All-Grain Brewing Essentials

BYO Boot Camp 2021
March - Online

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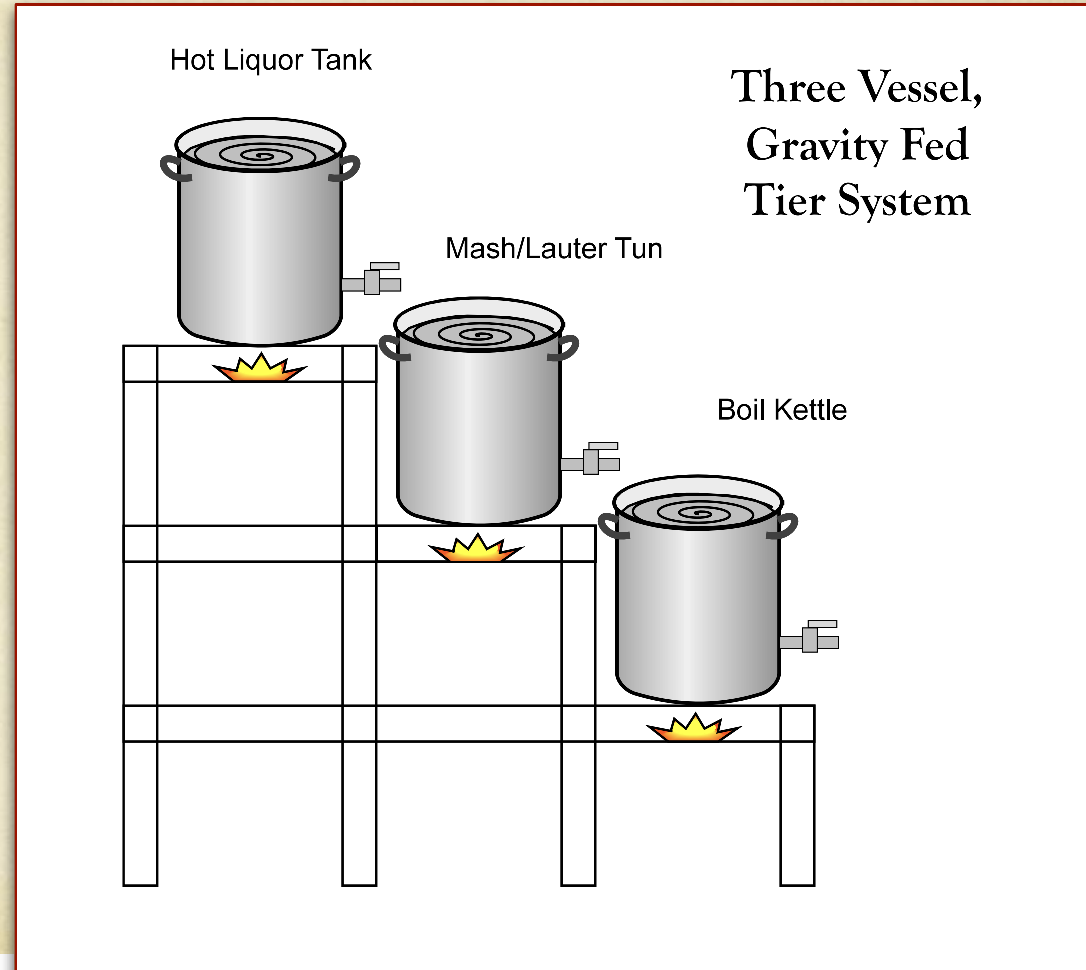
Class Overview

- Barley and Malting
- Crushing
- Mashing Process and Systems
- Getting the Wort Out
- Water and Treatment
- Q&A – ALL DAY

Basic Steps for All-grain

- Crush the malt
  - Obtain a good mixture of largely intact husks, medium bits, small bits, and flour.
  - Better crush = faster conversion, more yield, but…
- Soak it in hot water
  - Soak it for an hour at 149-155°F (65-68°C).
  - Malt enzymes convert grain starch to sugar
- Drain off the wort
  - Rinse (Sparge) the grainbed with additional water.
  - Watch your runnings pH

Basic Wort Production



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What is Malt?

- Barley is a seed.
- Malting is a process of partial growth.
  - You Soak the barley to germinate it.
  - You let it grow a little bit.
  - You dry it to stop the growth.
  - You kiln it (toast or roast) to develop more flavor.
- The dried malt is delivered to the brewer.

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WHY do we Malt?

- A barley seed is as hard as a rock.
- You can't eat it until it is soaked and cooked, just like dried beans.
- Malting allows us to use the plant's natural enzymes soften the seed and make it easier to eat.
- But why eat it when you can brew with it!?

Malt

- Malt is germinated and dried/kilned barley
- Malting is the germination and drying process that unlocks the starches and enzymes for the brewer.

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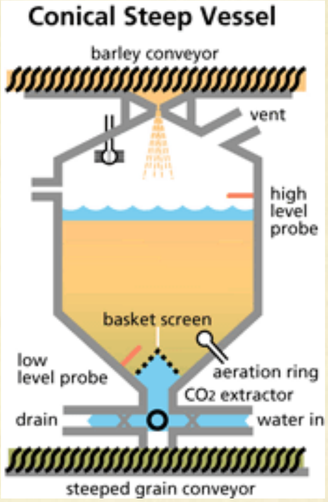
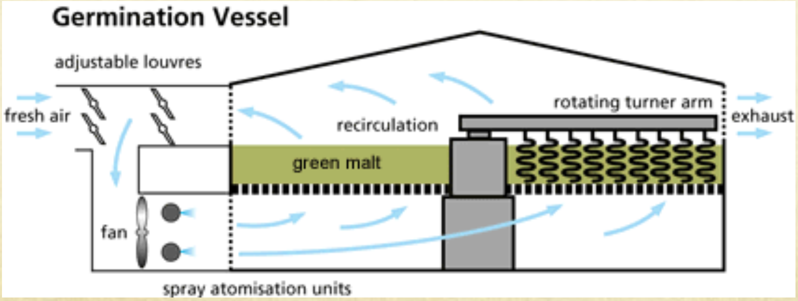
Malting

- Steeped under controlled conditions to allow consistent germination.





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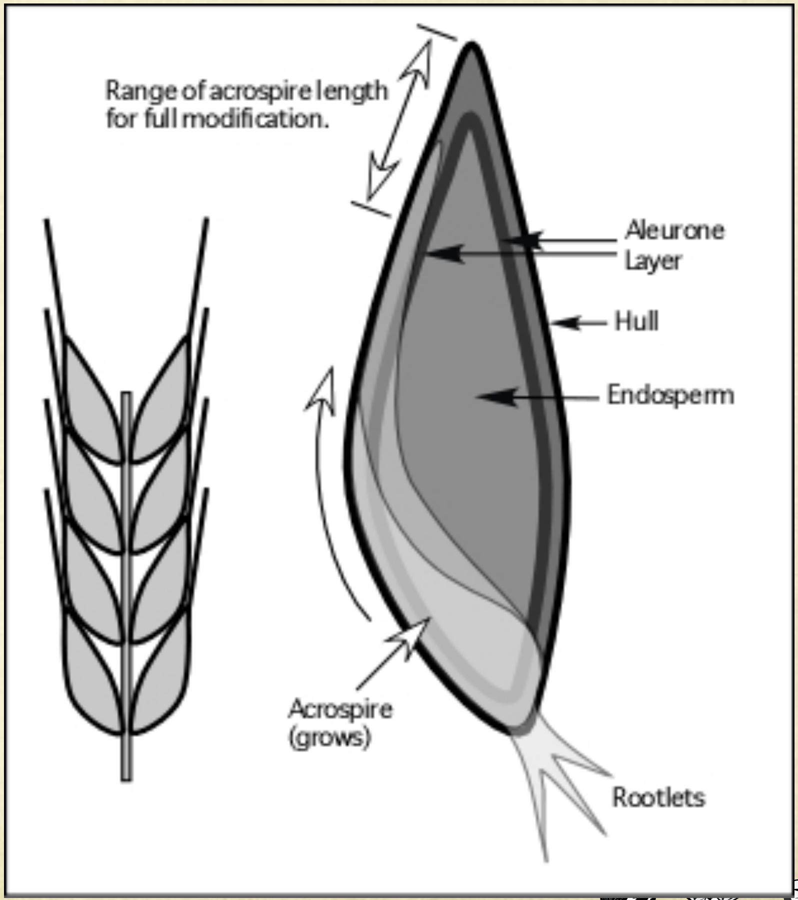
Malting and Mashing

- Malting and Mashing are two halves of the same process: creating fermentable sugars for the brewer.
- Modification describes how far the malting process has gone.
- Measured by:
  - Friability
  - Soluble to Total Protein (measured as Nitrogen)

“Modification”

- During malting the enzymes in the kernels unlock the protein-carbohydrate matrix to make the starches available for enzymatic transformation to sugars for the growing plant.



