Improving Brewhouse Efficiency for Small Brewers

Van Havig
I brew on a 7 BBL system, why should I care?

- Improving from 82% to 90% efficiency can result in 45 lbs less malt used per brew
- Being inefficient is NOT artisanal
- It’s easy to do
- The methods for improving brewhouse efficiency can also improve your beer
Brewhouse Efficiency

• Brewhouse Efficiency is a measure of the amount of extract recovered in the wort compared to the amount of extract available in the malt.

• It is a measure of how efficient your mashing and lautering procedures are but does not take into account the boil or anything thereafter.
Calculating Brewhouse Efficiency

- Number of pounds of each malt used
- Coarse grind as is extract % for each malt
- Gravity of wort in degrees Plato (P) - must be at $20^0$ C ($68^0$ F)
- Volume of Wort - must be at $20^0$ C ($68^0$ F)
What is the Coarse Grind as is %?

- Percentage by weight of extract obtained from the malt with a coarse grind in a laboratory mash
- Typically in the 75%-80% range for base malts
- Found on the malt analysis sheet available from your maltster
Accurately Determining the Volume of Wort

- Interior diameter of kettle in inches (often in 3” increments from 48” up) (ID)
- Volume of liquid in bottom “non-cylindrical” section of kettle in gallons (B)
- Sidewall height in inches (H)
- Volume measurement in inches from kettle man way (V)

Note: V is easiest to measure at end of boil, but the wort is at ≈ 100°C
Wort Volume Calculation

![Diagram of a cylindrical tank with dimensions ID, H, and B for volume calculation.](image)
Wort Volume Calculation

- Gallons per inch of sidewall
  \[ = \pi \left( \frac{ID}{24} \right)^2 \times \frac{7.48}{12} = (GPI) \]
- Volume of hot wort (at end of boil \(\approx 100^0C\))
  \[ = \frac{(((H-V)GPI) + B)}{31} \]
- Volume of wort at \(20^0C\) \((W)\)
  \[ = 0.96 \times \text{volume of hot wort} \]
  \[ W = 0.96 \times \frac{(((H-V)GPI) + B)}{31} \]
Calculating Brewhouse Efficiency

- Extract / BBL = \((259+P)*P)/100\)
- Total extract = \((\text{Extract} / \text{BBL})*W = (TE)\)
  i.e. 10 BBLs of hot 14 P wort
  \[= (((259+14)*14)/100)*10\]
  \[= ((273)*14)/10\]
  \[= 382.2\]
Calculating Brewhouse Efficiency

• Total potential extract (TPE)
  
  \[ \text{TPE} = \sum \text{(#'s of each malt)} \times \text{(CG as is %)} \]
  
  i.e. = (500#'s pale malt)(.78 CG as is) + (50#'s crystal malt)(.74 CG as is)
  
  = 390 + 37
  
  = 427
Calculating Brewhouse Efficiency

• Brewhouse Efficiency = TE/TPE

\[ \frac{((259+P)\times P)/100 \times (\text{wort volume})}{\sum (\#\text{’s of each malt})(\text{CG as is } \%) } \]

= 382.2/427

= 89.5\%
<table>
<thead>
<tr>
<th></th>
<th>Brew 1</th>
<th>Brew 2</th>
<th>Brew 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>OG (degrees Plato)</td>
<td>14.5</td>
<td>13</td>
<td>14.5</td>
</tr>
<tr>
<td>BBLs of Wort (hot)</td>
<td>10.24</td>
<td>10.24</td>
<td>10.24</td>
</tr>
<tr>
<td>Kettle measurement (neg)</td>
<td>-10.50</td>
<td>-10.50</td>
<td>-10.50</td>
</tr>
<tr>
<td>Grist Bill CG as is</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Malt</td>
<td>0.766</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Wheat Malt</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Munich, Vienna, etc</td>
<td>0.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crystal Malt</td>
<td>0.74</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Roasted Malt</td>
<td>0.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>555</td>
<td>555</td>
<td>622</td>
</tr>
<tr>
<td>Extract / BBL</td>
<td>39.66</td>
<td>35.36</td>
<td>39.66</td>
</tr>
<tr>
<td>Total amount of extract</td>
<td>389.69</td>
<td>347.46</td>
<td>389.69</td>
</tr>
<tr>
<td>Brewhouse efficiency</td>
<td>91.97%</td>
<td>82.01%</td>
<td>82.04%</td>
</tr>
</tbody>
</table>
Why do I keep using 82% as a low mark for brewhouse efficiency?

• We found that almost 25% of the Rock Bottoms were at or below 82% efficiency

• 33% had 89% - 91% efficiencies
What did we do about it?

