Myth Busting Kettle Sourcing.
The Appliance of Science.

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What is Kettle Souring?

Production of clean, refreshing, sour beers in a relatively short time.

Deliberate growth of Lactic Acid Bacteria (LAB) in wort

Reduction in pH to between 3.6 - 3.0.

Boiling of wort to eliminate bacteria prior to moving into cold side of brewery.
Kettle Sourcing Process:

- Mash and sparge as normal
- Boil wort briefly to sanitise
- Cool to 35-40°C
- Drop pH to 4.5 (food grade acid)
- Purge out $O_2$ with $CO_2$
- Inoculate
- Blanket with $CO_2$ then seal stack and manway
- Sour over 36-72+ hours

Aim is to create conditions for LAB to thrive whilst preventing growth of contaminating bacteria and production of off flavours
Kettle Sourcing Process:

- All reference to this process has been anecdotal
- No data provided to show efficacy and/or necessity of the key steps
- No studies, that I was aware of, took apart the process and analysed its key assumptions:
  - Pre-boiling eliminates contaminating bacteria
  - Reducing pH to 4.5 inhibits contaminating bacteria
  - Oxygen in the process leads to butyric acid production
  - Purging wort with CO₂ strips out O₂
  - Blanketing with CO₂ prevent O₂ ingress
The plural of anecdote is not data.
Outline

Acidity
Bacteria and pH
Oxygen
Starters cultures
Proof of Concept
Questions
Acidification of Wort with Lactic Acid

#795 King of Ashton (12.5°P)
100 mL titrated with 1 mL additions of 8.8% Lactic Acid (0.98M or 88g/L)

- At pH 5.6 ~98% dissociated
- At pH 3.86 (pKa) 50% dissociated
- At pH 3.50 ~30% dissociated
- At pH 3.00 ~10% dissociated

Target pH range: [3.5, 4.5]
pH and Titratable Acidity

- pH meter measures $H^+$ ions
- pH is not the best measure of how “sour/tart” a beer will be perceived
- Organic acids are only partially dissociated
- Our tongues perceive all the acid, dissociated or not\(^1\)
- Titratable acidity (ASBC method Beer-8) measures all acids

**Confound issues**
- Mix of acids determines the “softness” or “sharpness” of perceived acidity
- Residual sugar

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### pH and Titratable Acidity

- Data from White Labs except HND, POC
- Beers tested for: pH, titratable acidity, organic acid profiles and sensory characteristics

<table>
<thead>
<tr>
<th>Beer</th>
<th>pH</th>
<th>TA g/L</th>
<th>Acids- by HPLC</th>
<th>Plato (final)</th>
<th>Sensory- 0 to 3</th>
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</thead>
<tbody>
<tr>
<td>HND</td>
<td>4.51</td>
<td>3.42</td>
<td></td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Beer E</td>
<td>3.67</td>
<td>4.40</td>
<td>Lactic, Malic, Citric</td>
<td>3</td>
<td>1.5</td>
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<tr>
<td>POC</td>
<td>3.52</td>
<td>7.83</td>
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<td>1.6</td>
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<td>Beer D</td>
<td>3.35</td>
<td>8.92</td>
<td>Lactic, Malic, Citric</td>
<td>2.1</td>
<td>1.95</td>
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<td>Beer C</td>
<td>3.50</td>
<td>10.0</td>
<td>Lactic, Malic, Acetic, Acetic</td>
<td>2</td>
<td>2.54</td>
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<td>Beer B</td>
<td>3.57</td>
<td>10.6</td>
<td>Lactic, Acetic, Malic, Citric</td>
<td>0</td>
<td>2.25</td>
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<tr>
<td>Beer A</td>
<td>3.41</td>
<td>12.2</td>
<td>Lactic, Malic, Citric, Acetic</td>
<td>1.1</td>
<td>2.65</td>
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<tr>
<td>Beer G</td>
<td>3.52</td>
<td>13.8</td>
<td>Lactic, Acetic, Malic</td>
<td>1.5</td>
<td>2.51</td>
</tr>
<tr>
<td>Beer F</td>
<td>3.55</td>
<td>15.8</td>
<td>Lactic, Acetic, Malic, Citric</td>
<td>1.5</td>
<td>2.56</td>
</tr>
<tr>
<td>Beer H</td>
<td>3.49</td>
<td>18.7</td>
<td>Lactic, Acetic, Malic</td>
<td>1.75</td>
<td>2.59</td>
</tr>
</tbody>
</table>

