Process and plant for the CONTINUOUS FERMENTATION of fluids

Konrad Müller-Auffermann
Fritz Jacob
Introduction

Continuous Fermentation

+ Advantages of continuous (fermentation) processes +

- Improved plant performance, due to the reduction of processing times
- Increased space-time yield
- A resulting reduction of the cost of capital
- Less space consumption due to smaller plants
- Reduced energy consumption, especially by avoiding costly energy peaks
- Reduced costs for cleaning, detergents, disinfection and amount of wastewater
- An increase in labor productivity
- Reduced personal costs
- Less losses
- Improved fermentation gas (e.g. CO₂) recovery
- Less cleaning intervals
- Lower equipment costs
- Achievement of high standards of hygiene in closed systems
- Qualitative benefits
- Achievement of a constant quality of the final product
Introduction

Continuous Fermentation
Introduction

Continuous Fermentation

- Disadvantages of continuous (fermentation) processes -

- Lack of flexibility with respect to sales fluctuations
- Each production line can only produce one type of product
- Increased costs for proper organization of work (24-hour operation)
- Better qualified personnel is needed
- Higher expenses for the preservation of infections
- For process stability, a consistent quality of the raw materials is necessary
- Increased risk of mutations of organisms due to aging and long-term stress

Significant changes of the product character
Introduction

Continuous Fermentation

R&D effort in continuous fermentation processes

More than 150 different relevant systems where found & studied…
Introduction

Continuous Fermentation

Continuous fermentation processes in praxis

Coutts (1959): Dominon Breweries (New Zealand), New Zealand Breweries Ltd. (New Zealand), Canadian Breweries Ltd. (Canada), San Miguel Brewery Co. (Manila)

Fort Woth Fermenter (1965): Carling Brewing Company (USA)


APV Tower Fermenter (1960): Cape Hill Brewery (England), Brewery in Burton upon Trent (England), Brewery in Runcorn (England), Brewery in Warrington (England), Oranjeboom Brewery (Netherlands), Cerevecera del Norte (Spain)

Gotha Fermentation System (1973): Brewery Gotha (East Germany)
Technology offers significant advantages, which will gain importance in the near future.

In praxis only very few systems with free cells were tested (40-50 years ago!)

Nearly all of them failed.

Due to those failures and the potential higher efficiency the research and development has focused on systems with immobilized cell reactors.
• Does further research in this field make sense?
• Why did systems fail in the past?
• Which systems should be preferred; Immobilized or Free-Cell Systems?
1. Yeast is supposed to stay in the systems for a long time period

   - Permanent stress
   - Aging
   - Mutationes

   = Negative influence on the product

2. Infections

3. Complexity of the systems

   Higher affords for the usage and maintenance
Demands

1. Yeast should be treated nearly identically to classical batch process
2. System has to be safe against infections
3. Simple construction and usage
4. Integrable into existing plant
5. Multifunctionality
6. Usage of existing equipment if possible

Economic and ecological advantages
High constant product quality
Key to success: Properties of the yeasts

Yeasts determine the product character!

Intentionally adapted to batch process since centuries

Significant gain of knowledge within the past 40-50 years!

Influence:
- Temperature
- Pressure
- Substrate properties
- Aeration
- Cell amount
- Age

http://www.bier.de

http://truthfall.com
Continuous Fermentation

**Concept**

**Free cell systems**
- Yeast cycles can be reproduced
- Aged yeast can be discharged
- Lower risk of permanent infections

- Larger reactors
- More produced biomass
- Rather complicated systems

= Lower Efficiency?!?

**Immobilized cell systems**
- Small reactors
- Less produced biomass
- Uncomplicated systems

= Higher Efficiency?!?

