The Science of Mashing

Jamie Ramshaw M Brew
IBD 25/10/17
mash  (mǎsh)
n.
1. A mixture of malt or other ingredients with water, heated to convert starches into fermentable sugars for use in brewing or distilling.
2. A mixture of ground grain and nutrients fed to livestock and fowl.
3. A soft pulpy mixture or mass.
5. A crushing or grinding.
Purpose

- Extract the starch from a source
- Convert the starch into a sugar that can be utilised by Yeast
- Control the extent of conversion
- Extract what is wanted and leave behind what is not

- Starch source
- Water
- Process
A Source of Starch - Barley
Barley
Barley

- Contains:
  - Starch
  - Protein
  - Beta Glucans and Gums
  - Polyphenol in husk
- Need to prepare the barley for quick extraction and degradation at the brewery
- Malting
Germination

- Aleurone
- Endosperm
- Embryo
- Water
- Scutellum (cotyledon)
- GA
- α-amylase
- Sugar
- Radicle
Harvest

- Grown on light soil
- Winter and spring varieties
- Harvest Winters then Wheat then Springs
Storage

- Condition kept to prevent microbial and insect infestation
  - Moisture content max
  - Temperature max
  - Monitored regularly
- Held here until dormancy breaks
  - Can force dormancy to break
- Micro malting used to assess the barley and configure the barley’s best process
Steep

- Soaking and air rests
- Mimics rainfall
- Triggers germination in non-dormant grain
Kiln

- Stops Germination
- Drive off water by free and forced drying
- Creation of colour and flavour can occur here

- Malt
  - A stable parcel of easy to access starch
Germination and Kilning
Approved UK Barley

- There are approved varieties of barley
- Must pass through a number of standards in order to be approved
  - Seed
  - Agronomic
  - Malting
  - Brewing
# Malt Specification

## Finest Pale Ale Malt (Golden Promise)

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture %</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>Extract °P/kg (7 Dry)</td>
<td>306</td>
<td></td>
</tr>
<tr>
<td>Colour °EBC</td>
<td>3.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Total Nitrogen %</td>
<td></td>
<td>1.55</td>
</tr>
<tr>
<td>Total Soluble Nitrogen %</td>
<td>0.58</td>
<td>0.68</td>
</tr>
<tr>
<td>Soluble Nitrogen Ratio</td>
<td>38.0</td>
<td>44.0</td>
</tr>
<tr>
<td>Friability %</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Homogeneity %</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>Steely Corns %</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>Glucan I Wort (ppm)</td>
<td></td>
<td>120</td>
</tr>
<tr>
<td>Diastatic Power IOB “dry”</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>Screenings % &lt;2.2mm</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>NDMA (ppb)</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>
Germination
Mashing Chemistry
Mashing Chemistry

Glucose, Fructose
Maltose, Sucrose
Maltotriose
Cellibiose
Beta-Limit Dextrin
Dextrins, Oligosaccharides, Polysaccharides
Mashing Chemistry

\[
\text{H} - \text{C} = \text{O} \\
\text{H} - \text{C} - \text{OH} \\
\text{HO}-\text{C}-\text{CH} \\
\text{H}-\text{C}-\text{OH} \\
\text{H}-\text{C}-\text{OH} \\
\text{CH}_2\text{OH}
\]

[Diagram of D-glucose with labeled atoms and 1,5 ether linkage]
Mashing Chemistry

Amylose

Alpha Amylase

Amylopectin

Beta Limit Dextrinase

Beta Amylase
Optimal Conditions

- Highest Extract, temp range
  - Highest Fermentable Extract
- Reducing Sugars, temp range
- Stuck Mash pH
- Proteases
- Glucanases
- Alpha Amylase
- Beta Amylase
- Starch Gelatinisation
- Polyphenol Extraction pH
Water

\[ \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^- \]

\[ \text{pH} = \log_{10}\{1/\text{H}^+\} \]
Water

• pH is the logarithm of the reciprocal of the hydrogen ion concentration.
• The pH of the incoming water has little effect upon the pH of wort and beer.
• The critical factor is alkalinity (bicarbonate) of brewing liquor
• The whole of the brewing process is pH dependent
## Water

<table>
<thead>
<tr>
<th>Process</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquor</td>
<td>6.0 – 8.0</td>
</tr>
<tr>
<td>Mash</td>
<td>5.2 – 5.5</td>
</tr>
<tr>
<td>1st Runnings</td>
<td>4.8 – 5.2</td>
</tr>
<tr>
<td>Last Runnings</td>
<td>&lt; 5.6</td>
</tr>
<tr>
<td>Wort at Copper Up</td>
<td>5.1 – 5.4</td>
</tr>
<tr>
<td>Wort at Copper Out</td>
<td>4.9 – 5.2</td>
</tr>
<tr>
<td>Beer post fermentation</td>
<td>3.8 - 4.2</td>
</tr>
</tbody>
</table>
**pH control in the Mash**