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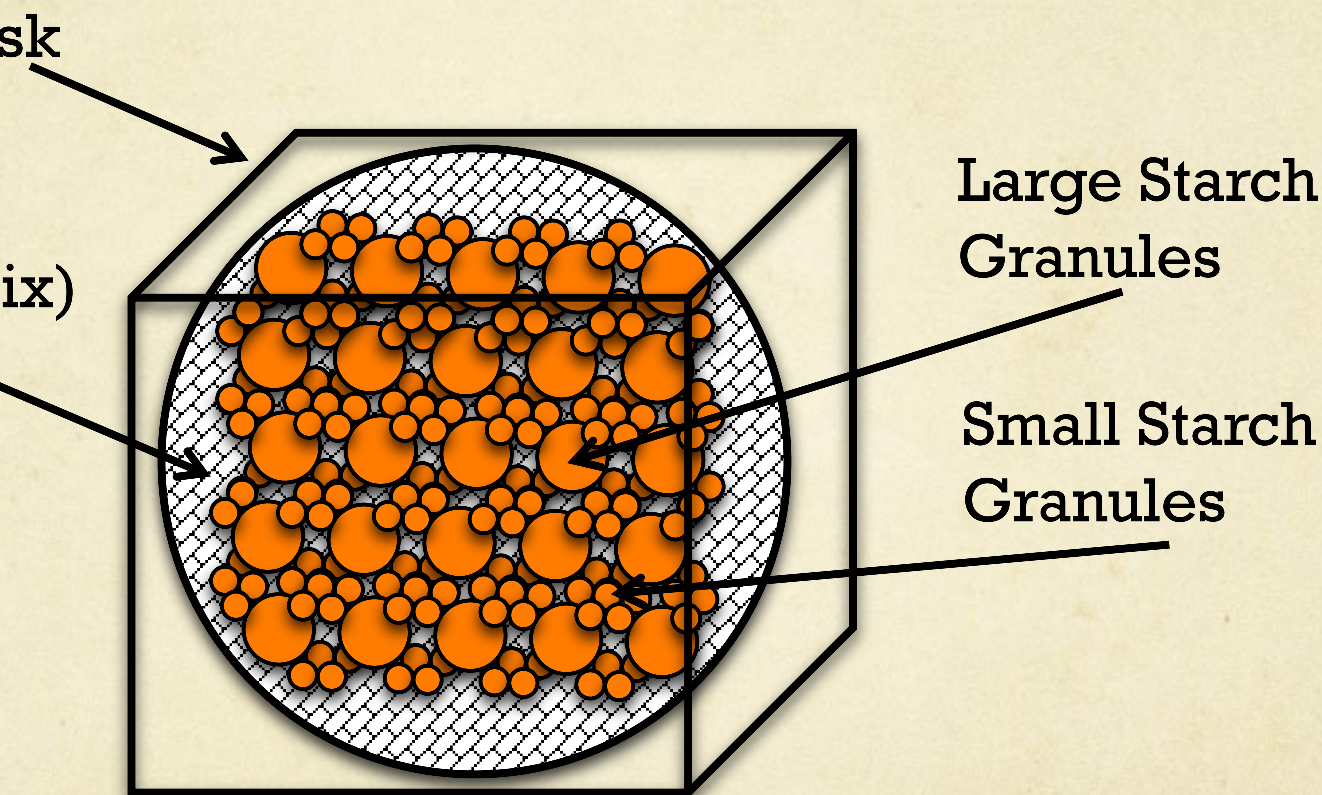
How Malting Works

- The barley kernel contains starch granules in a protein and carbohydrate matrix.
- Germination releases proteolytic (protein) enzymes, beta glucanase, and alpha amylase.
- The purpose of malting is to unlock this matrix and make the starches accessible to the amylase enzymes.
- The amount of unlocking is called Modification.
- After modification, the malt is dried for storage.

Barley Before Malting



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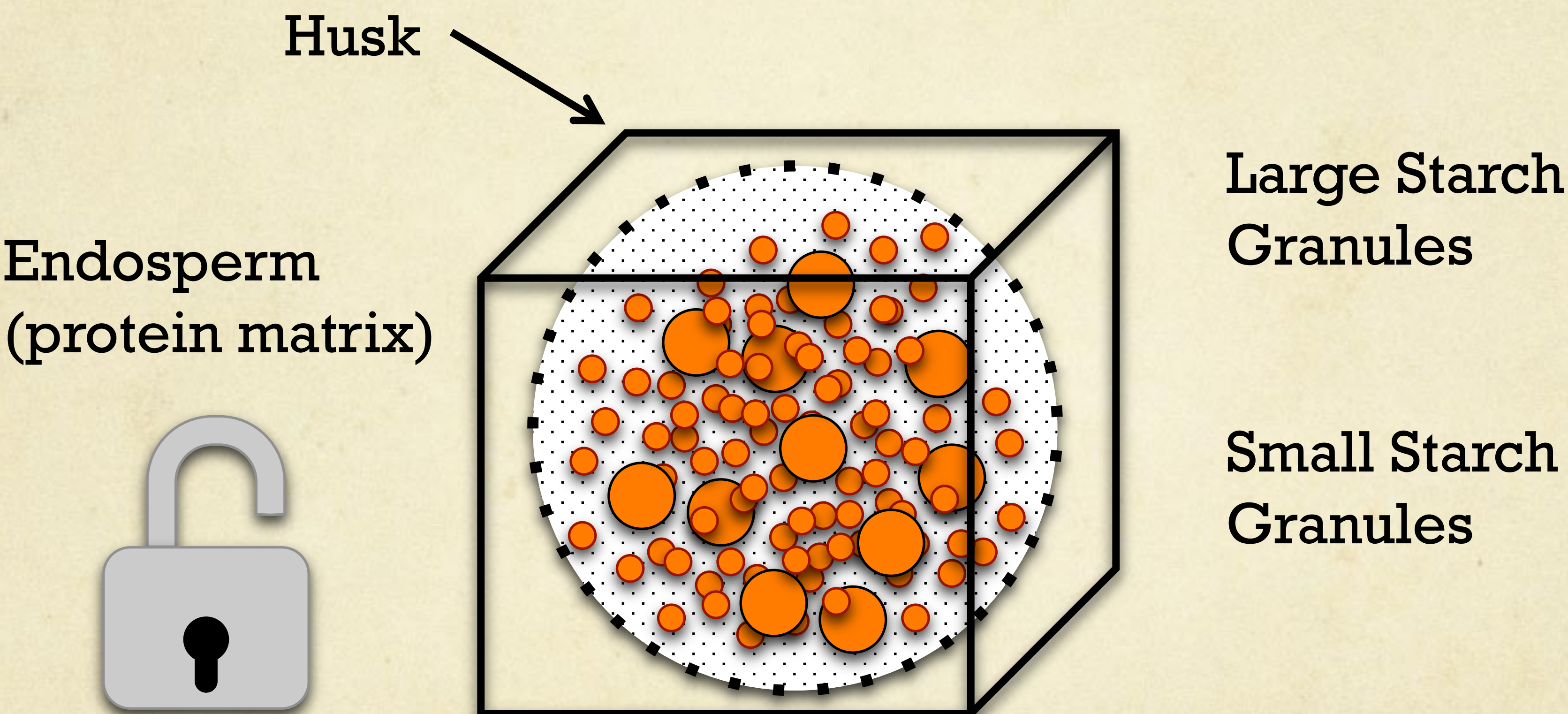
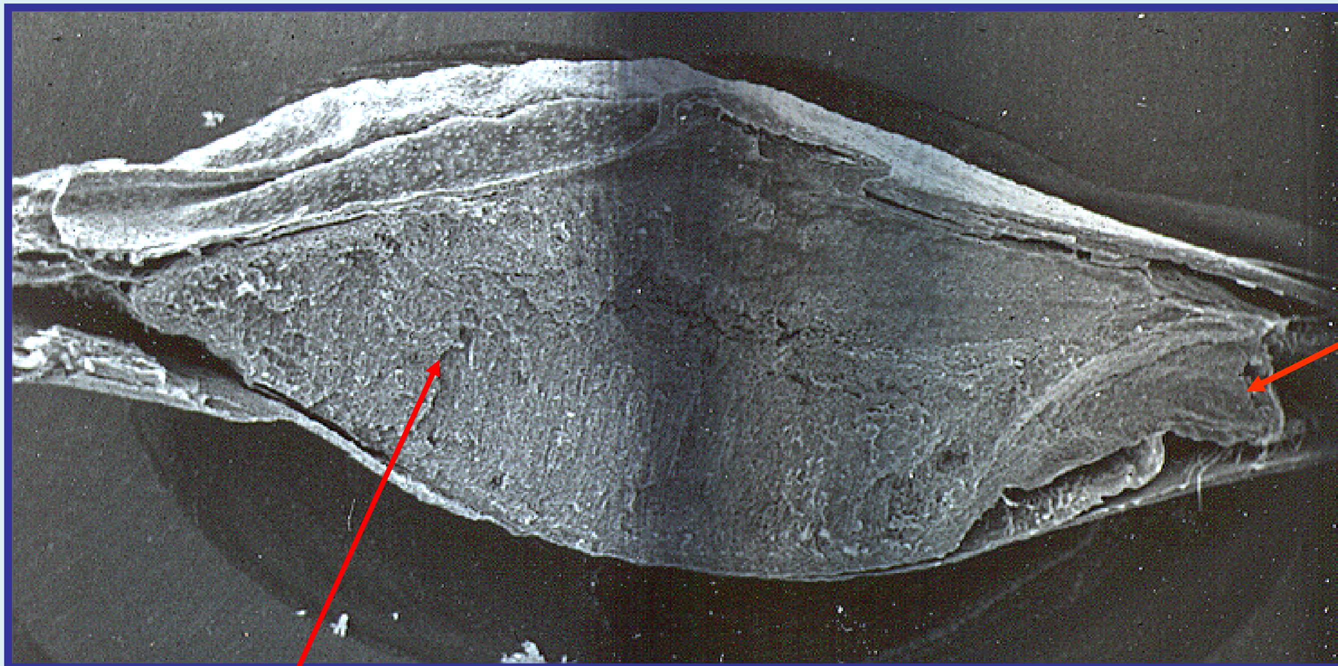
Barley After Malting

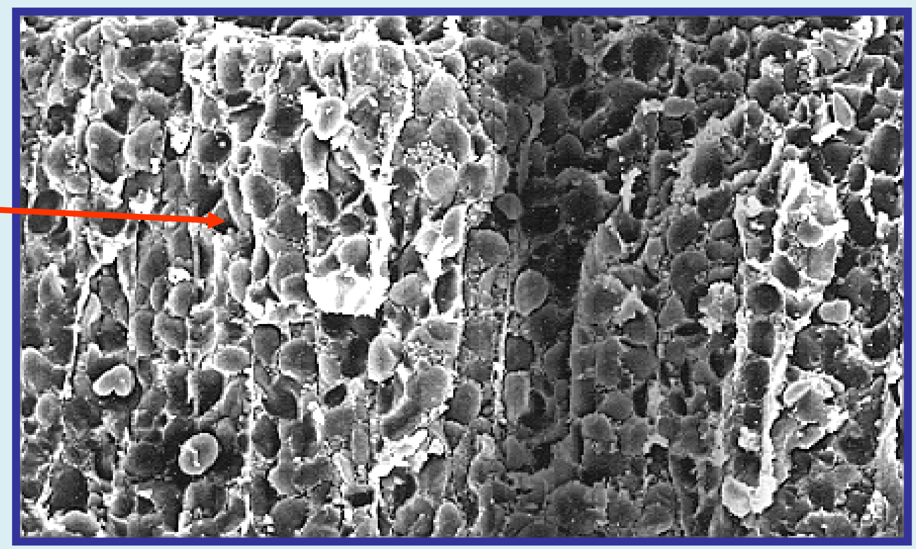




Embryo

Endosperm

starch
protein
cell wall
- beta-glucan
- arabinoxylan (pentosan)



Malting/Mashing

- Modification is the degree of unlocking.
- Mashing and malting are two parts of the same overall process of making sugar available to the brewer.
- The more you malt, the less you have to mash.

