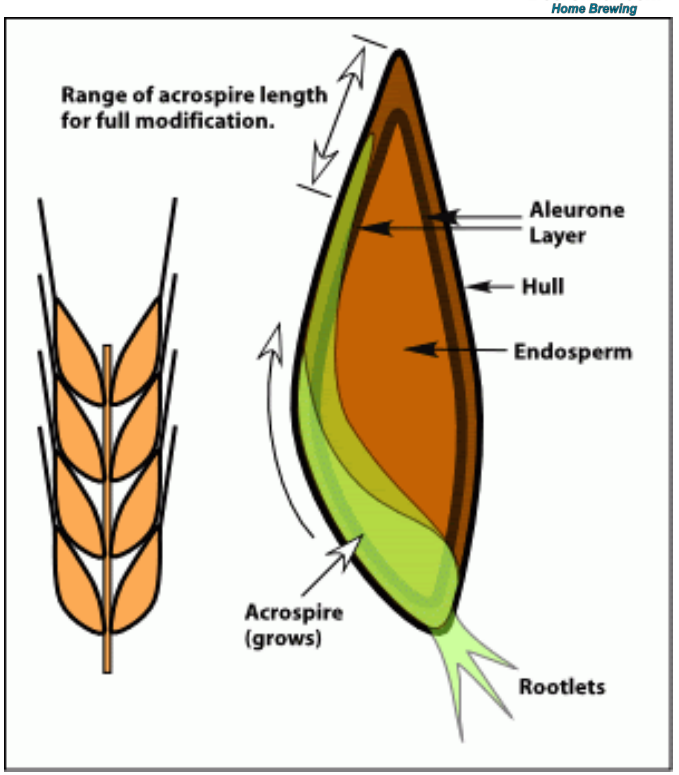
Advanced Ingredients

Brad Smith, PhD

Malted Barley

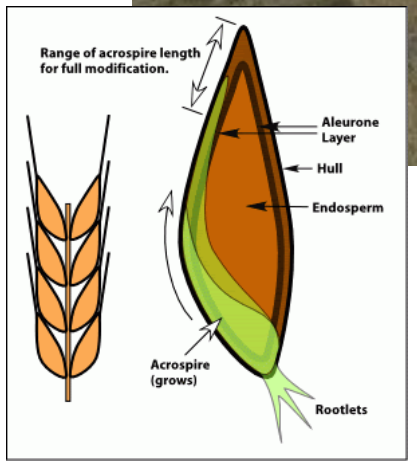
- Core ingredient in Beer
  - Raw barley that has been “malted”
  - Barley seed has germinated and then halted by drying with hot air
  - Darker malts are roasted



Source: How to Brew, Palmer

Malting process

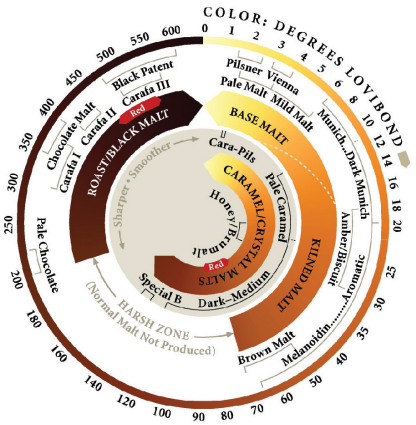
- Steps in Malting
  - **Steeping** – increase moisture from 12% to 40% with wet stand and dry rest.
  - **Germination** – Seed begins to grow, developing malt enzymes used in mash. Rootlets also develop. Monitor Acrospire length to determine endpoint.
  - **Kilning** – Reduces grain moisture back to around 5%, breaks down SMM into DMS. Can also heat or roast to produce darker malts.
  - **Deculming and cleaning** – Removes rootlets of malt, cleans malt and package for sale