- $\text{CO}_2 + \text{H}_2\text{O} \Leftrightarrow \text{H}_2\text{CO}_3 \Leftrightarrow \text{HCO}_3^- \Leftrightarrow \text{CO}_3^{2-}$

- The presence of Carbonates in the mash removes Hydrogen ions, raising the pH

- $\text{H}_3\text{PO}_4 \Leftrightarrow \text{H}_2\text{PO}_4^- \Leftrightarrow \text{HPO}_4^{2-} \Leftrightarrow \text{PO}_4^{3-} \Rightarrow \text{Ca}_3(\text{PO}_4)_2$

- The presence of Calcium in the mash adds Hydrogen ions, lowering the pH

- For an infusion mash using a standard Pale Ale Malt we target 200ppm of Calcium and less than 40ppm alkalinty as Calcium Carbonate in the liquor to achieve pH of 5.2-5.4
Mashing Process Overview

- Grist particles hydrate, starch granules swell and gelatinise
- Low MW particles solubilise and are degraded by enzymes
- Enzymes disperse through the mash liquor to reach substrate
- Enzymes breakdown the large polymers that are then solubilised and degraded
- Enzymes become deactivated
Mashing Process

• Therefore the following parameters will contribute to the composition of the wort produced
  – Milling
  – Mashing
  – Liquor to grist ratio
  – The mash stand temperature
  – The mash pH
  – The duration of the mash stand
Milling

- Pre milled against own mill
- Extract against run off
  - Degree of crush is a balance
  - Low crush gives best run off
  - High crush gives best extract

  - Husk open but in large pieces
  - Endosperm broken but not all flour
Mashing

• Aim is to hydrate the crushed malt and form a floating bed at a predetermined temperature
• Preparation:
  • Preheat insulated mash tun, then drain
  • Cover the plates with liquor
• Ensure plenty of treated liquor for mash and sparge is available at a controlled flow rate
• Use cold liquor to hit ‘Strike’ temperature
• Target mash at 65°C, liquor:grist 2.5Litres:1kg
• Ensure grist and liquor mix efficiently
Mashing

• Mash Thickness
  – Increased liquor to grist ratios, thinning the mash:
    • Reduces the stability of mash enzymes
    • Dilutes enzymes and substrates
    • Leads to quick conversion but rapid destruction of enzymes
    • Used in Decoction systems as mash is pumped and roused
  – Thicker mashes are stable but risk poor hydration
## Mashing

- **Strike Heat**

\[
\text{Initial Heat} = \frac{\text{St} + \text{RT}}{\text{S} + \text{R}} + \frac{1/2\text{H}}{\text{S} + \text{R}}
\]

- S specific heat of malt
- T temperature of malt
- R liquor to grist ratio
- H is slaking heat of malt

- *Strike heat can be above 69°C for a 65°C Mash Stand*
Mashing
Mash Conditions

- Highest Extract, temp range
- Highest Fermentable Extract
- Starch Gelatinisation
- Alpha Amylase
- Beta Amylase
- Reducing Sugars, temp range
- Stuck Mash pH
- Proteases
- Glucanases
- Polyphenol Extraction pH
# Mash Conditions

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Extract</td>
<td>5.2-5.4</td>
<td>65-68</td>
</tr>
<tr>
<td>Most Fermentable</td>
<td>5.3</td>
<td>65</td>
</tr>
<tr>
<td>alpha amylase max activity</td>
<td>5.3-7.2</td>
<td>70</td>
</tr>
<tr>
<td>Beta amylase max activity</td>
<td>5.1-5.3</td>
<td>60-65</td>
</tr>
</tbody>
</table>
Mash Conditions

• Increased Mash temperature
  – Gelatinises starch and hydrates grist particles quickly
  – Speeds up enzyme action
  – Reduces the viscosity of the wort
  – Inactivates the enzymes

• A 1 hour infusion mash at optimal temperature, pH and thickness will give greatest extract and an attenuation of approximately 80%
Sparge

- Time and Temperature
  - To halt enzyme action and fix sugars 75-80°C
  - Wort less viscous
- Flow rate
  - To wash out sugars efficiently
  - 1.5 hrs standard
- End of run off
  - pH control
- Bed depth
  - The need to recirculate
Good Mashing

Control
- Raw materials
- pH
- Temperature
- Hydration
- Time

Means
- Quality Malt
- Liquor treatments
- Measured and Controlled
- Volume and Flow Rate
- Measured and consistent
Consequences

• Poor extract
• High or low attenuation
• Excess polyphenol and silicate
• Starch
• Beta gluten and protein issues
Any Questions

Jamie Ramshaw M Brew