HND - The Golden Hind    POC - Proof of Concept
Acidity and Bacterial Growth/Viability

$\Delta pH$ (Proton Motive Force)

Additional mechanisms: production of alkali, macromolecule protection, etc.
Lactic Acid Bacteria (LAB) - Sources

Grain: LAB on grain surface (also enteric bacteria)
   Not necessarily *Lactobacillus* e.g. *Weissella cibaria*

Yoghurt: LAB used to sour milk
   Usually a mix of LAB (e.g, *Lactobacillus, Streptococcus,*
   and *Bifidobacterium* sp.)
   Most likely inoculated with pure culture

Pure: Isolated and pure cultured
   White Labs, Wyeast etc.
Lactic Acid Bacteria (LAB)

• Facultative anaerobes
  • can grow in or tolerate presence of oxygen
  • generally don’t respire (detoxify $O_2$ via oxidative stress response)
  • fermentative
    • homolactic - lactic acid only
    • heterolactic - lactic and acetic acid/ethanol

• Acid tolerant neutrophiles
  • growth optimum is just below neutral
  • can tolerate pH down to ~3
Oxygen and Off Flavours in Kettle Soured Beers

Vegetal, cabbage, cooked tomato, sulphur

• caused by Enteric bacteria
• obligate aerobes or facultative anaerobes
• acid sensitive (eliminated around pH 4.5)

“poo, farts, sick, smelly feet, sweat, gone-off curry, sour milk”

• butyric acid
• made by Clostridia and related sp. (spore forming bacteria)
• obligate anaerobes
• acid sensitive
• brewing ‘folklore’ states that occurs in presence of Oxygen
Key Assumptions revisited

- Pre-boiling eliminates contaminating bacteria
  - Yes, except for spore formers
- Reducing pH to 4.5 inhibits contaminating bacteria
  - Will inhibit or eliminate acid sensitive strains
- Oxygen in the process leads to butyric acid production
  - No, opposite is the case
- Purging wort with CO₂ strips out O₂
  - Maybe
- Blanketing with CO₂ prevent O₂ ingress
  - Diffusion!

Adequate pitch of bacteria renders these steps unnecessary
Hypothesis

Original hypothesis:
Most likely cause of Butyric Acid in Kettle Sours is a low initial pitch of bacteria in the absence of Oxygen

Revised hypothesis:
The most likely cause of off flavours in Kettle Sours is a low initial pitch of bacteria
Pitching for Kettle Sour Fermentation.

Think of pitching LAB in the same terms as pitching yeast*
- healthy, viable, vital cells
- appropriate pitch rate
- rapidly consume O₂
- quickly reduce pH to 4.5 and below

The larger the pitch,
the shorter the lag phase,
the more rapidly pH will drop,
the greater the protection against contaminating bacteria

* Except for adding O₂, don’t want to add but don’t need to go to excessive lengths to keep it out.
What is an Appropriate Pitch Rate?

- 10% v/v for re-pitch. Cambridge Brewing Company\(^1\)
- Minimum 2.5% v/v for starter culture\(^1\)
- 4-12% v/v for re-pitch. Breakside Brewery\(^2\)
- Starter culture at 0.6% v/v. Mystery Brewing Company
- Lellamand WildBrew Sour Pitch - Pitch rate is \(>10^7\) cfu/mL
- Literature \(~10^7\) cfu/mL

Starter Cultures

**Starter:**
3 x 1.8L sterile 10% DME (8.8°P)
10g acidulated malt, 10g “local” malt
Incubate until pH 3.6 to 3.5

**Re-pitch:**
Harvest in to keg prior to boil
Flush kettle drain, harvest in to clean keg
Store in cold room with blow off
Warm up and mix prior to inoculating next batch

**Frozen stocks:**
1:1 mix of starter culture and sterile 40% (w/v) trehalose.
-20°C for 1 year
-80°C indefinitely.
Thaw vial and inoculate in to flask to make fresh starter culture
Starter Cultures

Culture temperature ~25°C  

pH 4.5 in ~20 hrs.