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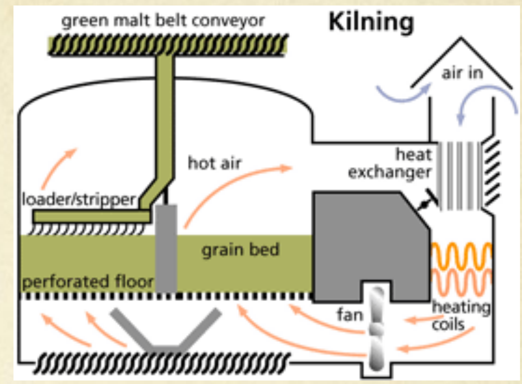
Unmalted vs Malted

- Unmalted
  - Hard, glassy protein/ carbohydrate matrix
  - Cell walls intact (lots of beta glucan)
  - Most proteins large and insoluble (~30% is soluble).

- Malted
  - Friable, reduced protein/ carbohydrate matrix
  - Cell walls reduced (beta glucans reduced).
  - 80% of the total soluble protein is rendered.

Kilning

- Green malt is transferred to kilns for warm air drying to arrest the germination process and reduce the moisture content of the grain to 4%.The kilning process takes around 18 - 24 hours. At this stage the malt takes on its distinctive flavor and color.



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Characteristic Specialty Malts

- Amber (Victory®, Biscuit®) – Cookie to Cracker to Toast to Crust
- Aromatic, Melanoidin – rich dark flavors of bread crust
- Caramel (C20L, 40, 80, 120) – Honey to caramel to toasted marshmallow

Roast Specialty Malts

- Brown Malt– heavily toasted crust, bordering on harsh.
- Pale Chocolate – harsh, bordering on cocoa and coffee. Dry grain and wood.
- Chocolate – Not sweet. Cocoa and Coffee
- Roast Barley - Coffee

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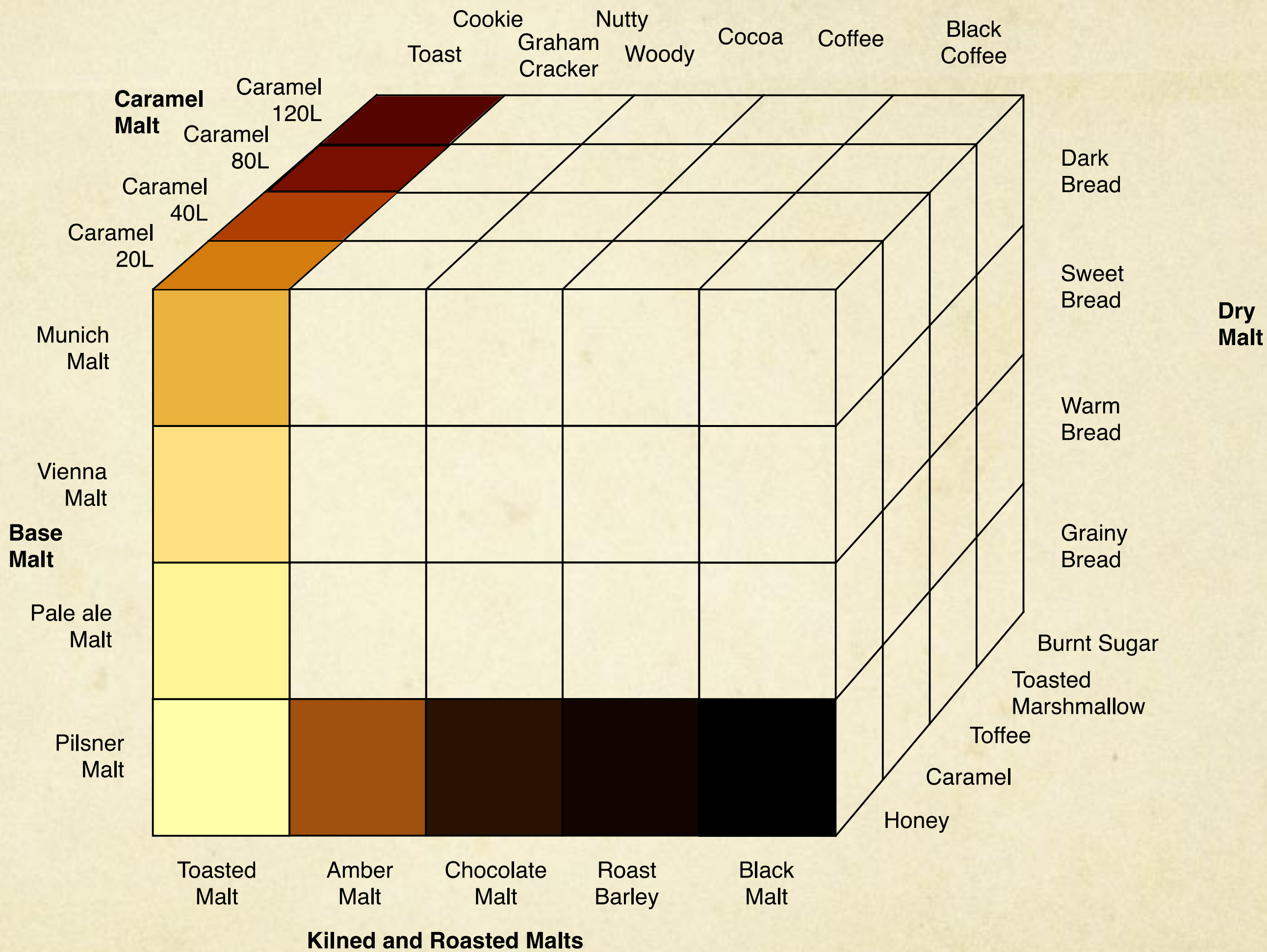
Malt Space



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Crushing the Malt

- The basic idea is to crush the grain into small pieces so it can be rapidly wetted.
  - You want to leave the husks mostly intact.
  - The grain husks are don’t dissolve and provide a matrix for draining off the wort.
- The finer the crusher, the harder it will be to lauter.
  - There are 2 Roller and 3 Roller mills.
  - 3 roller gives more small pieces and flour than 2 roller.
  - Smaller = Faster, but who cares?
  - Adjustability is good to get a better crush on wheat, and small grains.

VLB Mean Grist Size Analysis

- From Kunze, Technology of Malting and Brewing

Sieve	Grist type	MEBAK Mesh Hole Size (inch)	Lauter Tun	Mash Filter
1 (#14)	Husks	.050"	21%	1%
2	Coarse Grits	.040"	16%	3.5%
3 (#30)	Fine Grits 1	.020"	34%	21%
4 (#60)	Fine Grits 2	.010"	14%	39%
5	Flour	.005"	5%	31%
Pan	(dust)		10%	4.5%

Break

Let’s crush some grain!

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The Mashing Process

- Step 1: Crush it
  - Small pieces, large surface area, wet more easily.
- Step 2: Solubilization of the Starch
  - Also called gelatinization. Wet inside and out.
  - Needs high temperature to dissolve.
- Step 3: Liquefaction
  - Alpha amylase breaks really long chains into shorter chains
- Step 4: Conversion
  - Alpha, beta, and limit dextrinase convert the starch chains to fermentable sugars.

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Typical gelatinization temperatures of cereal starches

Grain		
Barley	136–149°F	58–65°C
Wheat	136–147°F	58–64°C
Rye	135–158°F	57–**70**°C
Oats	135–162°F	57–**72**°C
Sorghum	**156–167°F**	**69–75°C**
Corn (Maize)	**162–172°F**	**72–78°C**
Rice	**158–185°F**	**70–85°C**

