Brewing Water Treatments

By John Palmer, MBAA Editor-in-Chief
BYO NanoCon, 2020

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Why Do We Adjust Brewing Water?

- To Improve Beer Yield – to hit our target mash pH!
- To Improve Beer Flavor
  - And prevent carbonate scale.
- What do we adjust?
  - Mineral composition
- How do we adjust it?
  - Salt additions
  - Acid additions
  - Ion Removal Processes (e.g., Reverse Osmosis)

When do we adjust it?

- "The key point for control of pH throughout the brewing process is during mashing. This is due to the major influence that can be exerted at this stage on the content and format of the buffer systems that will operate subsequently in the wort and beer."
  - Taylor, D.G., The Importance of pH Control during Brewing, *MBAA Tech. Quart.* 27:131-136, 1990.

Know Your Source Water

- Surface Water
  - Low in Minerals, High in Organics
  - Often requires Carbon Filtration to remove taste & odor compounds
- Ground Water
  - High in Minerals, Low in Organics
  - Often requires ion-exchange or RO to reduce Alkalinity
- How is your source water disinfected?
- Does your Source change during the year?

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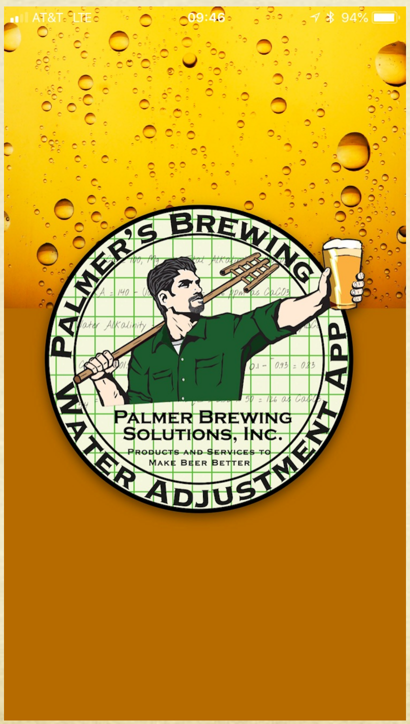
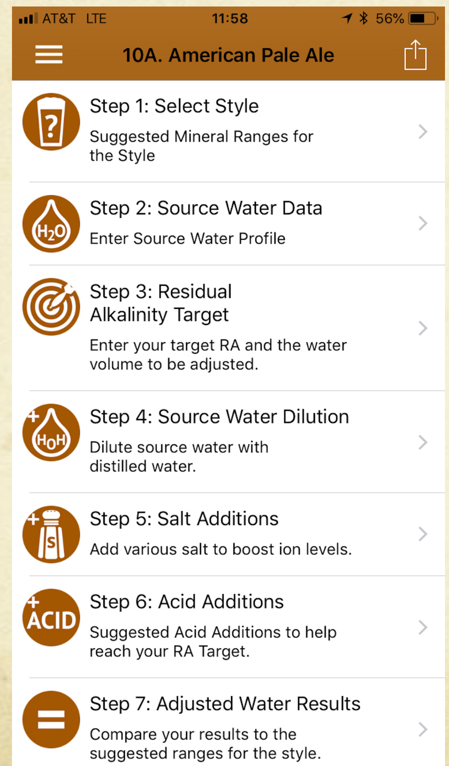
Two Groups of Ions

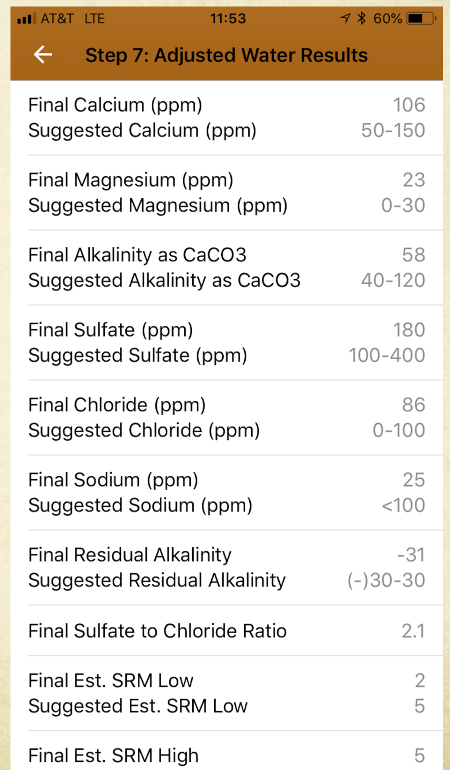
- **Affect pH:**
  - Calcium
  - Magnesium
  - Total Alkalinity
- **Affect Flavor:**
  - Sulfate
  - Chloride
  - Sodium

