pH in the Brewery
A Much Underestimated Brewing Variable
Thomas Kraus-Weyermann

WEYERMANN® Malting Company
BAMBERG - GERMANY
OUTLINE

- What Is pH?
- Why Is pH Important in the Brewery?
- The pH-Pathway through the Brewery
- Ideal pH-Targets for a Few Classic Beer Styles
- What Can a Brewer Do to Adjust pH-Values That Stray Too Far from the Optimum?
- Q&A
Overview

Proper Mash Acidification

- Effects on mash
- Effects on wort
- Effects on fermentation
- Effects on shelf life

Effects on Foam Retention & Flavor Stability

Effects on Flavor & Taste
What is pH?

From WEBSTER’S:

pH \( \text{pē-āch} \) n: the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter used in expressing both acidity and alkalinity on a scale whose values run from 0 to 14 with 7 representing neutrality, numbers less than 7 increasing acidity, and numbers greater than 7 increasing alkalinity.

The Inventor of the pH-Scale: Danish Carlsberg Brewing Chemist Søren Peder Lauritz Sørensen (1868 – 1939)
Always measure mash-pH at the same stage in the mashing process:
At the beginning of saccharification either of a single mash or the first decoction mash.
Before measuring the pH-value of fermenting or finished beer, always first dissipate its CO$_2$ by agitating it with an egg beater or sending it through a coffee filter.
The pH-Scale

Coloration of pH-Indicator-Strip

Acid — Water — Base

Färbung des Indikators:
Pfärbung des Indikators:

pH-Skala:

Die Lösung ist:

Säure
Wasser
Lauge

pH

sauer
neutral
alkalisch

Sour
Neutral
Alkaline
# A Few Interesting pH-Values for Reference

<table>
<thead>
<tr>
<th>Substance</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery acid</td>
<td>0.5</td>
</tr>
<tr>
<td>Lemon juice</td>
<td>2.4</td>
</tr>
<tr>
<td>Household vinegar</td>
<td>2.9</td>
</tr>
<tr>
<td>Human skin</td>
<td>5.5</td>
</tr>
<tr>
<td>Distilled water</td>
<td>7.0</td>
</tr>
<tr>
<td>Human blood</td>
<td>7.34 – 7.45</td>
</tr>
<tr>
<td>Sea water</td>
<td>8.0</td>
</tr>
<tr>
<td>Household bleach</td>
<td>12.5</td>
</tr>
<tr>
<td>Caustic Soda</td>
<td>14</td>
</tr>
</tbody>
</table>
Effects on Mash

- More efficient enzymatic processes and faster saccharification
- Positive effects on protein degradation (FAN free amino nitrogen)
- Better glucan degradation
- Better lautering performance
Example: Proteolytic Enzymes

- **Endopeptidases**
  pH optimum 5.0 (@104-122°F / 40-50°C)

- **Carboxypeptidases**
  pH optimum 5.2 (@122 – 140°F / 50-60°C)

- **Dipeptidases**
  pH optimum 8.2 (@104-113°F / 40-45°C)

- **Aminopeptidases**
  pH optimum 7.2 (@104-113°F / 40-45°C)
Example: Diastatic Enzymes

- Beta-Amylase
  pH optimum 5.4 – 5.6 (@140-149°F / 60-65°C)

- Alpha-Amylase
  pH optimum 5.6 – 5.8 (@158-167°F / 70-75°C)
Effects on Wort (pH 5 – 5.5)

- Better protein precipitation and break formation
- Therefore, better FAN configuration
- However, paler wort color and less isomerization
Effects on Fermentation

- Higher zinc content (0.10 – 0.18 mg/l at a mash-pH of 5.5 – 5.6) leads to better fermentation performance and “softer” beer
- Higher polyphenol content leads to better flavor and flavor stability
- Higher wort acidity accelerates the pH-drop during fermentation and thus enhances microbiological stability
- Mash acidification enhances phosphate buffering (= resistance to change in pH-value upon dilution of solution)
Finished beers with pH-values at or below 4.4 have greater foam stability and head retention than those with values of 4.5 and above.

Sensory studies show that acidulated beers receive higher sensory ratings and consumer acceptance than do non-acidulated beers.

Consumers tend to describe acidulated beers as “tasty,” “fresh,” “palatable,” “balanced,” “drinkable,” and “pleasantly bitter.”
Mash-pH Targets for a Few Classic European Beer Styles

Czech Pilsner and Bock pH 4.50 – 4.80
Kölsch and Alt pH 4.15 – 4.40
Bavarian Hefeweizen pH 4.10 – 4.40
English Ales pH 4.00 – 4.20
Lambic pH 3.40 – 3.90
Gueuze and Framboise pH 3.30 – 4.50
Berliner Weisse pH 3.20 – 3.40
Techniques for Influencing Mash-pH

- Water Treatment
- Composition of Grain Bill
- Biological Wort Acidification (Lactic Acid)
- Acidulated Malt
Brewing in the "good old days"
Traditionally, beers used to be acidified primarily by way of malolactic fermentation in the fermenter (during which malic acid was converted to softer-tasting lactic acid). Examples are Lambic and Gueuze from Belgium as well as Berliner Weisse and the rare Leipziger Gose from Germany.

The key objectives of malolactic fermentation, as of all beer acidification, are an improvement of the finished beer’s flavor and an extension of its shelf life.
Modern Acidification Methods

- Today, biological acidification in the mash tun and kettle is a normal part of the modern brewing process.