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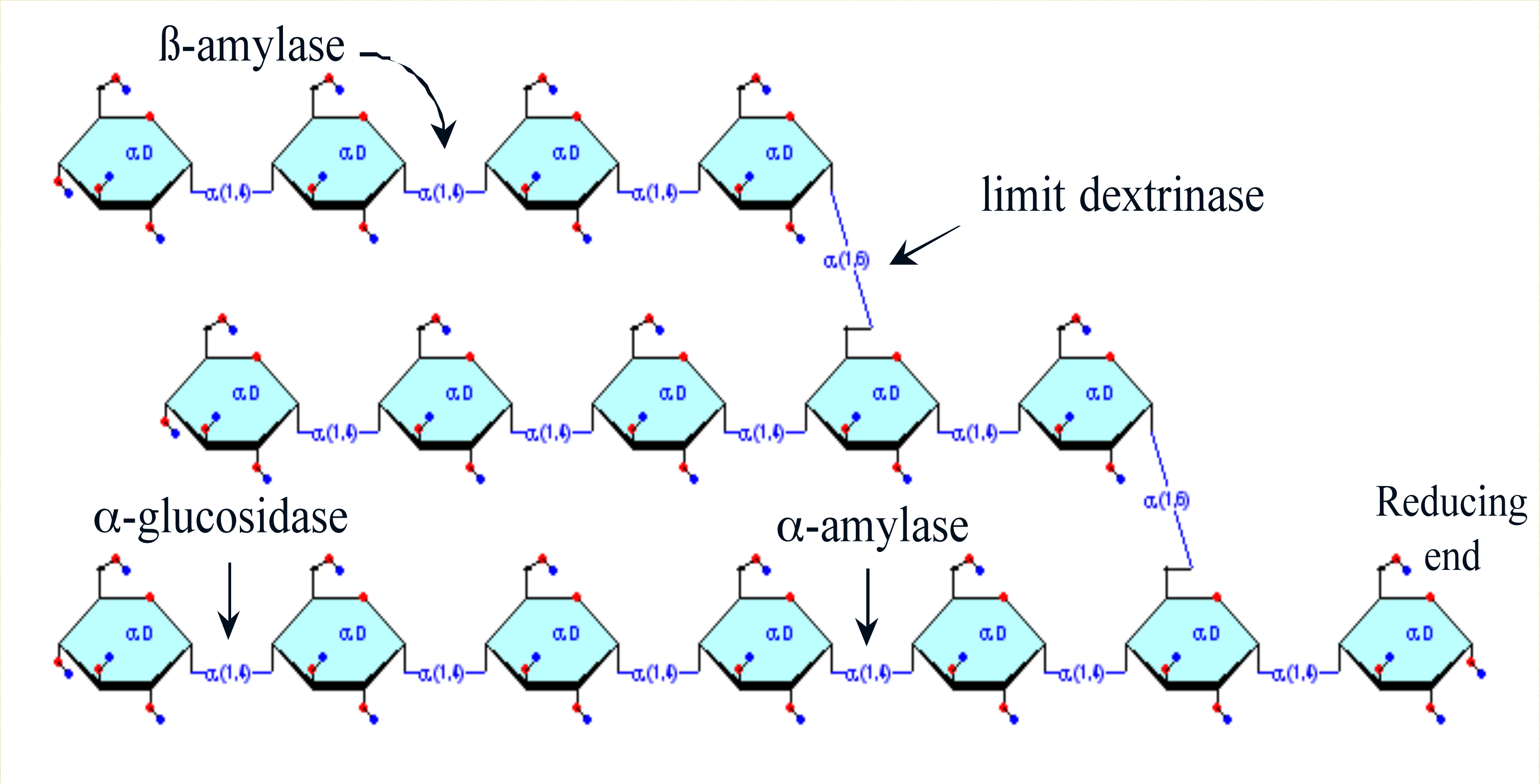
Adjunct Mashing

- Only Barley and Wheat have low gelatinization temperatures, every other grain needs to be cooked first.
- This is why we use Flaked Rye, Oats, Corn, and Rice.
    - The flakes are steam cooked, then flattened between rollers for higher surface area and better conversion.

Starch is degraded by the four diastase enzymes



200 years Ago…

- Breweries had their own malting house as part of the brewery.
- Barley had less diastatic power and took longer to malt, typically 5 days.
- Protein rests and decoction mashing were invented to finish the malting process.
- Boiling released more starch = higher yield.
- Modification as Soluble to Total protein index = ~35%

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Today

- Malts are highly modified: S/T = 40-45%
- Malts have more diastatic power: 2X?
- A protein rest is not needed for further modification.
- Decoction will still produce tasty Maillard Reaction products without using a protein rest.
- Conversion will happen in 15-30 minutes.
- The yield is a function of Crush and Lautering.

Composition of fermentable extract

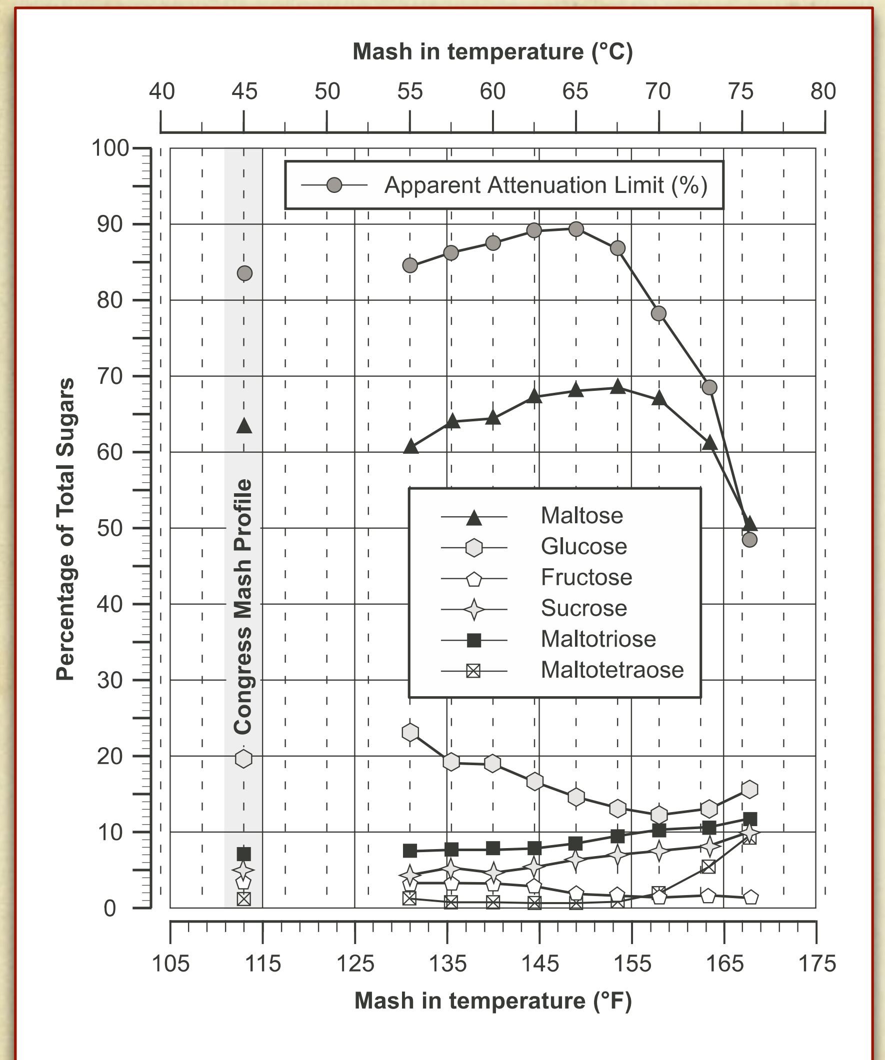
(Mash-149°F), (wort gravity 1.024-1.036 °P)

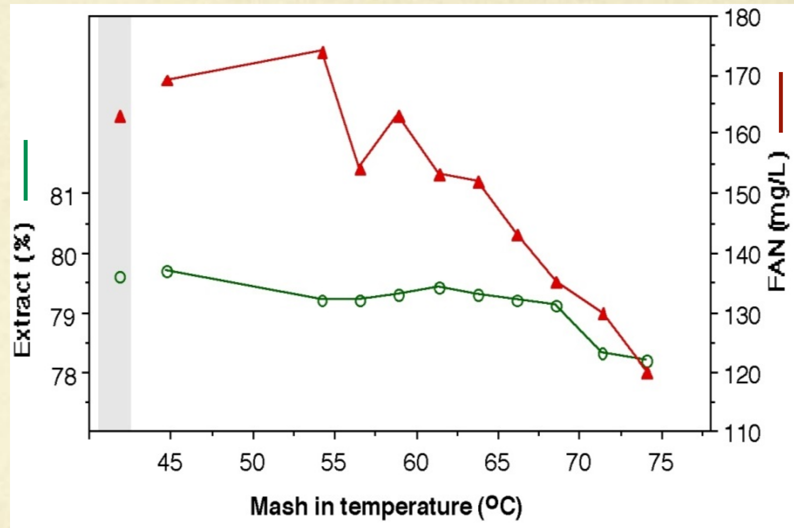
(Evans et al., 2005, J Am Soc Brew Chem 63: 185-198).

Sugars	Mean level (mmole/L)	Fermentable extract (%)	
		mean	range
Glucose	**34**	**16.9**	**12.5-22.9**
Fructose	4	1.9	1.4-3.1
Sucrose	11	5.3	1.5-6.6
Maltose	**138**	**67.6**	**61.0-70.5**
Maltotriose*	16	7.9	5.1-9.5
Maltotetrose**	1	0.5	0.0-2.0
Total	204	100.1	

*** Partially fermentable depending on yeast strain, ** poorly fermentable sugar**

The influence of mash temperature on AAL, FAN and sugar





Flavor implications

- Acetate esters increase as wort maltose level decreases

See: Evans, E, Collins, H, Eglinton, J, & Wilhelmson A (2005). *J. Am. Soc. Brew. Chem., 63: 185-198.*

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Soluble/Total Nitrogen Ratio

- Also known as the Kolbach Index.
- The ratio indicates the degree that the endosperm (carbohydrate/protein matrix) has been enzymatically unlocked (***modified***).
- To generalize*: an S/T ratio of
  - 30–36 is less-modified (Decoction)**
  - 36-42 is well-modified (Single, Multi-Infusion)
  - 42–48 is highly-modified (Single Infusion)

**Opinions vary*

***Protein Rest-able*

Temperature Rests

- Acid Rest
  - Not necessary for lowering pH
- Beta Glucan Rest
  - Lowers mash viscosity when using unmalted grains
- Protein Rest
  - Improves yield with less modified malts.
  - Increases FAN when using >25% adjuncts.
- Beta Amylase Rest makes maltose
- Alpha Amylase Rest makes all kinds of sugars

Acid Rest

- 95-113°F, (35-45°C)
- Happens during malting. Phytase denatured during kilning (~99%).
- Phytase breaks down malt phytin, releasing phosphates.
- Temperature also used for doughing-in.
    - **Promotes oxidation of fatty acids via lipoxygenase.**
    - **Promotes growth of lactic acid bacteria.**
    - **I don’t recommend this temperature rest.**

Don’t Do It!

