
- Aeration via venturi injection: 18 l/hl (oxygen content of aerated wort 7-8 mg/l)
- Wort: pale all malt wort, 11.5°P original gravity

ANALYTICAL METHODS

- Sulphur dioxide: MEBAK 2.29.2 (distillation method)
- Forced aging of beer: 1 day shaking, 4 days storage at 40°C

RESULTS

Change of the antioxidant activity during fermentation.
In wort, no antioxidant activity using the ESR method can be detected. The development of the lag time occurs during fermentation starting at the second fermentation day. The lag time shows an exponential correlation with the sulphur dioxide content during fermentation.

**INFLUENCE OF WORT AERATION (FLOTATION)**

- Wort aeration with 42 l/h (3 h contact without yeast)
- After 3 hours pitching of yeast and second aeration with 18 l/h

**without removal of cold break**

- control
- flotation without yeast
- flotation with yeast

**with removal of cold break**

- control
- flotation

In wort, no antioxidant activity using the ESR method can be detected. The development of the lag time occurs during fermentation starting at the second fermentation day. The lag time shows an exponential correlation with the sulphur dioxide content during fermentation.
- Aeration of the pitching wort without yeast has no negative effect on the antioxidant activity.
- The removal of cold break using the flotation technique results in a significantly reduced antioxidant activity.
- Second aeration after 6 hours leads to a significant decrease in antioxidant activity and sulphur dioxide content.

**ORAUFASSEN (TOPPING UP)**

- Pitching with aerated wort (18 l/hl) and yeast count 20E+6/ml
- Topping up (Drauflassen) at different times

<table>
<thead>
<tr>
<th>Concentration [mg/l]</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tbody>
<tr>
<td>SO₂</td>
<td>7.1</td>
<td>9.2</td>
<td>8.2</td>
<td>29</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td>7.0</td>
<td>8.2</td>
<td>7.4</td>
<td>6.5</td>
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<tr>
<td>acetate-esters</td>
<td>11</td>
<td>12</td>
<td>14</td>
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<td>amino acids</td>
<td>804</td>
<td>822</td>
<td>652</td>
<td>633</td>
</tr>
</tbody>
</table>
MULTI-FILLING OF CYLINDRO-CONICAL FERMENTATION TANKS

- Control
- Tank 1
- Tank 2
- Tank 3
- Tank 4
- Tank 5

- Aerated wort (18 l/h) with yeast count 10E+6/ml
- Aerated wort (42 l/h) with yeast count 40E+6/ml
- Unaerated wort
- Aerated wort (18 l/h)

Graphs show:
- Timing of topping up with aerated wort [h]
- Lag time [min.]
- Acceptance of forced aged beer [%]

Legend:
- □ lag time
- ✗ taste test of forced aged beer
• Topping up with yeast leads to a lower antioxidant activity. As a consequence, lower concentrations of sulphur dioxide, acetaldehyde and esters are found in the beers, whereas the higher alcohols show higher concentrations.

• When topping up with aerated wort, the timing has great impact on the development of antioxidant activity during fermentation.

CONCLUSION

• Pitching and aeration as well as multi-filling technique of cylindro-conical fermentation tanks have a great influence on the antioxidant activity, measured as the lag time by ESR spectroscopy, and on flavour stability. The development of the antioxidant activity during fermentation starts 24 hours after pitching and shows an exponential correlation with sulfur dioxide content.

• Aeration of the wort without yeast pitching does not affect the antioxidant activity of beer. Aeration and simultaneous removal of cold break, as happens during flotation, leads to reduced antioxidant activity and flavour stability.

• The timing of second aeration during fermentation, as well as the intervals of ‘drauflassen’ (topping up), can lead to significant reduction of the antioxidant activity and of flavour stability. ‘Drauflassen’ with aerated wort after 2.5 and 7.5 hours resulted in a significant decrease of antioxidant activity. To find out the optimal intervals for multi-filling of cylindro-conical fermentation tanks, other factors, such as fermentation temperature and yeast condition, have to be taken into consideration.