- Biologically (naturally) produced lactic acid results in better flavor stability in the finished beer than does artificially produced lactic acid.
The old Dortmunder Kronen Brewery (above) and post-WWII Kronen beer delivery trucks (right)
Well-Kilned, Melanoidin-Rich Malts that Reduce Mash-pH Levels

- Munich Malts
- Melanoidin Malts
- Dark Caramel Malt such as Caramunich® Types 1, 2, and 3; Carawheat®; Caraaroma®; Caraamber®
- Roasted Malts such as Carafa® Types 1, 2, and 3, as well as Carafa® Special (De-Husked) Types 1, 2, and 3
<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>---</td>
<td>7.0</td>
<td>%</td>
</tr>
<tr>
<td>Wort color</td>
<td>3.0</td>
<td>6.0</td>
<td>EBC</td>
</tr>
<tr>
<td>Wort color</td>
<td>1.7</td>
<td>2.8</td>
<td>°Lovibond</td>
</tr>
<tr>
<td>Protein (dry substance)</td>
<td>10.0</td>
<td>12.5</td>
<td>%</td>
</tr>
<tr>
<td>Acid rate</td>
<td>40</td>
<td>60</td>
<td>%</td>
</tr>
<tr>
<td>pH</td>
<td>3.30</td>
<td>3.60</td>
<td>pH</td>
</tr>
</tbody>
</table>
### Reduction in Mash- & Wort-pH by % of Acidulated Malt as Part of Grain Bill

<table>
<thead>
<tr>
<th>Example in 0.5% Increments</th>
<th>% Acidulated Malt in Test Grist</th>
<th>Mash-pH</th>
<th>Wort-pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting Mash</td>
<td>0.0%</td>
<td>5.84</td>
<td>5.96</td>
</tr>
<tr>
<td>Acidification Level 1</td>
<td>0.5%</td>
<td>5.77</td>
<td>5.91</td>
</tr>
<tr>
<td>Acidification Level 2</td>
<td>1.0%</td>
<td>5.71</td>
<td>5.87</td>
</tr>
<tr>
<td>Acidification Level 3</td>
<td>1.5%</td>
<td>5.67</td>
<td>5.83</td>
</tr>
<tr>
<td>Acidification Level 4</td>
<td>2.0%</td>
<td>5.62</td>
<td>5.79</td>
</tr>
<tr>
<td>Acidification Level 5</td>
<td>2.5%</td>
<td>5.56</td>
<td>5.75</td>
</tr>
<tr>
<td>Acidification Level 6</td>
<td>3.0%</td>
<td>5.50</td>
<td>5.71</td>
</tr>
<tr>
<td>Acidification Level 7</td>
<td>3.5%</td>
<td>5.46</td>
<td>5.68</td>
</tr>
<tr>
<td>Acidification Level 8</td>
<td>4.0%</td>
<td>5.41</td>
<td>5.64</td>
</tr>
<tr>
<td>Acidification Level 9</td>
<td>4.5%</td>
<td>5.38</td>
<td>5.60</td>
</tr>
<tr>
<td>Acidification Level 10</td>
<td>5.0%</td>
<td>5.34</td>
<td>5.56</td>
</tr>
<tr>
<td>Acidification Level 11</td>
<td>5.5%</td>
<td>5.27</td>
<td>5.50</td>
</tr>
</tbody>
</table>
Results: pH-lowering by using Weyermann® Acidulated Malt in Grain Bill

Graphs of Mash- & Wort-pH Drop by % of Weyermann Acidulated Malt in Grain Bill
First Measure Your Mash-pH!

Then, for every 0.1 pH-point reduction required in your mash acidity, use 1% of Weyermann Acidulated Malt in your grain bill!

The exact reduction in acidity may vary slightly, depending on brew house design factors and brewing processes.
To Summarize the Workings of Acidulated Malt, It...

- Contains 1 – 2% lactic acid
- Lowers mash, wort, and beer pH-values
- Enhances enzymatic activity in the mash
- Improves extract efficiency
- Enhances flavor and foam stability
- Extends shelf life of finished beer
- Promotes a satisfying consumer experience

Importantly, Acidulated Malt NEVER imparts “sour,” acidic notes to the finished beer, as long as its portion of the grain remains below 10%!
... Let's hear it for ACIDULATION!

WEBSTER'S again:

acidophilus milk \ˌas-ə-,däf-(ə)-ləs\ n [NL Lactobacillus acidophilus, lit., acidophilic Lactobacillus]: milk fermented by any of several bacteria and used therapeutically to change the intestinal flora

acidosis \ˌas-ə-'dō-səs\ n: an abnormal state of reduced alkalinity of the blood and of the body tissues — acidotic \ˌäd-ət-ik\ adj

acid test n: a severe or crucial test

acidulate \ˌə-'sij-ə-,lät\ vt [L acidulus]: to make acid or slightly acid — acidulation \ə-,sij-ə-'lā-shən\ n

acidulent \ˌə-'sij-ə-lənt\ adj [F acidulant, fr. prp. of aciduler to acidulate, fr. L acidulus]: ACIDULOUS

acidulous \ə-'sij-ə-ləs\ adj [L acidulus sourish, fr. acidus]: acid in taste or manner: HARSH syn see SOUR
... and this is where we make it, in our plant in Bamberg, Bavaria, Germany!
... and this is where we test it, in our pilot brewery on the Company grounds in Bamberg!
And for the Last Word ... We turn to the Rolling Stones:

“If you can't get no. Oh, no, no, no.
Hey, hey, hey. That's what I say:
If you can’t get no A-CI-DU-LA-TION
Though you try and you try and you try, ...”

... Just stop by just stop by just stop by
Our booth and pick up your pH-Info-Kit!

Thank you for listening!