Brewing Science

Mashing and Brewing
Mashing & Brewing

− Mashing
  • The enzymatic conversion of starch to maltose and proteins to amino acids

− Brewing:
  • Extraction of hop flavors and aromatic compounds
  • Sterilization of wort
Mash Tun

Photo/text credit to David Lee, Central Washington University
Mashing

Photo/text credit to David Lee, Central Washington University
An Example Mash Profile:

**Mash Name**: Pilsner Mash  
**Sparge Water**: 6.08 gal  
**Sparge Temperature**: 172.4 F  
**Adjust Temp for Equipment**: TRUE  

**Total Grain Weight**: 10 lbs 5.6 oz  
**Grain Temperature**: 72.0 F  
**Tun Temperature**: 71.6 F  
**Mash PH**: 5.20

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Step Temperature</th>
<th>Step Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash In</td>
<td>Add 23.04 qt of water at 98.0 F</td>
<td>95.0 F</td>
<td>5 min</td>
</tr>
<tr>
<td>Protein Rest</td>
<td>Heat to 125.6 F over 10 min</td>
<td>125.6 F</td>
<td>15 min</td>
</tr>
<tr>
<td>Sacch Rest</td>
<td>Heat to 145.4 F over 10 min</td>
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**Sparge**: Batch sparge with 2 steps (Drain mash tun, 6.08gal) of 172.4 F water

**Mash Notes**: 
Mash Rests

Acid Rest

• Mashing step designed to lower the mash pH.

• The enzyme phytase converts phytin into calcium phosphate, magnesium phosphate, and phytic acid. The phosphates precipitate out, while the phytic acid lowers the pH of the mash.

• Phytase is active between 86° F and 128° F, with an acid rest at 95° F common.

Provided by Ken Woodson & the North Texas Home Brewers Association
Mash Rests

Acid Rest

• Acid rests can take a few hours to lower mash pH. As an alternative, mineral salts like calcium sulfate (gypsum) or calcium chloride can be added to the brewing water to lower mash pH. Also, food grade acids, such as lactic acid or phosphoric acid, can be added to brewing water to lower mash pH.

• The enzyme beta glucanase is active during this rest. This enzyme breaks down beta glucans. Under modified malts and some adjuncts with high levels of beta glucans can lead to stuck mashes.
An Example Mash Profile:

<table>
<thead>
<tr>
<th>Mash Profile</th>
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<th>Mash Name: Pilsner Mash</th>
<th>Total Grain Weight: 10 lbs 5.6 oz</th>
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<tr>
<td>Sparge Water: 6.08 gal</td>
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*Sparge*: Batch sparge with 2 steps (Drain mash tun, 6.08gal) of 172.4 F water

*Mash Notes:*
Mash Rests

Protein Rest

• The protein rest is used to convert higher molecular weight proteins into lower molecular weight proteins.

• *This rest should only be used with under modified malts.* Malts with a Kolbach index (ratio of soluble protein to total protein) greater than 40% have been sufficiently modified during malting and should not undergo a protein rest.

• The enzymes that breakdown proteins are peptidases and proteinases.
Mash Rests

Protein Rest

• Proteinase converts large proteins like large peptones and albumins into smaller molecular weight proteins. Large proteins can cause haze in your beer. Proteinase works best between 122° F and 131° F and a pH between 4.6 – 5.2.

• Peptidase works on small proteins and is optimal between 113° F and 122° F and a pH between 4.6 – 5.2. The smallest proteins, amino acids, are good for yeast nutrition. Small to mid-sized proteins are good for head retention and contribute to the body of your beer.
An Example Mash Profile:

**Mash Profile**

- **Mash Name:** Pilsner Mash  
- **Sparge Water:** 6.08 gal  
- **Sparge Temperature:** 172.4 F  
- **Adjust Temp for Equipment:** TRUE  
- **Total Grain Weight:** 10 lbs 5.6 oz  
- **Grain Temperature:** 72.0 F  
- **Tun Temperature:** 71.6 F  
- **Mash PH:** 5.20

**Mash Steps**

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**Sparge:** Batch sparge with 2 steps (Drain mash tun, 6.08gal) of 172.4 F water

**Mash Notes:**
Mash Rests

Starch Conversion / Saccharification Rest

• For all grain brewing, this rest is necessary to convert starches into simple sugars for yeast metabolism.

• The enzymes alpha amylase and beta amylase attack the 1-4 links in amylose and amylopectin, to reduce them to simpler sugars.
Starch Conversion Rest

Beta Amylase

• Beta amylase attacks the end of the starch chain by breaking off two glucose molecules at a time; however, this enzyme stops attacking the given chain when it encounters a 1-6 link.

• Beta amylase works best at mash temperatures between 140 °F and 148 °F.