- Long term stress for yeasts
- Yeast ages in system
- Higher risk of yeast mutations
- Higher risk of permanent infection
Stress situations for yeasts in the brewery

- Oxidative stress
- Anaerobic shift
- Cold shock
- Cold shock
- Osmotic stress
- Oxidative & osmotic stress
- Ethanol & nutrient stress
- Ethanol stress

**Concept**

Continuous Fermentation

**Diagram**

- **PROPAGATION**
  - Number of cells
  - Oxygen conc.
- **FERMENTATION**
  - Extract conc.
  - Temperature
  - Ethanol conc.
- **MATURATION**

**Table**

- Time
- Number of cells
- Oxygen conc.
- Extract conc.
- Temperature
- Ethanol conc.
Concept

Continuous Fermentation

Brewers: Traditional & hard to convince…

www.langersamstag.ch/media/bierbrauer-susch.jpg
Concept

Continuous Fermentation

Systemes with free cells!!!
Conclusion

Many systems are very complex.

Often many mechanical parts are being used.

Difficult clean ability ➔ higher risk of infections.

Commissioning times are often long.

Nearly no system focuses on yeast demands.

Yeasts are supposed to stay in systems for long time periods.

Often no possibility to remove yeasts and particles regularly.

Concept: Continuous Fermentation

Patent- & literature research: Free cell systems
Concept: Continuous Fermentation

- Usage of state of art equipment!
- Simple installation of a central conduction pipe through which the fermentate can be charged or discharged
- Other installations for intake/outtake in the top part of the tank are foreseen
- Further equipment like a cooling system for the conduction pipe may be integrated
- Particles and yeasts can be discharged at the tank bottom
- The system is operated continuously or at least semi-continuously
Concept

Continuous Fermentation
Advantages

Continuous Fermentation

Fermentation progress & resulting yeast stress

Extrakt [%]

Extrakt [°P]

0  20  40  60  80  100

0  24  48  72  96

0.00  2.92  5.84  8.76  11.68
Advantages of this concept

- The yeast cycles, as they exist in classical batch fermentations can be simulated
- Particles (e.g. trub, yeasts) as well as gases can be discharged and added to the process variable
- Pressure and temperature gradients can be adjusted precisely.
- Existing plants may partly be used by modification
- The function, commissioning, as well as the cleaning and maintenance are fairly easy

--? Economic advantages ?--
In a classical batch fermentation the filling time and the discharge times should each not be longer than 10% (referring to the fermentation) (Example: 5 days main fermentation = 120h: Filling/discharge time max = 12h each)

**Simplified calculation**

**Longer filling and discharge cycles would lead to the following disadvantages**

(Independent of batch size!)

- Due to the longer supply of amino acids more Diacetyl will be produced
- The oxygen supply might lead to oxidations
  - The yeast cycles may be disrupted
  - The content can not be cooled fast enough
### Classical Batch Fermentation

<table>
<thead>
<tr>
<th>Filling</th>
<th>Fermentation</th>
<th>Discharge</th>
<th>CIP</th>
<th>Occupation time</th>
<th>Necessary tanks</th>
<th>Tanks/day</th>
<th>Tank size</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 h</td>
<td>5 days</td>
<td>12 h</td>
<td>4 h</td>
<td>148,0 h</td>
<td>14 tanks</td>
<td>2</td>
<td>50% daily production</td>
</tr>
<tr>
<td>9,6 h</td>
<td>4 days</td>
<td>9,6 h</td>
<td>3,2 h</td>
<td>118,4 h</td>
<td>14 tanks</td>
<td>2,5</td>
<td>40% daily production</td>
</tr>
<tr>
<td>7,2 h</td>
<td>3 days</td>
<td>7,2 h</td>
<td>2,4 h</td>
<td>88,8 h</td>
<td>14 tanks</td>
<td>3,3</td>
<td>30% daily production</td>
</tr>
<tr>
<td>4,8 h</td>
<td>2 days</td>
<td>4,8 h</td>
<td>1,6 h</td>
<td>59,2 h</td>
<td>14 tanks</td>
<td>5</td>
<td>20% daily production</td>
</tr>
<tr>
<td>2,4 h</td>
<td>1 day</td>
<td>2,4 h</td>
<td>0,8 h</td>
<td>29,6 h</td>
<td>14 tanks</td>
<td>10</td>
<td>10% daily production</td>
</tr>
</tbody>
</table>