- **Mineral Concentrations**
  - 0-50 ppm is Low
  - 50-100 ppm is Medium
  - 100-150 ppm is High
  - **>150** ppm is a **Problem**

Palmer's Water App







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How Water Affects Beer Flavor

- <u>Water Residual Alkalinity</u> drives Mash pH,
  Mash pH drives Beer pH,
  Beer pH drives beer flavor expression.
- <u>Seasoning Balance</u>: Sulfate and Chloride
  - More Sulfate = drier, more assertive hops
  - More Chloride = rounder, fuller, sweeter malt
- <u>Seasoning Level:</u> (Total Dissolved Solids-TDS)
  - TDS is proportional to Calcium salt concentrations…

The Water pH is Not Important.

- The water pH is not important.
- The water pH is the chemical equilibrium of the water, i.e., the balance of hardness and alkalinity.
  - Higher pH = more alkalinity than hardness
  - Two different waters can have the same water pH
- High mineral water vs. Low mineral water:
  - Can have same Water pH.
  - Will have different Mash pH.
- Mash pH drives Beer pH, which drives beer flavor!

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Effect of Beer pH on Flavor

- In general, a lower beer pH focuses and brightens the malt and hop flavors.
  - Better for single-malt pale beers.
  - Dark beers can become a singular "roast" character.
- In general, a higher beer pH broadens and opens up malt and hop flavors.
  - Better for multiple-malt dark beers.
  - Pale beers can become dull and harsh.

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Seasoning Balance - Sulfate and Chloride

- They affect the flavor balance of the beer – Dryness vs. Fullness, Hoppy vs. Malty
- The actual amounts are more important than the ratio.
  - It is not magic – 40:10 ≠ 400:100
- Useful range is 5:1 to 0.5:1
  - Maximum suggested sulfate is 500 ppm, even 100 ppm works.
  - Maximum suggested chloride is 200 ppm
  - Recommend to not exceed combined sum of 500 ppm. (Tastes Minerally)

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TDS Effect –Mineral Structure

- Light vs. Heavy Seasoning
- Bohemian Pilsner (TDS = 50 ppm
  - Rich, malty beer backed by large soft bitterness. Smooth finish balanced between malt and hops. No sharp edges.
- German Pils (TDS = 150 ppm)
  - Crisp and bitter hop forward character, followed by clean malt and dry finish. This is a beer defined by clean edges.
- Dortmunder Export (TDS = 750 ppm)
  - Balanced rich malt and firm dry bitterness. A "castle" of beer structure. Lower alcohol but doesn't taste like it.

What is Residual Alkalinity?

- Residual alkalinity is the difference between effects of the Total Alkalinity and Hardness on mash pH.
  - RA = Total Alkalinity – (Ca + ½ Mg)/3.5
    Note: Units must be mEq/L or ppm as $CaCO_3$
    3.5 factor is dependent on Mash Ratio and Crush
- Calcium and Magnesium react with malt phosphates to produce hydrogen ions and lower mash pH, if there is sufficient calcium....
  - $10Ca^{+2} + 12HCO_3^{-1} + 6H_2PO_4^{-1} + 2H_2O \rightarrow Ca_{10}(PO_4)_6(OH)_2 + 12CO_2 + 12H_2O + 2H^{+1}$
  - Magnesium also reacts, but about half as much.