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Beta Glucanase Rest

- **<u>For Use With 20+% of Unmalted Grains</u>**
  - <u>Flaked barley, oats, wheat, and rye.</u>
- Beta Glucan gums add body and raise viscosity, causing difficulty in lautering.
- Gums are 4-6% by weight in unmalted grain, 0.5% in malted grain.
- Beta glucanase 104-118°F (40-48°C) for 15-20 minutes.
- Breaks down hemi-cellulose and other non-starch polysaccharides (gums).

Protein Rest

- **<u>For Use for Less-Modified Malts and Grains</u>**
  - <u>S/T less than 40%.</u>
- 113-131°F, (45-55°C) <u>15 minutes maximum</u>
- These enzymes have survived from malting.
- Proteases solubilize Hordeins (barley storage proteins) and promote foam and haze.
- Peptidases break small proteins into smaller proteins and amino acids (FAN).
  - You can have too much FAN! Promotes diacetyl…
  - A protein rest REDUCES body from modern malts.

Temperature Overlap!

- Beta Glucan Rest: 104-118°F (40-48°C)
- Ferulic Acid Rest: 113-131°F, (45-55°C)
  - Actually takes 30-60 minutes just to get 1 ppm…
- Protein Rest: 113-131°F, (45-55°C)
- IF you do one, you are probably doing them all!
- Be Aware! Watch the clock!

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Beta Amylase

- Prefers 136-145°F, (58-63°C)
- Low thermo-stability: Denatured to 25% activity after 30 minutes at 149°F, (65°C).
- Remember! Barley Starch not fully gelatinized until 149°F, (65°C)!
- Denatured by low pH, less than 5.2, especially if less than 5.0.
- Can only make maltose from the end of the chain.

Limit Dextrinase

- Prefer 140-149°F, (60-65°C), but active to 153°F, (67°C).
- Better thermostability than Beta Amylase.
- Maintained 60% of activity after 30 minutes at 149°F, (65°C).
- Can cut the branch points, reducing limit dextrins to fermentable sugars.
- Converts Amylopectins to Amylose.

Alpha Amylase

- Prefers 158-165°F, (70-74°C), but active 140-167°F, (60-75°C).
- Also active at lower temperature, 104°F (40°C)
- Can work alone, but works best with beta amylase and limit dextrinase.
- Can cut the starch chain anywhere except next to the branch point.

The Mash Tun

- We conduct the mash in a large vessel.
- The mash tun can be a kettle or a cooler.
- Mashing in a kettle allows us to apply heat to adjust the mash temperature.
- Mashing in an insulated cooler means “set and forget”, but can be adjusted by infusions or decoctions.

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Single Infusion Mash

Schedule Description	Temperature	Time (minutes)	Comments
Highest Fermentability	149°F (65°C)	30–60	Highest fermentability but least body.
Best Yield	152.5°F (67°C)	30–45	Best yield, good fermentability, and good body.
More Dextrinous	158°F (70°C)	30	More body, less fermentable.

Actual Example
OG 1.050

- Malts
  - 5 lbs. of 2 row base malt
  - 4 lbs. of Vienna malt
  - 1/2 lb. of Crystal 80L malt
  - 1 oz. of debittered black malt

Hops	Boil Time	IBUs
1 oz. of Liberty (4%)	40	13
1 oz. of Liberty (4%)	20	9
1 oz. of Liberty (4%)	10	5
Total IBUs		27

- Yeast California Lager
- Fermentation Schedule: 3 weeks at 62F, no racking.

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Low Temperature Mash

- Mashed in and held at 150°F for 1 hour.
- **Slow Conversion**
- OG 1.050
- FG 1.010
- Apparent Attenuation = 80%

High Temperature Mash

- Mashed in and held at 158°F for 1 hour.
- **Faster conversion**
- OG 1.052
- FG 1.014
- Apparent Attenuation = 73%

Multiple Rest

Schedule Description	Temperatures	Time (minutes)	Comments
Traditional Maximum Fermentability	140°F (60°C) 158°F (70°C)	15–30 15–30	The beta amylase rest temperature is at the lowest end of the range.
Maximum Fermentability/ Highest Yield	145°F (63°C) 158°F (70°C)	15–30 15–30	will convert highly modified malts more quickly.
Protein Rest plus Beta and Alpha Rests	122°F (50°C) 145°F (63°C) 158°F (70°C)	15–20 15–30 15–30	Protein rests are used for high percentage of unmalted adjuncts.

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Multiple Con't

Schedule Description	Temperatures	Time (minutes)	Comments
Beta Glucan Rest or Ferulic Acid Rest plus Protein Rest	104°F (40°C) 122°F (50°C) 145°F (63°C) 158°F (70°C)	10–20 10–20 15–30 15–30	This schedule is similar to the previous but includes the 104°F/40°C rest, for beta glucans or to create more ferulic acid in a wheat mash to enhance the clove character of Bavarian wheat beers.

Understanding Decoction

- Why did they boil the grain??
- Invented when Malting was weird science.
  - Barley was hard to malt, and variable.
  - Barley had half the diastatic power it does today.
  - Both malting and mashing took longer and had less yield.
- Invented before thermometers!
- Invented before most specialty malts existed!
- Invented before stainless steel kettles!
  - Copper was scarce and expensive.
  - Kettles were not built very big due to metal availability and joining technology.

Understanding Decoction cont.

- Decoction solved these issues by:
- Could mash in a wooden tub and boil in the kettle.
- Boiling fully solubilized the starches for better conversion by the available enzymes.
- Temperature: Starting at bath water temperature and then triple decocting (third, third, third). It worked.
  - Each temperature rest would be discovered to match different enzyme groups: Protease, Beta Amylase, Alpha Amylase.
- Specialty malts largely didn't exist

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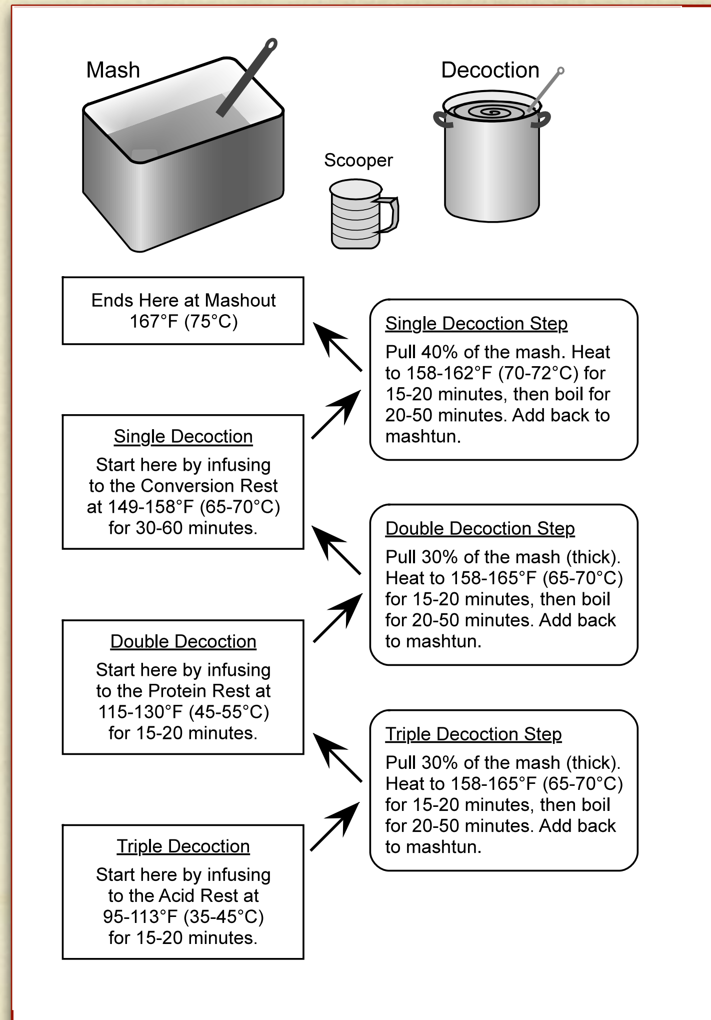
Decoction Mashing

Note: Holding the decoction at the conversion rest is a modern addition. Not really needed.



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In my opinion

- Decoction and step mashing were invented to solve brewing problems we don't have today.
- Today's malts are not designed for yesterday's processes, and therefore should not be used from an engineer's point of view.
  The wort will be over-mashed.
- We can produce the same results by single infusion mashing with specialty malts.
- Nearly every professional craft brewer utilizes single temperature infusion mashing to create today's award-winning beers.

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Yield

- How much sugar do you get from your mash?
- **Total Soluble Extract, Fine-grind, Dry-basis, is about 80% by weight for a base malt.**
  - Table Sugar (sucrose) is a disaccharide like maltose, and yields 100% of itself as soluble extract, AND gives an OG of **1.046** per pound when dissolved in water to create 1 gallon of sugar solution.
- Therefore, base malt at 80% soluble extract, yields a gravity of 80% of 1.046, => **1.037**
- <u>You</u> will typically get 75% of that maximum 80%, i.e., 75% x **37 ppg** = 28 ppg

Points Per Pound Per Gallon

- This is algebra.
- Wort collected is Volume x Gravity (points)
- Yield is Points per Pound per Gallon
  - Points/Pound/Gallon = Points×Gallons/Pound
- Efficiency (%) is your Yield divided by the laboratory maximum yield. (37 ppg)
- (You)/37 = % Efficiency

Your Efficiency

- Your Brewing Efficiency is the total amount of soluble extract that you collect **<u>in your boil kettle</u>,** compared to the 80% FGDB.
- For example: you mash and lauter 12 lbs of grain to collect 7 gallons of 1.045 wort in your boil kettle.
  - 7 x 45 = 315 (gallon points)
  - 315 ÷ 12 = 26.25 (gallon points per pound or ppg)
  - 26.25/37 = 71% Efficiency
  - If you collected 7.5 gallons, => 28 ppg, or 76%
  - If you collected 7.75 gallons => 29 ppb or 78.5%