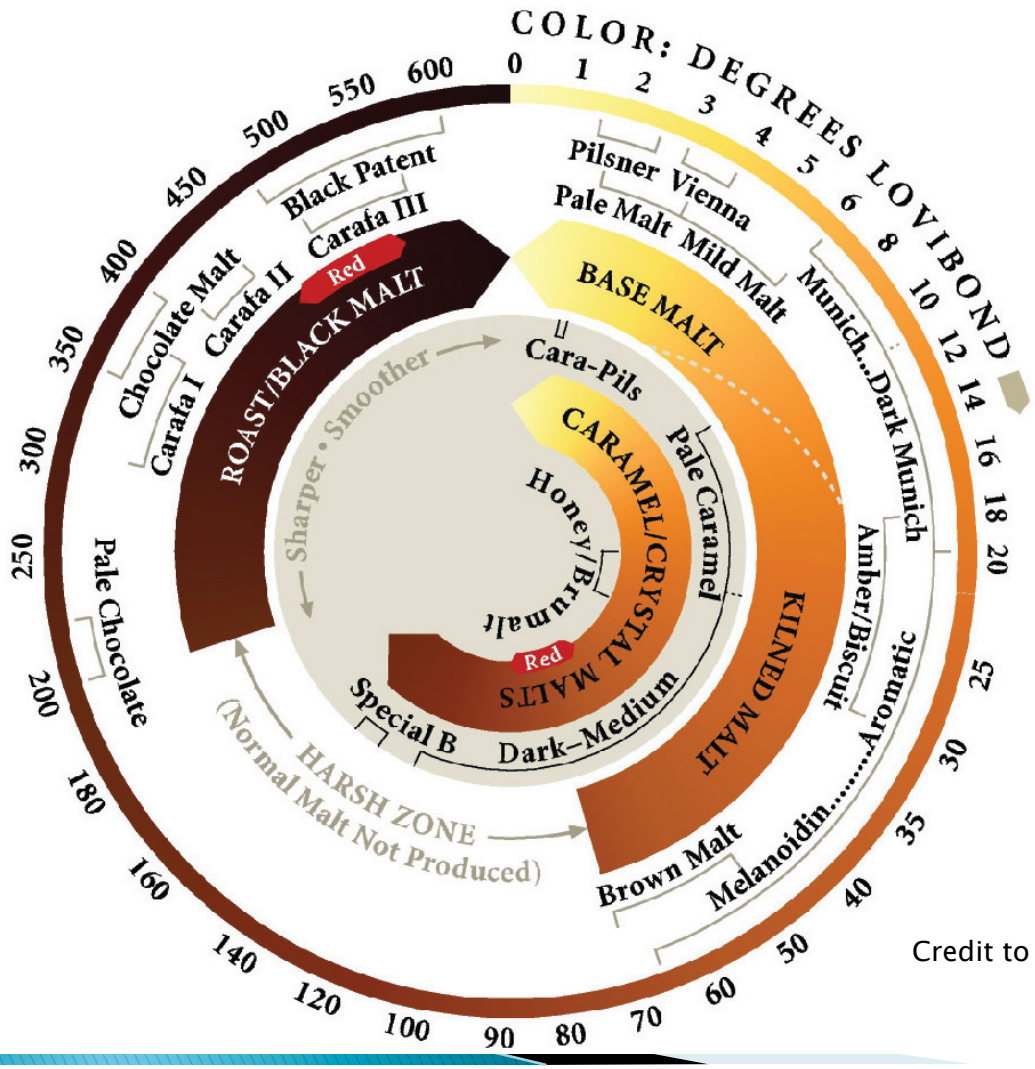


Floor malting – Wikipedia

Malt Types

- Base Malts (Pilsner, Pale, Vienna, Munich, Mild)
  - Traditional malting process. Temperature is varied to produce light/medium base malts.
- Kilned/Color Malts (Amber, Aromatic, Brown)
  - Base malts that are kilned to darker colors, creates malty flavors through Maillard reactions. Reduces enzymes, develops "malty" profile. Generally must be mashed.
- Roast Malts (Chocolate, Black Patent, Carafa)
  - Base malts roasted at high temperature. Typically no enzymes left. Astringent, coffee like flavors.
- Caramel/Crystal Malts (Cara-pils, Caramel/Crystal, Special-B)
  - Start as "wet" pale malt, but grain is then "stewed" wet at mash temperatures, breaking down starches in the grain. This leaves a "sweet" finish. Grains are then kilned which can caramelize the sugars in darker versions. Effectively these are "mashed" while in the grain, so they can be used in extract beers.





Avoid the "Harsh Zone"

Credit to Randy Mosher, *Mastering Homebrew*

Malt Data Sheet

Briess Pale Ale Malt (Source: Briess Malting)

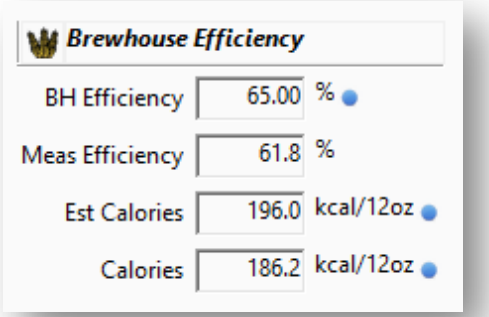
TYPICAL ANALYSIS

Mealy / Half / Glassy	98% / 2% / 0%
Plump	80%
Thru	2%
Moisture	4.0%
Extract FG, Dry Basis	80.0%
Extract CG, Dry Basis	78.5%
Extract FG/CG Difference	1.5%
Protein	11.7%
S/T	42.0
Alpha Amylase	45
Diastatic Power (Lintner)	85
Color	3.5º Lovibond