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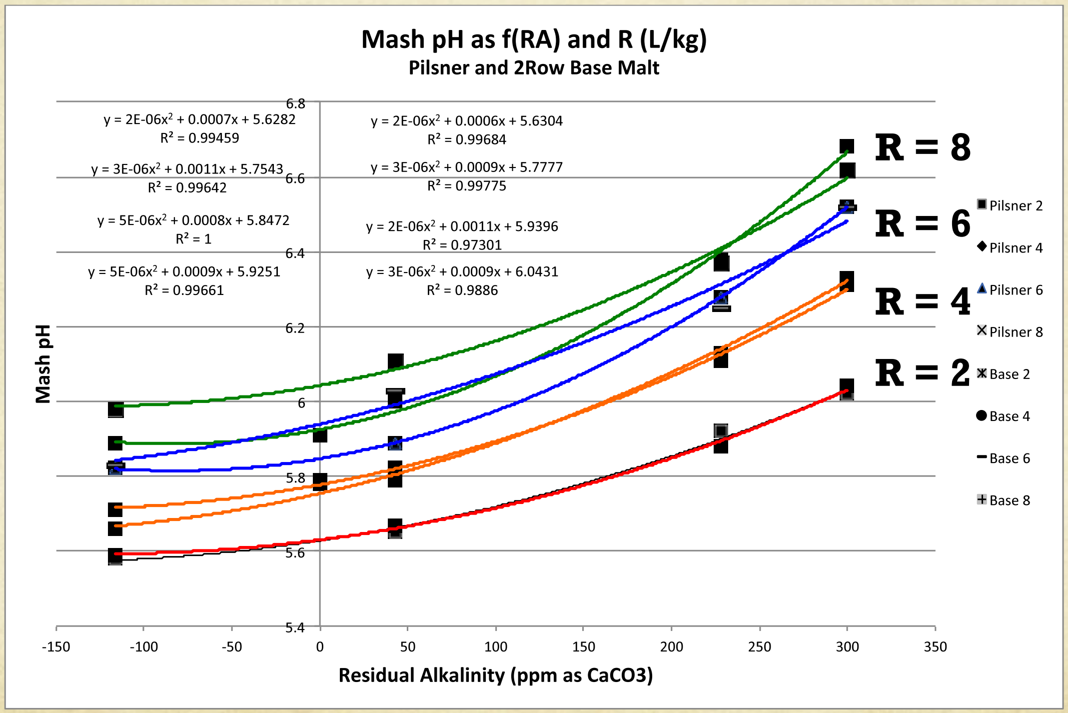
RA has Increasing Effects



Mash ph is the Equilibrium between Water Chemistry and Malt Chemistry

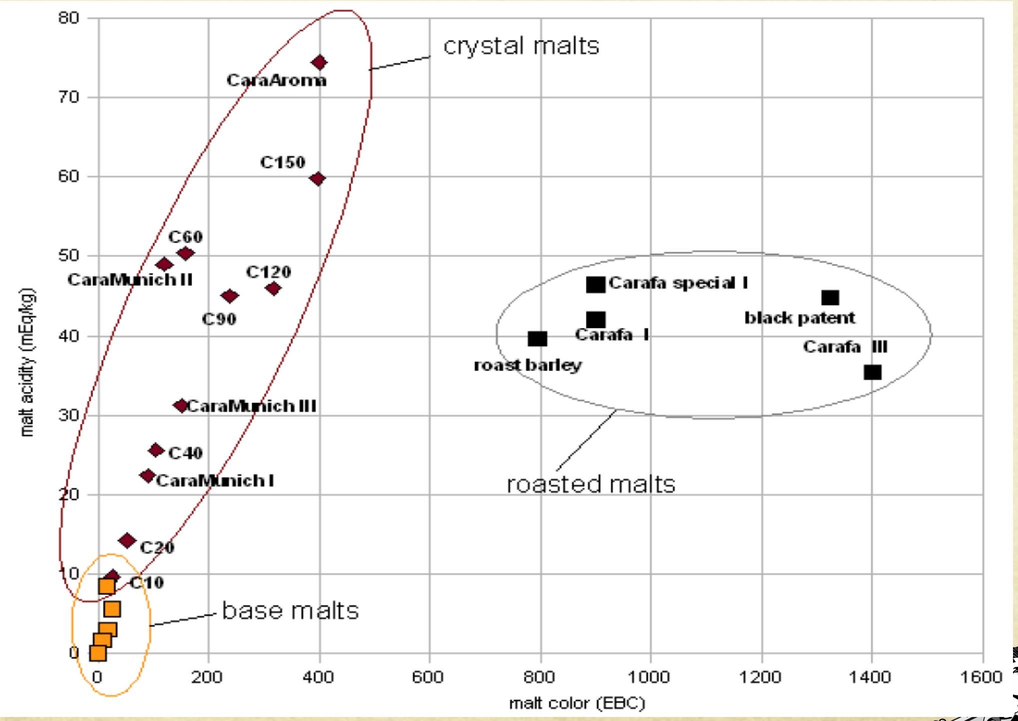
- The effect of water chemistry in the mash is summarized by Residual Alkalinity.
  - Calcium and malt phosphates react to lower mash pH
  - Alkalinity buffers that reaction.
- Malts are either alkaline or acidic relative to your target pH (5.2-5.6).
  - Base malts are generally alkaline (> 5.6).
  - Specialty malts are generally acidic (< 5.2).