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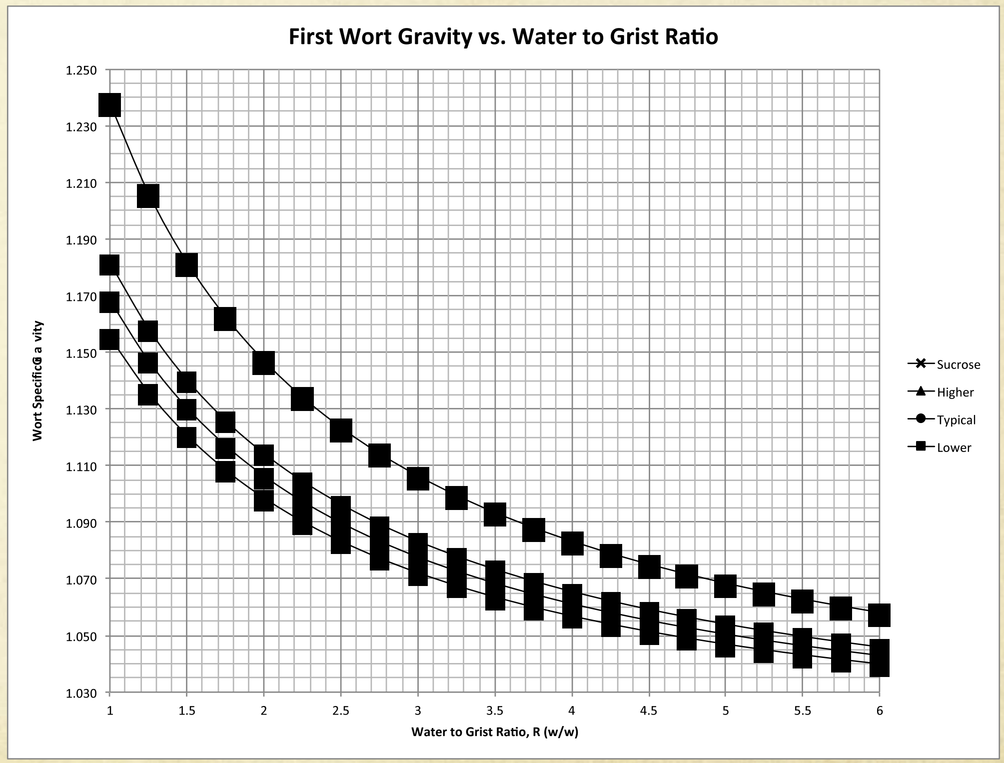
First Wort Gravity and R

- SG1 = 260/(260–(100***X***/(R+***X***)))
- ***X*** is the % of soluble extract yield, (i.e., 75%)
- where R = Rv • ρ
- ρ = 0.985 kg/L

Grist Ratio Qts/lb, (L/kg)	Typical First Wort Gravity	Typical Net Wort Vol. * Qts/lb, (L/kg)
0.75, (1.5)	1.147	0.25, (0.5)
1, (2)	1.117	0.5, (1)
1.25, (2.5)	1.097	0.75, (1.5)
1.5, (3)	1.083	1, (2)
1.75, (3.5)	1.073	1.25, (2.5)
2, (4)	1.065	1.5, (3)



*1/2 Qts./lbs. retained wort.

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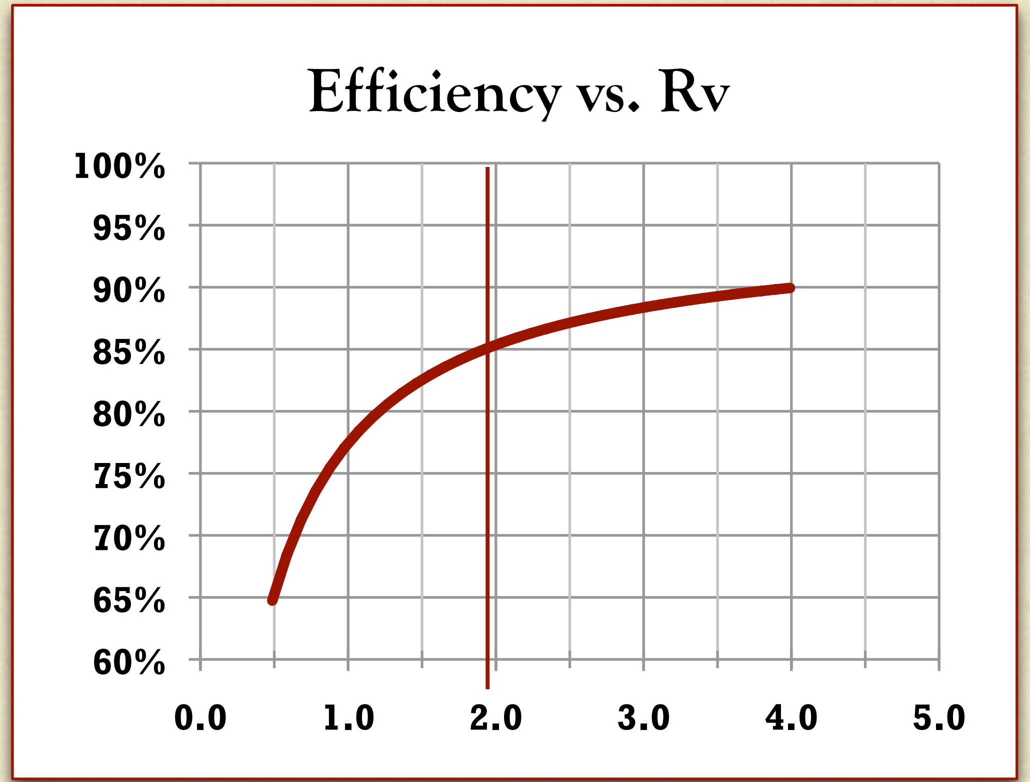
Infusion Mash Rv



Efficiency is asymptotic at 92% at 16 Qts./lbs.

Best bang for the buck at about 2 qts./lbs…

Brewing Strong Beer

- You can mash with wort to increase the gravity for strong beers.
- The first runnings is a function of water to grist ratio.
- Mashing with the previous wort adds these gravities together.
- Example (assuming 1 L/kg retained wort):
  - At 2 Qts./lbs., the wort gravity is 1.060 and the wort yield is about 3 L/kg. Therefore, for 2 x 10 kg of malt, the first mash yields 30 L of 1.060.
  - The second mash of 30 L for 10 kg (3:1) would yield 20 L of (1.078 + 1.060) <u>1.138</u> !

Break

Let's make Wort!

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of Vessels, Trade-offs

- More vessels = More options + more cleaning
- 3 Vessels = Most options and most cleaning.
  - Best control of process, highest lautering efficiency.
  - Efficiency = money.
- 2 Vessels (No hot liquor tank)
  - Good Control
  - Less sparging = less efficiency (better wort)
  - Small footprint
- 1 Vessel (All-in-one systems)
  - Good Control, but No or Low Sparge (better wort)
  - Small footprint
  - Easy clean-up

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Brew In A Bag

- Essentially a no-sparge method, without recirculation or clarification.
  - Higher water to grist ratio = thinner enzymes, more sensitive to water chemistry issues.
  - BIAB does not rely on lautering; you drain the wort from the bag.
  - BIAB has lower wort retention due to bag pressure, yielding more wort, better efficiency.
  - You can crush finer, but for small gains.
- Simplest option, Tastes great, Less Work.

Lautering and Sparging

- Lauter means to clean, to purify.
  - Vorlauf is the recirculation of the wort thru the grainbed to clarify it.
  - Once clarified, it can be drained to the kettle.
  - Rinse (sparge) the grainbed for more wort.
- Your Brewing Efficiency mostly depends on:
  - Quality of the rinse.
  - Quantity of the rinse.

Lautering Process

- Läuter means to clean, clarify, and purify.
- Lautering is the process of separating and clarifying the wort from the mash to the kettle.
  - Vorlauf (vorläufig) means "preliminary," as in, preliminary clarification.
- Sparging means to sprinkle, and basically we are rinsing the grainbed of residual sugar.
- HOW we do that can make a big difference in efficiency and yield.

Lautering Efficiency

- The majority of yield problems are caused by poor lautering; not the crush, not the mash.
- The extract is there in the mash. YOU need to separate it!
- A false bottom is the most effective way to drain extract from the entire mash.
- However, this assumes uniformity of flow.
- Compaction can cause preferential flow.

Rinsing vs. Draining

- Traditional lautering calls for the grainbed to be sparged (rinsed) of the retained wort.
- Two Ways to Sparge:
  - Continuous: Water IN= Wort OUT
    - Works best with uniform flow thru false bottom
  - Batch: First Wort is Drained, water is added as a batch, stirred, vorlaufed, and drained again.
    - Works best with large coolers and manifolds.
- Draining doesn't need uniform flow as long as ALL of the wort is drained.