• A mash pH between 5.2-5.5 is recommended; however, a mash pH between 5.2-5.3 favors beta amylase.
Starch Conversion Rest

Alpha Amylase

• Alpha amylase attacks starch chains by randomly breaking 1-4 links; however, this enzyme cannot break 1-6 links.

• Alpha amylase works best at mash temperatures between 154 °F and 162 °F.

• A mash pH between 5.2-5.5 is recommended, however, a mash pH between 5.4-5.5 favors alpha amylase.
# An Even Simpler Brew Profile

**Mash Profile**

- **Mash Name**: Single Infusion, Full Body, No Mash Out
- **Sparge Water**: 4.52 gal
- **Sparge Temperature**: 168.1 F
- **Adjust Temp for Equipment**: TRUE
- **Total Grain Weight**: 10 lbs
- **Grain Temperature**: 72.0 F
- **Tun Temperature**: 72.0 F
- **Mash PH**: 5.20

## Mash Steps

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Step Temperature</th>
<th>Step Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash In</td>
<td>Add 11.25 qt of water at 174.4 F</td>
<td>158.0 F</td>
<td>45 min</td>
</tr>
</tbody>
</table>

**Sparge**: Fly sparge with 4.52 gal water at 168.1 F

**Mash Notes**: Simple single infusion mash for use with most modern well modified grains (about 95% of the time).
Mashing Methods

Single Infusion Mashing

• Only one mash step is performed, the starch conversion rest.

• Hot water is added to the grain bill to reach the strike temperature. The strike temperature is usually a fixed temperature between 149 °F and 158 °F. The mash is normally held at this temperature for at least 60 minutes or until starch conversion is complete.

• Mash rest temperatures between 149 °F to 153 °F favor beta amylase over alpha amylase, which produces a more fermentable wort. Mash rest temperatures between 154 °F and 158 °F favor alpha amylase and therefore produce a more dextrinous wort.
Mashing Methods

Single Infusion Mashing

• Single infusion mashing is common for making British ales from well modified malts.

• Use single infusion mashing with well modified malts.
  – Do not use infusion mashing with a malt that has a Kolbach index (ratio of soluble protein to total protein) less than 38%.
  – The difference between the dry basis fine grind and coarse grind indicates the degree of malt modification. The smaller the difference the more modified the malt. If DBFG – DBCG exceeds 1.8% then Infusion mashing is not recommended.
Mashing Methods

Step Mashing

- Is more involved than single infusion mashing
- Allows the use of under modified malts
- Historically, step mashing has been used to brew Kölsch, Düsseldorf Altbier, and Belgium ales.

Provided by Ken Woodson & the North Texas Home Brewers Association
Mashing Methods

Step Mashing

• To perform a step mash with an acid rest:
  – Add hot water to your grain bill to achieve an appropriate rest temperature for an
    acid rest. Hold the mash at this temperature until the proper pH is achieved. Note
    this may take more than one hour.
  – Add hot water infusion or direct heat to raise the mash to the appropriate protein
    rest. Hold the protein rest for about 30 minutes.
  – Add hot water infusion or direct heat to raise the mash to the saccharification rest.
    Hold the mash at this temperature for about an hour or until starch conversion is
    verified with iodine test.
  – Add hot water infusion or direct heat to raise to mash out temperature, 168 ° F and
    170 ° F.

• Recall that the acid rest is designed to lower mash pH and to allow beta glucanase to
  break down beta glucans. If the mash has the appropriate pH, 5.2 – 5.5, and you use
  well modified malts that are low in beta glucans, then the acid rest is not necessary.

• To perform a step mash without the acid rest, follow the same steps above, except start
  the process at the protein rest by adding hot water to achieve a mash temperature
  appropriate for a protein rest.
Decoction? What?

### Mash Profile

**Mash Name:** Decoction Mash, Single  
**Sparge Water:** 4.29 gal  
**Sparge Temperature:** 168.0 F  
**Adjust Temp for Equipment:** FALSE  
**Total Grain Weight:** 13 lbs 12.0 oz  
**Grain Temperature:** 72.0 F  
**Tun Temperature:** 72.0 F  
**Mash PH:** 5.20

### Mash Steps

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Step Temperature</th>
<th>Step Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Rest</td>
<td>Add 22.60 qt of water at 159.8 F</td>
<td>151.0 F</td>
<td>35 min</td>
</tr>
<tr>
<td>Saccharification</td>
<td>Decoct 7.50 qt of mash and boil it</td>
<td>168.0 F</td>
<td>45 min</td>
</tr>
</tbody>
</table>