Kilned vs. Roasted Acidity

- In general, distilled water mash pH for a specialty malt is proportional to malt color.
  - Darker = lower pH
- Roasting causes pyrolyzation and breakdown of buffers and acids.
- Therefore, dark Caramel malts often have higher buffering power than Roast malts.
- Dark Roast malts often have higher initial acidity, but less buffering power than dark caramel.
- See: J. Guerts, Specialty Malt Acidity, MBAA-Jacksonville, 2015.

Kilned vs. Roasted Acidity

- Kilned malts seem to follow a linear trend.
- Roasted malts appear to be clumped.



From K. Troester,
www.braukaiser.com

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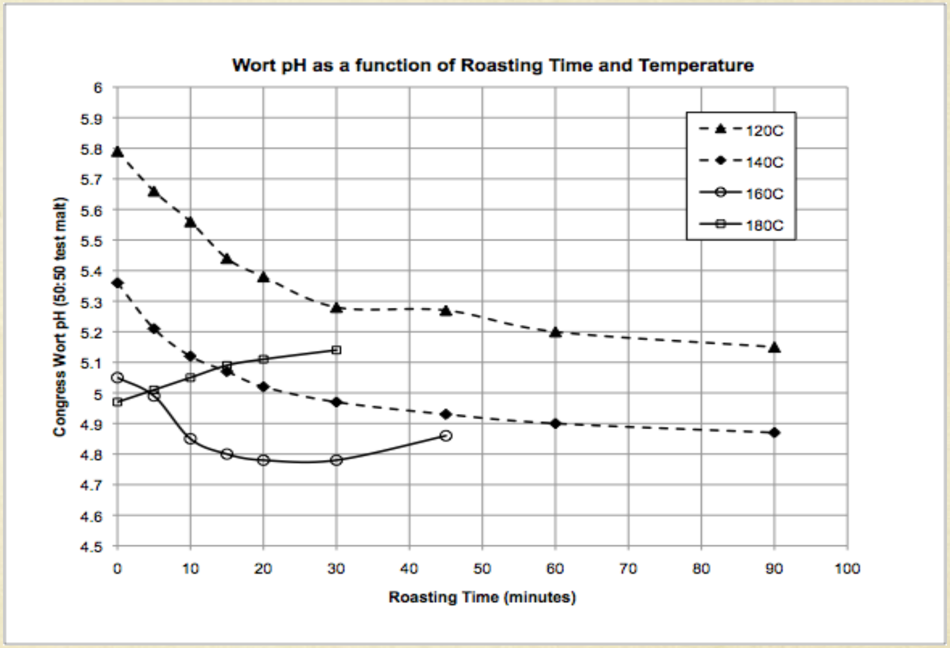
Kilned vs. Roasted Acidity

- Basically, malt acidity peaks as a function of malt color.
- The highest colored Kilned malts are the most acidic.
- Roasted malt acidity tends to decrease with increasing color (roasting time).