### Continuous Fermentation

<table>
<thead>
<tr>
<th>Filling</th>
<th>Fermentation</th>
<th>Discharge</th>
<th>CIP</th>
<th>Occupation time</th>
<th>Necessary tanks</th>
<th>Tanks/day</th>
<th>Tank size</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 days</td>
<td>120 h</td>
<td>5+1 Tanks</td>
<td>100% daily production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 days</td>
<td>96 h</td>
<td>4+1 Tanks</td>
<td>100% daily production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 days</td>
<td>72 h</td>
<td>3+1 Tanks</td>
<td>100% daily production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 days</td>
<td>48 h</td>
<td>3+1 Tanks</td>
<td>66% daily production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 day</td>
<td>24 h</td>
<td>3+1 Tanks</td>
<td>33% daily production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Advantages**

Continuous Fermentation
## Costs of a modern tank cleaning with fresh substances

<table>
<thead>
<tr>
<th>Detergent</th>
<th>Consumption</th>
<th>Price/Unit [Euro]</th>
<th>Costs [Euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water [m³]</td>
<td>5,6</td>
<td>3,83</td>
<td>21,47</td>
</tr>
<tr>
<td>Caustic [l]</td>
<td>37</td>
<td>0,07</td>
<td>3,07</td>
</tr>
<tr>
<td>Acid [l]</td>
<td>6,9</td>
<td>0,81</td>
<td>5,58</td>
</tr>
<tr>
<td>Desinfection [l]</td>
<td>1,3</td>
<td>1,76</td>
<td>2,29</td>
</tr>
<tr>
<td><strong>Total costs [Euro]</strong></td>
<td></td>
<td></td>
<td><strong>32,41</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heating energy</th>
<th>Consumption</th>
<th>Price/Unit [Cent]</th>
<th>Costs [Euro]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Step 45°C [kWh]</td>
<td>85,2</td>
<td>1,55</td>
<td>1,32</td>
</tr>
<tr>
<td>2. Step 65°C [kWh]</td>
<td>221,6</td>
<td>1,55</td>
<td>3,42</td>
</tr>
<tr>
<td><strong>Total costs [Euro]</strong></td>
<td></td>
<td></td>
<td><strong>4,74</strong></td>
</tr>
</tbody>
</table>

**Approx. Costs for the cleaning of one tank**: 37,15 Euro
## Simplified calculation

### Classical Batch Fermentation

<table>
<thead>
<tr>
<th>Fermentation time</th>
<th>Tank size</th>
<th>Costs per tank cleaning</th>
<th>Tanks/day</th>
<th>CIP costs/day</th>
<th>300 days production/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 days</td>
<td>100%</td>
<td>37,15 Euro</td>
<td>2</td>
<td>74,3 Euro</td>
<td>22.290 Euro/a</td>
</tr>
<tr>
<td>4 days</td>
<td>80%</td>
<td>29,72 Euro</td>
<td>2,5</td>
<td>74,3 Euro</td>
<td>22.290 Euro/a</td>
</tr>
<tr>
<td><strong>3 days</strong></td>
<td><strong>60%</strong></td>
<td><strong>22,29 Euro</strong></td>
<td><strong>3,3</strong></td>
<td><strong>74,3 Euro</strong></td>
<td><strong>22.290 Euro/a</strong></td>
</tr>
<tr>
<td>2 days</td>
<td>40%</td>
<td>14,86 Euro</td>
<td>5</td>
<td>74,3 Euro</td>
<td>22.290 Euro/a</td>
</tr>
<tr>
<td>1 day</td>
<td>20%</td>
<td>7,43 Euro</td>
<td>10</td>
<td>74,3 Euro</td>
<td>22.290 Euro/a</td>
</tr>
</tbody>
</table>