**Sparge:** Fly sparge with 4.29 gal water at 168.0 F

**Mash Notes:** Used in some authentic German styles. Attempt to draw decocion from the thickest portion of the mash. Profiles vary. Some traditional German mashes use a long acid rest at 40 deg C. Also some sources recommend the decoction amount be given a 15 minute saccharification rest at 158 F (70 C) before boiling it.
Mashing Methods

Decoction Mashing

- Helps breakdown proteins in under modified malts
- Improves extract efficiency
- Deoxygenates the mash which reduces hot side aeration
- Promotes the development of melanoidins for rich malt flavor and deeper color
- Raises the temperature of the mash from one rest to the next
- Traditionally, decoction mashing has been used to brew the following beer styles:
  - Oktoberfest
  - Traditional Bocks
  - Doppelbocks
  - Weizen

Provided by Ken Woodson & the North Texas Home Brewers Association
Mashing Methods

Decoction Mashing

To perform a double decoction:

1. Add hot water to achieve an appropriate temperature for a protein rest, i.e. 122 °F.
2. After a few minutes remove a thick portion of the mash (about 1/3 of the mash).
3. Heat the secondary mash to allow a short saccharification rest and then boil the secondary mash for about 30 minutes. Note that the main mash is held at the protein rest while the secondary mash is boiled.
4. Return the secondary mash to the main mash, this will raise the temperature of the combined mash to the saccharification rest.
5. Allow the combined mash to rest at the starch conversion temperature for about 40 minutes.
6. Remove another secondary mash (again about 1/3 of the mash) and boil the secondary mash for about 20 minutes. Note that the main mash is held at the starch conversion rest while the secondary mash is boiled.
7. Return the secondary mash to the main mash, this will raise the temperature of the combined mash to the mash out temperature.
Mashing Methods

Decoction Mashing

Notes:

1. Decoction mashing involves a protein rest. Like step mashing, only perform a protein rest with under modified malts.

2. The secondary (decoction) mash should be stirred continuously to avoid scorching; however, stir gently to avoid hot side aeration.

3. A variation of double decoction mashing is triple decoction mashing. Triple decoction is similar to double decoction, except, and extra decoction is removed to allow for an acid rest at the beginning of the mash routine.
Sparging

separate the crushed grain from the sweet liquid, the **wort**, that will become beer
Sparging

recirculation – recirculate the wort until it is clear

parti gyle – do one mash, then drain all the wort off, add more hot water, *do another mash*, drain all the wort, continue until all sugars are gone

- usually results in two or three smaller batches of beer that range from strong to medium to weak

sparging – do one mash, begin to drain the wort off and as the wort level falls, add hot water, *sparge water*, to rinse the sugars from the grains, continue until all sugars are rinsed

- usually get one big batch of beer that is one strength, weaker than *first runnings* of parti gyle but stronger than *second runnings*
Sparging
# Sparge Profile

## Mash Profile

**Mash Name:** Single Infusion, Medium Body, Batch Sparge  
**Sparge Water:** 5.33 gal  
**Sparge Temperature:** 168.0 F  
**Adjust Temp for Equipment:** FALSE  

**Total Grain Weight:** 15 lbs 6.1 oz  
**Grain Temperature:** 72.5 F  
**Tun Temperature:** 72.0 F  
**Mash PH:** 5.20

## Mash Steps

<table>
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<th>Name</th>
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<th>Step Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mash In</td>
<td>Add 21.82 qt of water at 162.2 F</td>
<td>152.0 F</td>
<td>60 min</td>
</tr>
</tbody>
</table>

**Sparge:** Batch sparge with 2 steps (Drain mash tun, 5.33gal) of 168.0 F water  
**Mash Notes:** Simple single infusion mash for use with most modern well modified grains (about 95% of the time).
Mash Tun with used Mash

These are the spent malt that acted as a filtering bed for the sweet wort.
Scraping out the used mash

Photo/text credit to David Lee, Central Washington University
Sweet Wort

Photo/text credit to David Lee, Central Washington University
Wort Composition
Carbohydrates

73% Fermentable

Kindly provided by Tom Pugh and David Ryder of Miller Brewing Company
Wort Composition

Fermentable Sugars

** need to adjust to normal wort

Kindly provided by Tom Pugh and David Ryder of Miller Brewing Company
Wort Composition

Amino Acids (** adjust to normal wort)

Not included: Cys (2 ppm) and Trp (50 ppm)

Kindly provided by Tom Pugh and David Ryder of Miller Brewing Company
Kettle

- Sweet Wort
- Bring to boil
  - Add hops
    - Extract flavors (bitter acids) and aromatic compounds
  - Sterilizes hopped wort
Brew Kettle

- Sterilization
- Protein coagulation
- Hop extraction
- Volatile removal

Kindly provided by Tom Pugh and David Ryder of Miller Brewing Company
Cooling