Data from Vandecan, S., et al. "Formation of Flavor, Color, and Reducing Power During the Production Process of Dark Specialty Malts," ASBC 69(3):150-157, 2011.

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Mash pH: Balancing a Triangle

Base Malt Alkalinity x Weight

\+

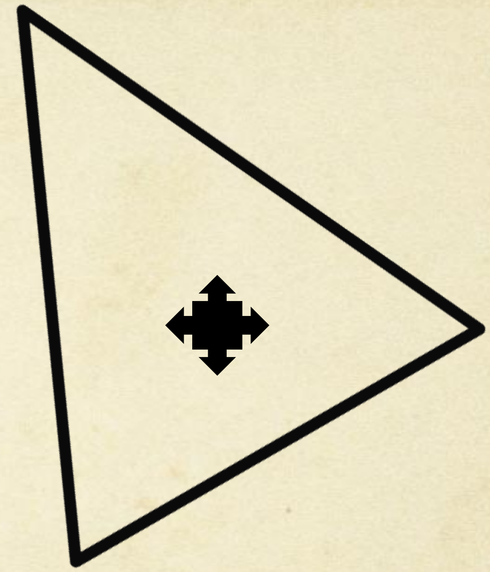
Specialty Malt Acidity x Weight

\+

Water Residual Alkalinity x Volume

=

Mash pH



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What Is the Optimum pH?

- It Depends:
  - There are many enzymatic processes occurring in the mash, each with its own optimum pH range.
  - The pH optima for proteolysis is lower than for saccharification.
- Therefore optimum mash pH represents a compromise between priorities: conversion, FAN, lauterability, etc.
  - “Optimum” Mash pH is generally based on optimum yield.
  - However, published opinions differ on what the optimum range is…

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pH for Best Yield, by Author

Briggs et al.:	5.2-5.4	(5.45-5.65 at 20°C)
Bamforth et al.:	5.3-5.8	(5.55-6.05 at 20°C)
Kunze:	(5.25-5.35)	5.5-5.6 at 20°C

- Best Yield is therefore 5.4-5.6
- Anecdotally, many brewers report better beer flavor with lower mash pH, 5.2-5.6 at 20°C.

  - Parentheses indicate pH/temperature conversion

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Testing pH

- A good $100 pH meter will give an accurate reading in about 15 seconds.
- Brewers want to differentiate between 0.1 pH units, therefore you need a meter with a resolution of 0.01.
- Every pH electrode typically has a useful life of 1-3 years if well maintained. After that, they tend to drift and are hard to calibrate.

LaMotte Order Code No. 1741

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pH and ATC

- Most modern pH meters have automatic temperature compensation (ATC).
- The purpose of ATC is to be able to measure a sample at a *different temperature* than the calibration temperature, and give an accurate reading of the pH *at that different temperature*.
  - i.e., it maintains calibration
- It does not compensate for the actual pH change of the solution due to temperature.

pH Changes with Temperature

- The pH of a solution will change with temperature, due to changes in activity (energy) and buffer response.
- Different worts (styles) will have different activities and different pH change with temperature.
- Generally, wort pH lowers by ~0.3 between room (20°C) and mashout temperature (75°C).
  - We use room temperature as a common standard for comparison. (ASBC MOA Beer-9, pH)

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Measuring pH

- Therefore, the pH measurement temperature must always be stated, and preferably, the measurement should be conducted at room temperature for best accuracy and easy comparison.