### Continuous Fermentation

<table>
<thead>
<tr>
<th>Fermentation time</th>
<th>Tank size</th>
<th>Costs per tank cleaning</th>
<th>Tanks/day</th>
<th>CIP costs/day</th>
<th>365 days production/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 days</td>
<td>100%</td>
<td>37,15 Euro</td>
<td>0,16</td>
<td>6,19 Euro</td>
<td>2.229 Euro/a</td>
</tr>
<tr>
<td>4 days</td>
<td>100%</td>
<td>37,15 Euro</td>
<td>0,13</td>
<td>4,95 Euro</td>
<td>1.783 Euro/a</td>
</tr>
<tr>
<td><strong>3 days</strong></td>
<td><strong>100%</strong></td>
<td><strong>37,15 Euro</strong></td>
<td><strong>0,1</strong></td>
<td><strong>3,72 Euro</strong></td>
<td><strong>1.337 Euro/a</strong></td>
</tr>
<tr>
<td>2 days</td>
<td>66%</td>
<td>24,52 Euro</td>
<td>0,1</td>
<td>2,45 Euro</td>
<td>883 Euro/a</td>
</tr>
<tr>
<td>1 day</td>
<td>33%</td>
<td>12,25 Euro</td>
<td>0,1</td>
<td>1,23 Euro</td>
<td>441 Euro/a</td>
</tr>
</tbody>
</table>
Plant concept with focus on simplicity with focus on brewery yeast demands

Technological advantages
• Low stress for yeasts
• Fractionization of particles, gas and organisms possible
• Yeast can live through the same cycles like in batch process

Economical and ecological advantages
• Less tanks = less needed space, lower investment costs, less equipment, control, and cleaning efforts necessary
• Less waste / consumption (beer, water, gas, CIP, yeast, energy, cooling…)
• Constant product quality

Conclusion

Advantages
Continuous Fermentation
But: not everything can be calculated or predicted…

Open questions:
For which drinks is such a technology suitable?
Can realistic conditions be achieved in small scale?
How should experiments be conducted in order to allow scale up?
What are the ideal parameters for a fast fermentation?
How does standard yeast react?
How can the physiological condition of the yeast be measured simple?

Can a small scale plant be built and be run under similar conditions?
How does such a product taste like?
How stable can such a plant be run?
How does the system react to infections?
How can the performance be optimized?
1. Investigation in order to evaluate the process suitability

In total **278** different fermented beverages were investigated

- **152 Drinks where made out of cereals or pseudo-cereals**
- **56 Drinks where milk-based**
- **17 Drinks where fruit-based**
- **53 beverages where made out of different ingredients**
<table>
<thead>
<tr>
<th>Name Getränk</th>
<th>Rohstoff u. Zusätze</th>
<th>Land</th>
<th>Dauer</th>
<th>Temperatur</th>
<th>MO</th>
<th>Quelle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bananen-Bier</td>
<td>Bananensaft, gerösteter Sorghum</td>
<td>Burundi</td>
<td>48-96 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>30, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Isongo</td>
<td>Bananen, Sorghum</td>
<td>Uganda</td>
<td>18-24 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>105, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Lubisi</td>
<td>Bananen, Fingerhirse</td>
<td>Tansania</td>
<td>96-120 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>107, 108, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Mbege</td>
<td>Bananen, Sorghum</td>
<td>Uganda</td>
<td>18-24 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>105, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Mwenge</td>
<td>Bananen, Sorghum</td>
<td>Uganda</td>
<td>18-24 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>105, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Uwarwa/Uwarwa</td>
<td>Bananen, Sorghum, gerösteter Sorghum</td>
<td>Burundi, Rwanda</td>
<td>48-96 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>30, 106, 105, 18 (S.89)</td>
</tr>
<tr>
<td>Urwaga</td>
<td>Bananen, Sorghum, Hirse o. Mais</td>
<td>Kenia</td>
<td>18-24 h</td>
<td>14-25 °C</td>
<td>Sac1</td>
<td>105, 105, 18 (S.89)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bananenwein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makia</td>
</tr>
<tr>
<td>Moru</td>
</tr>
<tr>
<td>Raha</td>
</tr>
</tbody>
</table>
Assessment of 49 types of beverages