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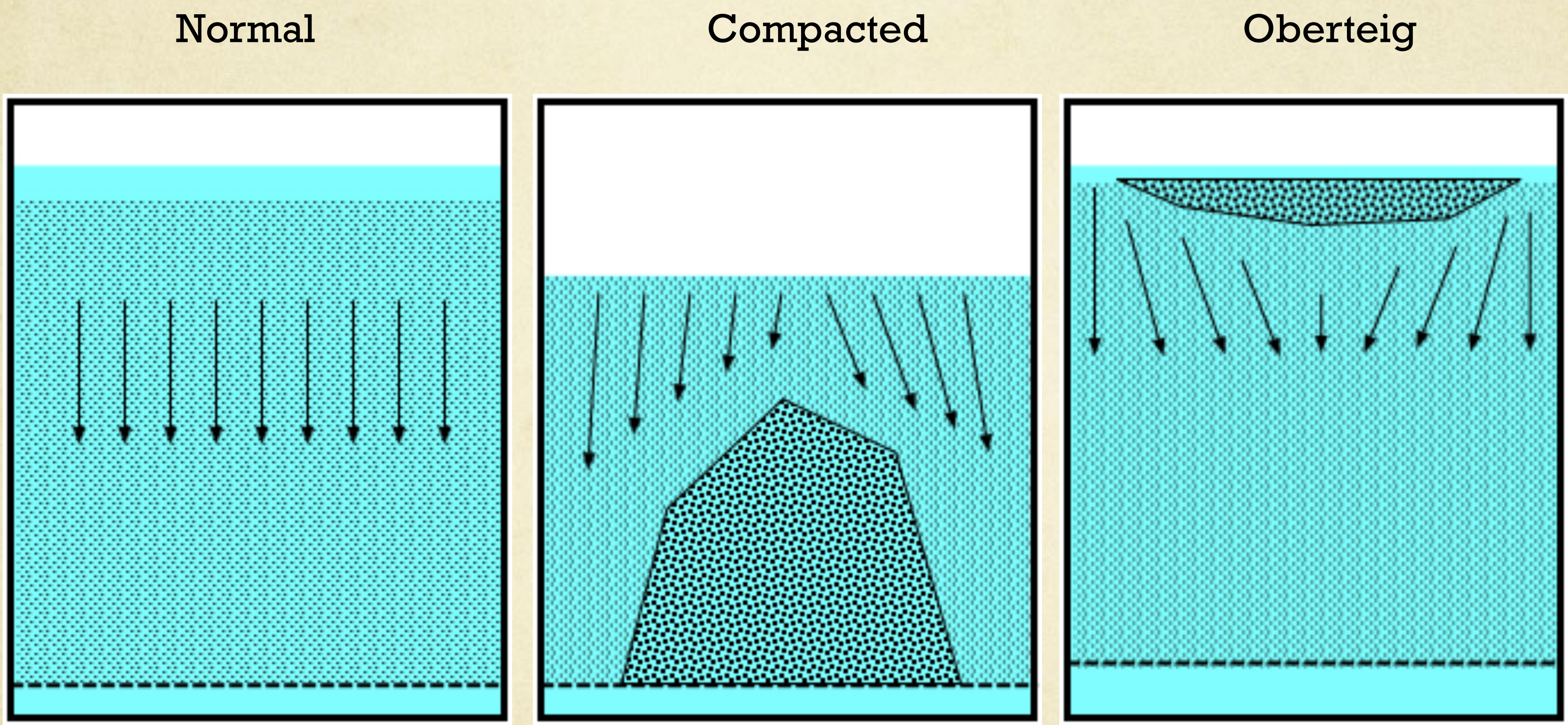
Compaction of Grainbed



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Lauter Flow to 2 Pipes

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Why Recirculation?

- Equalizes the mash temperature!
  - No hot or cold spots.
- Homogenizes the wort.
  - No high or low extract zones.
- Clarifies the wort of excess polyphenols, lipids, and gums.
  - Less trub in the kettle.
- Recirculation allows easier step-mashing.

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Sparge Efficiency

To yield 7 gal of 1.043 to boil to 6 gal of 1.050

Note retention factor	Standard r ≅ 1 L/kg	Batch r ≅ 1 L/kg	No-Sparge	BIAB r ≅ 0.5 L/kg
Grist weight	9.5 lbs.	10.3 lbs.	11 lbs.	10 lbs.
Rv (Qts./lbs.)	2	1.9	3.1	3.1
Efficiency	85%	78.4%	73.9%	81.1%
Mash Volume	5.7 gal	5.8 gal	9.4 gal	8.6 gal

My Recommendation

- Single Temperature Infusion Mash
  - Target Temperature: 67°C, 153°F
  - Water to Grist Ratio of ~2 qts/lbs., 4 L/kg
- Minimize Sparging for best quality wort
  - Uses more grain, but small cost for better beer.
  - No-sparge simplifies the process, and produces best wort.
- Recirculation during mashing is good.
  - Homogenizes temperature.
  - Clarifies wort.

One more thing…

- It is important to understand that we have been home brewing for thousands of years, and industrial brewing for a couple hundred.
- Large commercial breweries design equipment and procedures to solve problems that homebrewers don't have!
- Don't try to replicate a process or equipment that the big breweries use just because "that's the way they do it."

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Break

Water – The Final Frontier

- Most any water will make a good beer.
  - 1. Remove the chlorine.
  - 2. Achieve the target pH.
  - 3. Season to taste.
- Don't overthink adjusting your brewing water, you might just screw it up.
- The most important thing about water adjustment is getting your mash pH right.

Your Water

- If you have a home water softener, you probably have low hardness and high alkalinity.
- The common solution to hard water scale is to remove the hardness (calcium and magnesium) and replace it with sodium.
- This is the OPPOSITE of good brewing water.
  - Good: Medium to High Hardness, Low Alkalinity
  - Bad: Low Hardness, High Alkalinity
- Don't use softened water. Use the unsoftened and treat it with acid to remove the alkalinity.

Water, in general:

- Hardness is good (Ca, Mg)
- Alkalinity is bad (bicarbonate)
- Mineral Concentrations
  - 0-50 ppm is Low
  - 50-100 ppm is Medium
  - 100-150 ppm is High
  - >150 ppm is a Problem

In General, cont.

<u>Pale Beers</u>

Calcium: Medium

Magnesium: Low

Total Alkalinity: Low

Sulfate: Low, Med., or High

Chloride: Low, Med., or High

Sodium: Low or Med.

<u>Amber Beers</u>

Calcium: Medium

Magnesium: Low

Total Alkalinity: Medium

Sulfate: Low, Med., or High

Chloride: Low, Med., or High

Sodium: Low or Med.

<u>Dark Beers</u>

Calcium: Medium

Magnesium: Low

Total Alkalinity: High

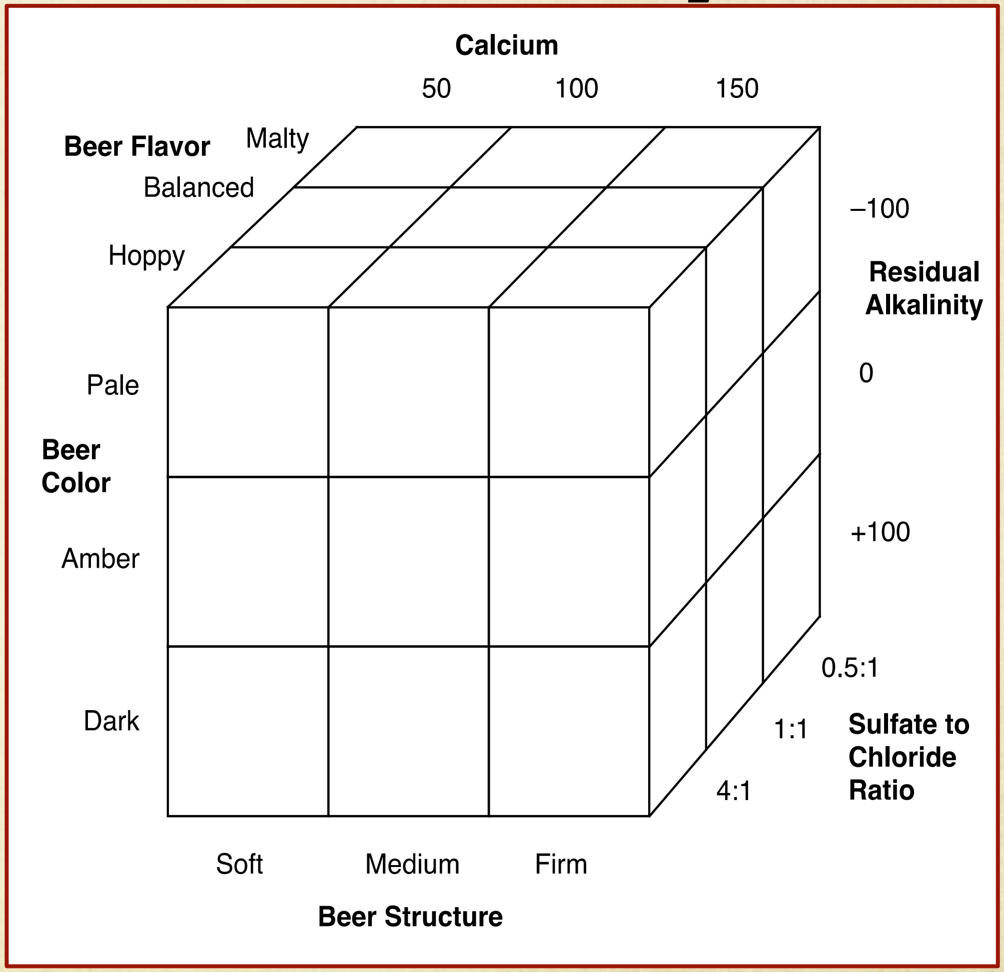
Sulfate: Low, Med., or High

Chloride: Low, Med., or High

Sodium: Low or Med.

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.