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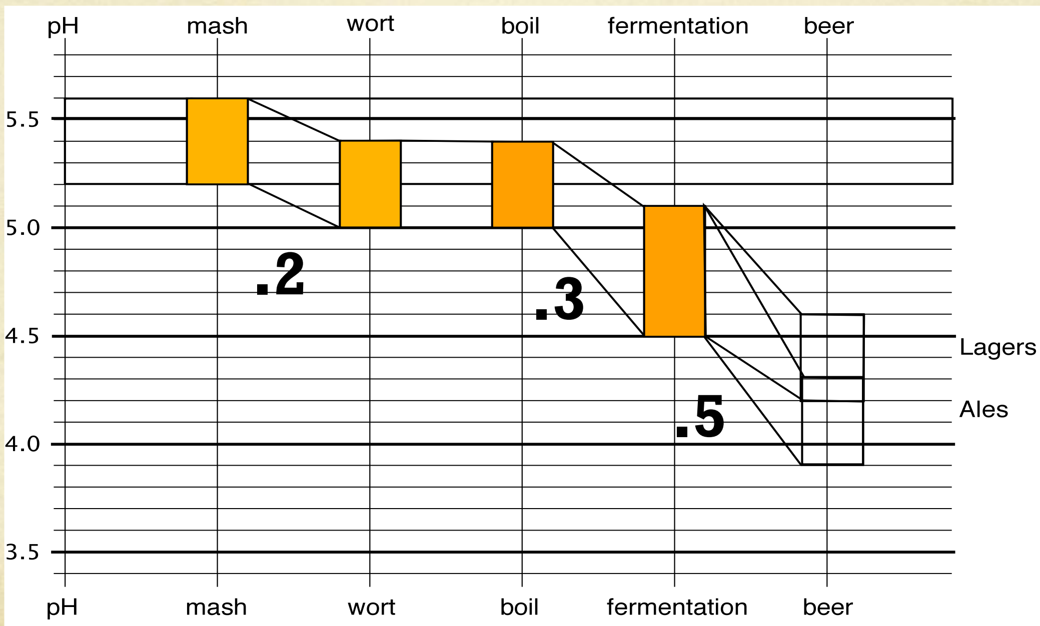
Mash pH Sets Up Beer pH

5.2-5.6



~4.0-4.6

Style/recipe dependent

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Adjusting Beer pH for Flavor

- Every beer recipe has an optimum beer pH, generally in the range of 4.0-4.6.
- Every beer should have a flavor portfolio that includes:
  - malt flavors and aromas,
  - hop flavors and aromas,
  - yeast flavors and aromas.
- If you can't taste or smell *everything*, you are probably not at the optimum beer pH.

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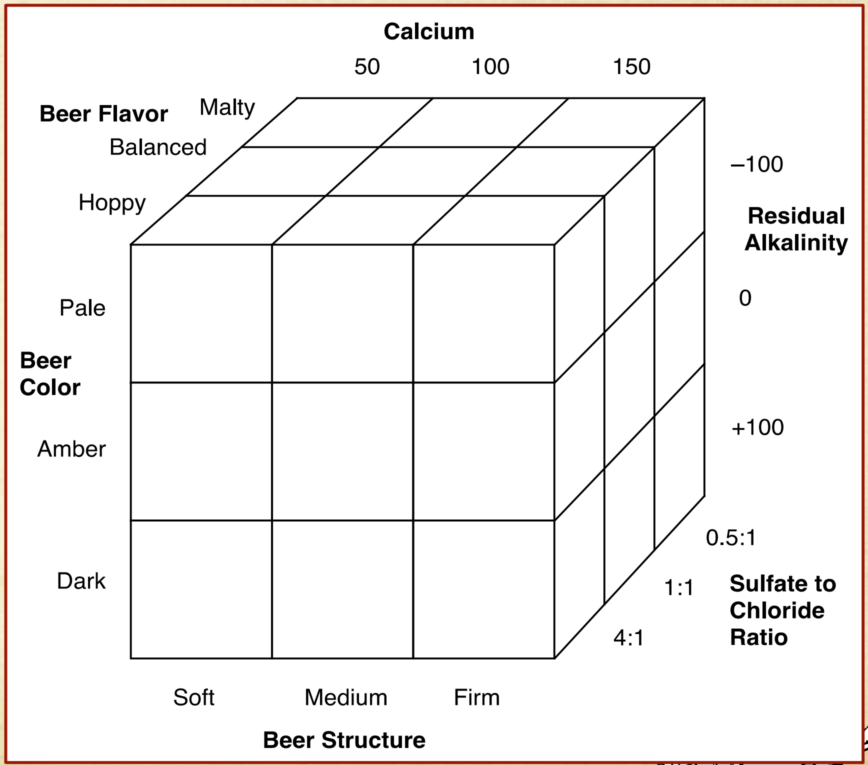
Suggested Mash pH Guidelines