1. Raw materials
2. Sales volume
3. Production period
4. Fermentation time
5. Production site
6. Sales area / Market

≥ 40 P = good
30-39 P = suitable
20-29 P = not appropriate
< 20 P = not suitable

Milk-based: 20% Milk - based
Cereal-based: 55% Cereal-based
Different Ingredients: 45%
Fruit-based: 86%

= not suitable

Konrad Müller-Auffermann
EBC 2012 From Chiller to Filler
2. Can small scale fermentations reflect realistic situations?
3. How should they be done in order to allow a scale up?

<table>
<thead>
<tr>
<th>EBC fermenter</th>
<th>Lietz fermenter</th>
<th>Laboratory fermenter</th>
<th>Weinfurter fermenter</th>
</tr>
</thead>
</table>

![Diagram of fermenters](image)
2. Can small scale fermentations reflect realistic situations?

3. How should they be done in order to allow a scale up?
2. Can small scale fermentations reflect realistic situations?

3. How should they be done in order to allow a scale up?
### 2. Can small scale fermentations reflect realistic situations?

### 3. How should they be done in order to allow a scale up?

#### Tests in order to check different substrates for their suitability

<table>
<thead>
<tr>
<th>Richtwerte</th>
<th>Normwert</th>
<th>W</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
<th>E6</th>
<th>G1</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAN (mg/l)</td>
<td>200-240</td>
<td>208</td>
<td>208</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
<td>107</td>
</tr>
<tr>
<td>Summe AS (mg/l)</td>
<td>1600-2000</td>
<td>1694</td>
<td>1240</td>
<td>826.3</td>
<td>348.5</td>
<td>723.5</td>
<td>186.7</td>
<td>399.4</td>
<td>1394.7</td>
<td>1062.3</td>
<td>729.2</td>
</tr>
<tr>
<td>pH-Wert</td>
<td>5.2</td>
<td>5.2</td>
<td>5.07</td>
<td>5.28</td>
<td>5.53</td>
<td>5.71</td>
<td>4.77</td>
<td>5.5</td>
<td>5.33</td>
<td>5.26</td>
<td>5.75</td>
</tr>
<tr>
<td>Ges. Lösl. N (mg/l)</td>
<td>900-1100</td>
<td>1056</td>
<td>1303</td>
<td>1071</td>
<td>450</td>
<td>721</td>
<td>875</td>
<td>544</td>
<td>980</td>
<td>1302</td>
<td>651</td>
</tr>
<tr>
<td>noch koagl. N (mg/l)</td>
<td>&lt; 25</td>
<td>21</td>
<td>34</td>
<td>43</td>
<td>15</td>
<td>57</td>
<td>36</td>
<td>19</td>
<td>9</td>
<td>53</td>
<td>64</td>
</tr>
<tr>
<td>Scheinbarer Extrakt [G/V%]</td>
<td>12</td>
<td>12,18</td>
<td>11,98</td>
<td>12,08</td>
<td>12,1</td>
<td>12,26</td>
<td>12,17</td>
<td>12,18</td>
<td>12,53</td>
<td>12,58</td>
<td>12,52</td>
</tr>
<tr>
<td>Farbe</td>
<td>5-15</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>15</td>
<td>19</td>
<td>25</td>
<td>77,5</td>
<td>19</td>
<td>55</td>
<td>31,3</td>
</tr>
<tr>
<td>TBZ</td>
<td>&lt; 45</td>
<td>29.5</td>
<td>119.5</td>
<td>118.8</td>
<td>283</td>
<td>66.6</td>
<td>123.9</td>
<td>94.9</td>
<td>82.7</td>
<td>280</td>
<td>47.5</td>
</tr>
<tr>
<td>Fructose (g/l)</td>
<td>1-2</td>
<td>1.52</td>
<td>1.9</td>
<td>1.68</td>
<td>0.71</td>
<td>0.1</td>
<td>0.51</td>
<td>0.1</td>
<td>0.5</td>
<td>0.49</td>
<td>0.02</td>
</tr>
<tr>
<td>Glucose (g/l)</td>
<td>10-12</td>
<td>10,86</td>
<td>13,09</td>
<td>12,41</td>
<td>8.31</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>3.51</td>
<td>3,03</td>
<td>1.5</td>
</tr>
<tr>
<td>Saccharose (g/l)</td>
<td>2-4</td>
<td>3.01</td>
<td>3.06</td>
<td>2.55</td>
<td>0.88</td>
<td>1,5</td>
<td>0.25</td>
<td>1</td>
<td>2.5</td>
<td>0.41</td>
<td>1.7</td>
</tr>
<tr>
<td>Maltose (g/l)</td>
<td>56-80</td>
<td>70.61</td>
<td>61.04</td>
<td>66.19</td>
<td>57.45</td>
<td>4.92</td>
<td>12.3</td>
<td>18.03</td>
<td>18.87</td>
<td>16.4</td>
<td>5.73</td>
</tr>
<tr>
<td>Maltotriose (g/l)</td>
<td>14-17</td>
<td>15</td>
<td>13,75</td>
<td>18,58</td>
<td>22,89</td>
<td>4,02</td>
<td>2,5</td>
<td>6</td>
<td>7,51</td>
<td>6</td>
<td>5,01</td>
</tr>
</tbody>
</table>
4. & 5. Reactions to different situations