Starter culture from grain (20g/1.8L)
# How has this Informed the Process at Mystery?

## Proof of Concept

### Grist.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maris Otter</td>
<td>28.9%</td>
</tr>
<tr>
<td>Golden Promise</td>
<td></td>
</tr>
<tr>
<td>Bohemian Pilsner</td>
<td>43.4%</td>
</tr>
<tr>
<td>Naked Oats</td>
<td>14.5%</td>
</tr>
<tr>
<td>Raw Triticale</td>
<td>13.2%</td>
</tr>
</tbody>
</table>

### Mash:

- 69°C (156°F) for 90 min

### Fermentation:

- London Ale III at 20°C (69°F)

### Hops.

<table>
<thead>
<tr>
<th>Hop</th>
<th>Amount and Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Dorado</td>
<td>0.5 lb at 60 min</td>
</tr>
<tr>
<td></td>
<td>5.0 lb in whirlpool</td>
</tr>
</tbody>
</table>

### Stats:

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG</td>
<td>9.4°P</td>
</tr>
<tr>
<td>FG</td>
<td>1.6°P</td>
</tr>
<tr>
<td>Attenuation</td>
<td>84%</td>
</tr>
<tr>
<td>ABV</td>
<td>4.1%</td>
</tr>
<tr>
<td>Final pH</td>
<td>3.52</td>
</tr>
</tbody>
</table>
Proof of Concept cont.

- Thorough rinse of kettle with hot (85°C) water
- Run off and sparge as normal in to kettle
- No pre-boil
- No pH modification
- Sanitise heat exchanger
- Cycle wort through heat exchanger
- Cool rapidly to ~40°C
- No CO₂ purge
- Impeller on
- Inoculate with starter culture

5.4L/1.43 gal in 7.6 bbl (0.6% v/v)
Proof of Concept Kettle Sour Fermentation

#808 44-30°C  pH 4.5 in ~5 hrs
#844 40-28 °C
Three cultures using #844 wort (not stirred, incubated at 36-38°C)

1. No pitch  
   bacterial growth, enteric, off aromas  
   pH 3.33
2. 0.06% v/v  
   good growth, no off aromas  
   pH 3.37
3. 0.60 v/v  
   good growth, no off aromas  
   pH 3.37
Proof of Concept Yeast Fermentation
Revised Kettle Sourcing *Fermentation* Process:

- Mash and sparge as normal
- Rinse kettle and connected pipework with hot water
  - boil wort briefly to sanitise
- Cool **rapidly** to 35-40°C
- Drop pH to 4.5
- Purge out $O_2$ with $CO_2$
- Inoculate *with appropriate size pitch of bacteria*
- Blanket with $CO_2$ then seal stack and manway
- Sour over **24-48 hours**
# Economic Impact

## Reduction in COGs

<table>
<thead>
<tr>
<th></th>
<th>Cost Saving</th>
<th>Time Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>no pre-boil</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>no CO₂</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>no food grade lactic acid addition</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>quicker turn around on brew house</td>
<td>✅</td>
<td>✅</td>
</tr>
<tr>
<td>reduced chance of off flavours/dumped batches</td>
<td>✅</td>
<td>✅</td>
</tr>
</tbody>
</table>
Further Research (literature & experimental)

- What is an optimal pitch rate? Does it change for different species? What about mixed cultures?
- As with yeast, does starting °P alter pitch rate?
- What bacterial species are responsible for butyric in kettle sour beers and under what conditions? Is it just *Clostridium* sp. from grain?
- How sanitised should the kettle be?
- What microbiota are we growing in our starter pitches?
- What are we selecting for in our re-pitches?
- How long does a bacterial brink remain viable?
- Does shortening souring time alter development of flavour, depth, character? If so, how? Is it better, or worse?
Questions?