- Pale beers: 5.2-5.4
- Amber beers: 5.3-5.5
- Dark beers: 5.4-5.6
  - Always cool a sample and measure at room temperature.
- Water pH is NOT important!
  - Different waters can have same pH.
  - You are putting the cart before the horse if you adjust water pH.

Adjusting Water for Style

- To Adjust water for style, use the cube:
  - Define the style by Flavor, Color, & Structure.
  - Read water profile by Calcium, Total Alkalinity, and Sulfate to Chloride Ratio.
    - Beer Color => Residual Alkalinity
    - Flavor Balance => Sulfate to Chloride
    - Beer Structure => Calcium level



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Suggested Salt Additions to RO Water (grams per gallon)

Beer	$CaSO_4$	$CaCl_2$	Baking Soda	Ca	Na	SO4	Cl	HCO_3	RA
Pale Hoppy	1	0.5	0	98	0	147	64	0	-70
Pale Balanced	0.75	0.75	0	100	0	111	96	0	-72
Pale Malty	0.5	1	0	103	0	74	127	0	-73
Amber Hoppy	1	0.5	0.5	98	36	147	64	95	+8
Amber Balanced	0.75	0.75	0.5	100	36	111	96	95	+6
Amber Malty	0.5	1	0.5	103	36	74	127	95	+4
Dark Hoppy	1	0.5	1	98	72	147	64	190	+86
Dark Balanced	0.75	0.75	1	100	72	111	96	190	+84
Dark Malty	0.5	1	1	103	72	74	127	190	+82

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Mini-mash pH Results

	Pale Hoppy RA = -70	**Pale Malty** RA = -70	**Amber Malty** RA = +5	**Dark Malty** RA = +80	*Delta*
Pale	**5.7**	**5.6**	**5.8**	**6.3**	*0.6*
Amber	**5.6**	--	--	**6.1**	*0.5*
Dark	**5.3**	**5.3**	**5.6**	**5.9**	*0.6*
delta	*0.4*	*0.3*	*0.3*	*0.4*	

3 grain bills:

- Pale: Base malt
- Amber: Base and 10% Crystal
- Dark: Base, 10% Crystal, 10% Roast
- Rv = 4 L/kg (2 qts./lbs.)

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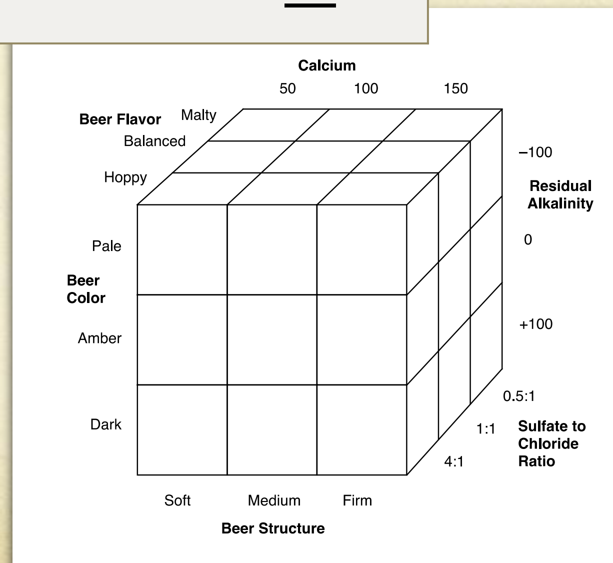
How Do I Adjust Water for Beer Style?