- We looked at what the top third of breweries were doing to see what commonalities existed that lead to excellent efficiencies
- Four different tun manufacturers, all with v-wire screens and no rakes, in 8, 12, and 15 BBL single infusion systems
- Check out “Portland Mashing” on You tube
Factors That Affect Brewhouse Efficiency

Mash Parameters
pH of Mash
Mill Settings / Coarseness of Grind
Lautering Technique
Mash Parameters

- Low temperature mashes (65°C - 149°F) => lower extract

- High temperature mashes (70°C – 158°F) => higher extract

- Thinner mash – 3:1 or higher liquor to grist => higher extract

- Thicker mash – 2:1 liquor to grist => lower extract
Results for Mash Parameters

• No consistent differences!
• This is NOT the place to try to increase brewhouse efficiency. It is a place to use brewhouse procedures to make your beer taste the way you want it to.
Mash pH

- Correct mash pH leads to higher extract
- $5.5 - 5.6 \ @ \ 20^\circ C (68^\circ F)$
- $5.2 - 5.3 \ @ \ 65^\circ C (149^\circ F)$
- Sufficient calcium levels (over 50 ppm) in the mash lead to better $\beta$-amylase function
Results for Mash pH

• At the Portland brewery we noticed up to a 2% decrease in brewhouse efficiency when pH was at least .2 out of specification. i.e. 5.0 or below mash pH, or 5.5 or above mash pH at 149°F
Mill Setting:
Using Sieves to Check Your Grind

- 8” dia x 2” deep testing sieves No 10, 14, 18, 30, 60, 100 and pan
- Available from McMaster-Carr for $44 per sieve and $25 for the pan and lid
- Mechanical shaker
We just used 14, 18, 60 and pan - total cost under $175 with shipping
ASBC method Malt-4

- Use 100 – 130 grams of grist - about a cup
- A rubber ball in each sieve
ASBC method Malt-4

• Shake side to side for 15 seconds – tap
• Shake back and forth for 15 seconds – tap
• Repeat for 3 minutes
The sieves will separate the grist into fractions
Weigh each fraction and calculate percentages
Results for Mill Setting

• ALL of the breweries with a VERY coarse grind had good brewhouse efficiencies (89% and above).
• NO breweries with finer grinds had efficiencies in the 89% or higher range.
# Results for Mill Setting

<table>
<thead>
<tr>
<th>Sieve #</th>
<th>British Mash Tun</th>
<th>U.S. Craft Mash Tun</th>
<th>Rock Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>53%</td>
<td>31%</td>
<td>68%</td>
</tr>
<tr>
<td>18</td>
<td>14%</td>
<td>32%</td>
<td>12%</td>
</tr>
<tr>
<td>60</td>
<td>22%</td>
<td>27%</td>
<td>14%</td>
</tr>
<tr>
<td>Pan</td>
<td>11%</td>
<td>9%</td>
<td>5%</td>
</tr>
</tbody>
</table>

Data from MBAA Practical Handbook for the Specialty Brewer, Vol. 1, ed. Karl Ockert
Lautering Technique

- Loose, permeable mash bed
- Even bed consistency
- Even bed depth
- Proper run off speed
Darcy’s Law

\[ Q = \frac{K \Delta P A}{L \mu} \]

- \( Q \) = flow rate
- \( K \) = permeability of the filter bed
- \( \Delta P \) = pressure across the filter bed
- \( A \) = surface area of the filter
- \( L \) = depth of the filter bed
- \( \mu \) = viscosity of liquid
Coarse grind leads to loose, consistently permeable mash beds.
Finer grind leads to tight beds that may channel.
Rock Bottom Case Study #1

• Brewery initially at 86% brewhouse efficiency with 120 minute lauter times

• The brewer excessively stirred the mash during mash in and just before vorlauf, resulting in tight mash beds
• Changing to minimal stirring (just enough to ensure consistency and none before vorlauf) resulted in looser beds

• Efficiencies increased to 89%, Lauter times decreased to 90 minutes
• The mill was then reset to a more coarse grind

<table>
<thead>
<tr>
<th>Sieve #</th>
<th>Initial Grind</th>
<th>New Grind</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>59%</td>
<td>71%</td>
</tr>
<tr>
<td>18</td>
<td>18%</td>
<td>10%</td>
</tr>
<tr>
<td>60</td>
<td>16%</td>
<td>13%</td>
</tr>
<tr>
<td>pan</td>
<td>7%</td>
<td>6%</td>
</tr>
</tbody>
</table>

• Efficiencies increased from 89% to 90.5%
Rock Bottom Case Study #2

• Brewery initially at 84.5% brewhouse efficiency with 60 minute lauter times
• The brewer slowed his initial lauter speed for the first third of lauter, then resumed his original speed
• The mill was also reset to the recommended coarse grind
• Efficiencies are now at 90% with 90 minute lauter times
Rock Bottom Case Study #3

- Brewery initially at 82% brewhouse efficiency, with tight, uneven mash beds

<table>
<thead>
<tr>
<th>Sieve #</th>
<th>Initial Grind</th>
<th>New Grind</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>59%</td>
<td>67%</td>
</tr>
<tr>
<td>18</td>
<td>14%</td>
<td>12%</td>
</tr>
<tr>
<td>60</td>
<td>19%</td>
<td>15%</td>
</tr>
<tr>
<td>Pan</td>
<td>8%</td>
<td>6%</td>
</tr>
</tbody>
</table>
• The mash beds loosened significantly
• The previously uneven mash beds evened out
• Far less sparge liquor was seen migrating to the walls of the tun
• Brewhouse efficiencies increased to 89%
Recommendations

• Calculate your brewhouse efficiencies on a regular basis (record on brewsheet)
• Buy a #14 sieve with pan and cover then set your mill so that approx. 70% of your grist remains on the sieve
Recommendations

- Do whatever else you can to keep your mash beds loose and even (don’t over stir!)
- Run off slowly at first, then more quickly
- Use a pH meter, and keep your mash pH in the correct range
Thank You

- To all the brewers of Rock Bottom Breweries, past and present

- Vhavig@gmail.com if you would like a copy of the brewhouse efficiency spreadsheet