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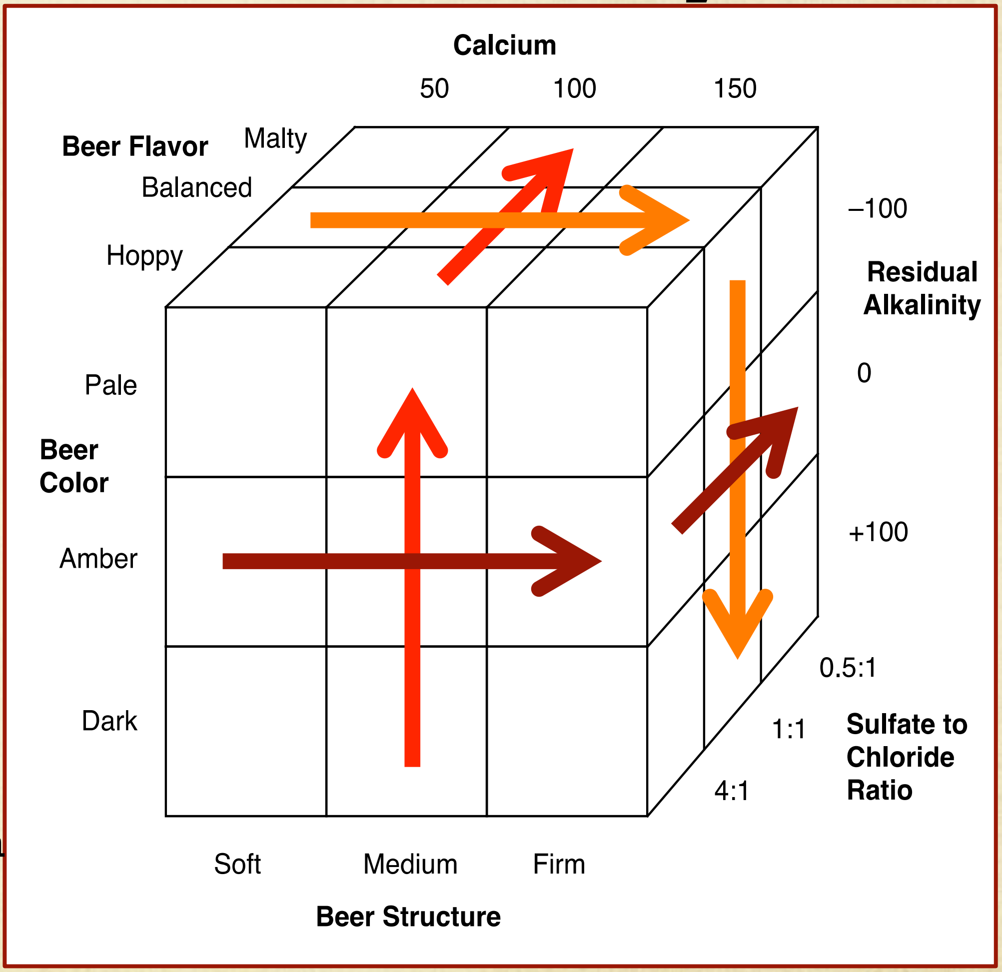
Adjusting Water for Style

- 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 Addtions to RO Water (grams per gallon)

Beer	$CaSO_4$	CaCl	Baking Soda	Ca	Na	SO4	Cl	HCO_3	RA
Pale Hoppy	1	0.5	0	98	0	147	64	0	-70
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 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 Malty	0.5	1	1	103	72	74	127	190	+82

(0.7 $CaSO_4$ and 0.8 CaCl for Balanced.)

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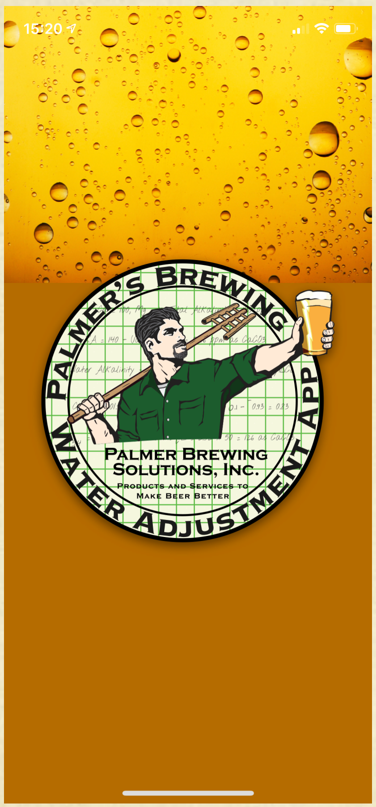
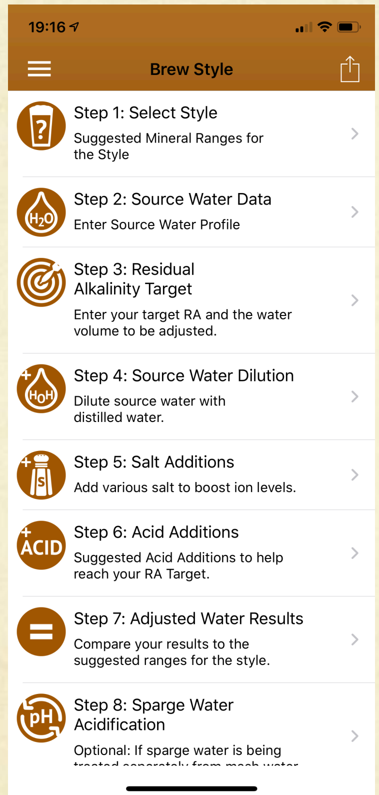
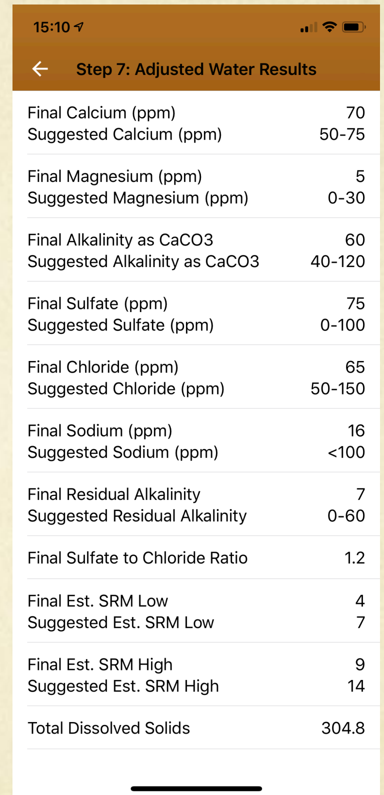
Palmer's Water App







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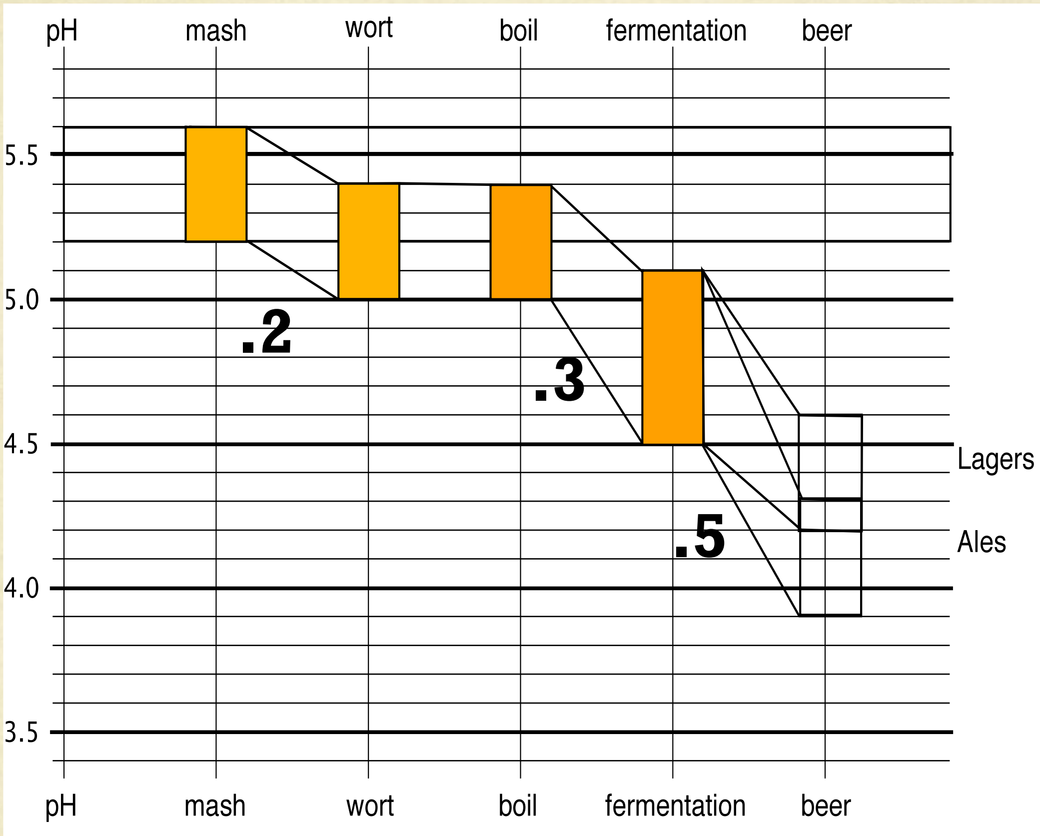
pH (Dun, dunt, Dahhh)

1. Residual Alkalinity is the cornerstone of Mash pH.
2. The Mash pH is the Equilibrium between the Water Chemistry and the Malt Chemistry.
3. The Mash pH sets up the wort pH.
4. The wort pH sets up the beer pH.
5. The beer pH controls how the beer flavors are experienced by your palate.

Mash pH Sets Up Beer pH

5.2-5.6



4.0-4.6

Style/recipe dependent

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Sidebar: What is pH?

- It is the concentration and activity of hydrogen ions in solution.
- A good analogy is Noise, measured as decibels.
  - You can monitor a process or group of children in the next room simply by paying attention to the noise level.
  - If you want to be serious about controlling your beer, you need to measure pH.

Choosing a pH Meter

- A good 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

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.

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Temperature Changes pH

- 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, pale 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)

WHEN & HOW to Measure pH?

- You are looking for a mash pH of 5.2-5.6 @ room temp, for saccharification.
- Measure the pH about 10 minutes into the mash.
- Cool the mash wort sample to room temp on a shallow dish, then measure with a pH meter.
- Note that the mash pH falls throughout the mash.
- If at first you don't succeed, brew again. (you can try to fix it now, but conversion happens quickly, so…)

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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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The pH Code*

- Mash pH is important
  - 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.
- Wort pH is important
- Beer pH is important
- Water pH is NOT!

* Really more like guidelines…

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Brewing Water Summary

1. Get the mash pH right: 5.2-5.6
    a. Beginning of the mash (5-15 minutes).
    b. Sample cooled to (near) room temperature.
    c. Test Strips are not reliable.

2. Adjust the brewing water salts to accentuate the flavors of the beer style you are making.
    a. Calcium Sulfate for more assertive hop character.
    b. Calcium Chloride for fuller malt flavor.

3. Most any water will work, this is about being better.

Questions?

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