Ca^{+2}	Mg^{+2}	Alk.	SO_4^{-2}	Cl^{-1}	Na^{+1}	Res. Alk.
40	10	120	40	35	32	86

1. What are the style characteristics that you want to brew?
   a) Color: Pale, Amber, or Dark?
   b) Flavor Balance: Malty, Balanced, or Hoppy?
   c) Structure: Soft, Medium, or Firm?



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Ca^{+2}	Mg^{+2}	**Alk.**	SO_4^{-2}	Cl^{-1}	Na^{+1}	**Res. Alk.**
40	10	120	40	35	32	86

1. Add Calcium based on:
   a) Structure (generally soft or medium) => 50-100 ppm
   b) Color/RA target => Calculate new RA after salt additions.

- For Pale, Hoppy, Medium:
  - Start by adding 1 gram/gallon of calcium sulfate

Ca^{+2}	Mg^{+2}	**Alk.**	SO_4^{-2}	Cl^{-1}	Na^{+1}	**Res. Alk.**
102	10	120	187	35	32	42

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How Do I Adjust Water for Beer Style?

Ca^{+2}	Mg^{+2}	Alk.	SO_4^{-2}	Cl^{-1}	Na^{+1}	Res. Alk.
102	10	120	187	35	32	42

2. Adjust RA based on beer color/gravity:
   a) Does RA need to decrease (pale)? => Neutralize with acid.
      - For Pale, Hoppy, Medium:
        - Add 0.75 ml per gallon of 88% Lactic Acid

Ca^{+2}	Mg^{+2}	Alk.	SO_4^{-2}	Cl^{-1}	Na^{+1}	Res. Alk.
102	10	3	187	35	32	–75

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How Do I Adjust Water for Beer Style?

Ca^{+2}	Mg^{+2}	Alk.	SO_4^{-2}	Cl^{-1}	Na^{+1}	Res. Alk.
102	10	120	187	35	32	-75

- Final Adjusted Water:
  1. Acidify to neutralize alkalinity first, then add calcium salts.
  2. Do a proportional mini-mash to verify mash pH target.

- When to add salts:
  - First priority is achieving your mash pH target.
  - Add most/all adjustments to HLT/MT to achieve mash pH target.
  - Second priority is achieving Flavor Balance and Structure.
  - Add additional salts or acid as necessary to kettle for flavor.

Neutralizing Alkalinity to brew Pale beers

- Acidification to reduce Total Alkalinity is easy.
  - Divide Total Alkalinity by 50 to get mEq/liter.
  - Ex. TA = 150 ppm as $CaCO_3$ ÷ 50 = 3 mEq/liter.
  - Use 3 mEq/Liter of 1N Acid per liter of water to neutralize the alkalinity.
- 1N solution is 85mL of 88% Lactic Acid added to water to make 1 liter (total).
- Mix acid solution with water in HLT and stir to vent the CO_2.
- Mash pH target of 5.2-5.4

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Adding Alkalinity to brew Dark beers

- Low mineral water needs alkalinity to buffer dark malts.
- Sodium Bicarbonate works better than Calcium Carbonate.
  - Sodium bicarbonate dissolves easily and reacts more quickly.
  - Hydroxides work faster but may have chemical taste.
- Add sufficient bicarbonate to raise residual alkalinity to:
  - 50-75 ppm as $CaCO_3$ for red and brown beers
  - 75-125 ppm for brown to black beers
  - RA amount depends on depth of color and OG.
- Mash pH target of 5.4-5.6

Adjusting Sparge Water

- Target Mash pH is the first priority.
- The next priority during sparging is to prevent pH rise (>5.8) and prevent astringency.
- Do not acidify water based on its pH, acidify based on its alkalinity.
- Options:
  - Use the adjusted HLT water to sparge with. Monitor runnings pH.
  - Use low alkalinity water to sparge with. Add salts as needed to kettle.
  - Acidify high alkalinity sparge water to neutralize Total Alkalinity (or Residual) and add salts as needed to kettle.

Summary

- #1: Adjust water to achieve good mash pH.
- #2: Adjust water to adjust beer seasoning.
- #3: Brewing is cooking — Don’t over-salt, but don’t be afraid to adjust it to your taste.

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Questions?