**Fermentations under the variations of**
- Cell amount (4 different)
- Aeration (aerated/not aerated)
- Temperature (3 different)
- Pressure (3 different)

**Additional tests**
- Alkohol stress
- Pressure stress
- High-Gravity-Stress
- Pressure variationes

**Tests for over one year!!!**

**Analyses**
- Extrakt
- pH-Value
- Alkohol
- FAN (alleAA!)
- VDK
- Biomass/Cell count
- GCs

3 usages, different steams
4. & 5. Reactions to different situations
6. Simple method in order to determine the yeast vitality

**Via CO₂-built up**

**Via particle size analysis**
R & D

Continuous Fermentation

Technology: Possibilities in small scale
Continuous Fermentation

Technology: Possibilities in small scale

From Chiller to Filler
Continuous Fermentation

Technology: Possibilities in small scale
Technology: Possibilities in small scale
Continuous Fermentation
Continuous Fermentation
Continuous Fermentation
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**Experiments & Results**

1-Tank Process (6 days)
- No bigger process problems
- Currency tests sucessfull
- Only small changes/simplifications necessary

3-Tank Process (33 days)
- No process problems
- Extract, Alkohol, pH-Value relatively constant
- Taste: constant good
- Contamination with wort bacteria: No long term problem!

4-Tank Process (35 days)
- No process problems
- Extract, Alkohol, pH-Value relatively constant
- Taste: constant good
- Contamination with different bacteria: No long term problem!

10 filling, discharging and CIP processes per tank less!!!
= totally 30-40x less!!!
Results

25/05/2012  01/06/2012  08/06/2012  15/06/2012  22/06/2012

Extrakt [°P]

B-T1  T1  T1-T2  T2  T2-T3  T3  T3-T4  T4

Continuous Fermentation
If you can’t explain it *simply*, you don’t understand it well enough.

– Albert Einstein
Thank you for your attention!

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Future trends in the beverage industry

- Energy efficiency
- Sustainability
- Transparency
- Individuality
- Funktionality
- Economy // Price

Continuous fermentation

Weltbierausstoß in Mrd. hl

Introduction

Continuous Fermentation