Sensory Profile – Congress Mash

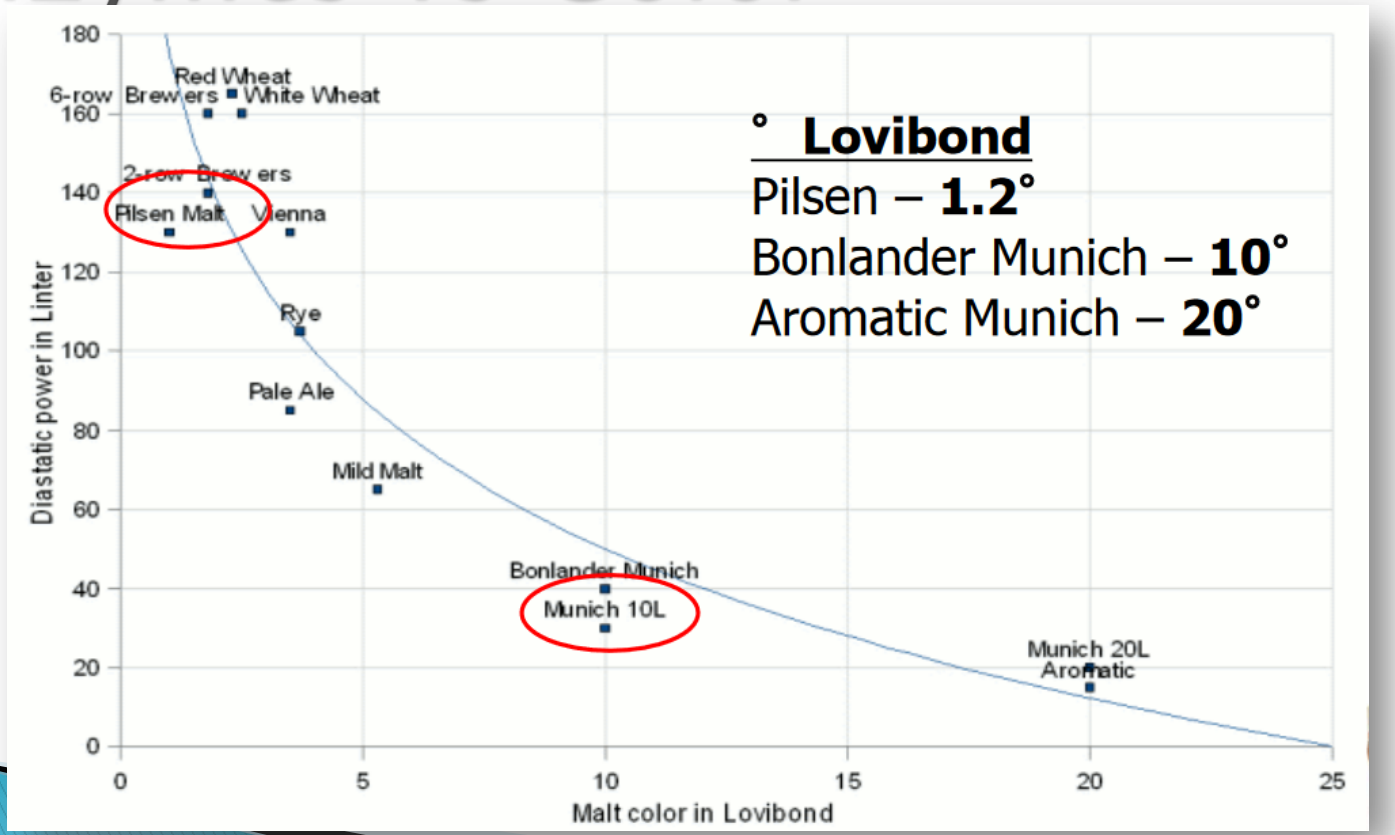
Efficiency and OG

- Your Efficiency drives your OG prediction for a recipe
- Start with Fine Grain Dry Yield (Potential)
  - Yield: 80% = 1.037 potential (Max is 1.046)
- Calculate gravity points:
  - Example: 10 lbs of Pale malt at 1.037 potential
    - For points we drop the 1.0 and multiply by 1000:
    - Points = 10 lbs x 37 points = 370 points
- Apply "brewhouse" or "mash" efficiency:
    - 370 points x 72% brewhouse eff = 266.4 points
- Divide by gallons of mash or final wort:
  - 266.4 / 5 gal = 53 points/gal
- This gives our OG for the wort into fermenter:
  - 53 points is an OG of 1.053
- For more complex cases, we add up points for each grain addition
  - Mash efficiency/pre boil vol will give you mash numbers
  - Software like BeerSmith does this for you…can also calc "actual" efficiency on session tab
- Key Point: Track your OG so you can calculate your efficiency for your next batch!



If your OG is too low, you need to lower your efficiency number

Enzymes vs Color



Source: Breiss Malting

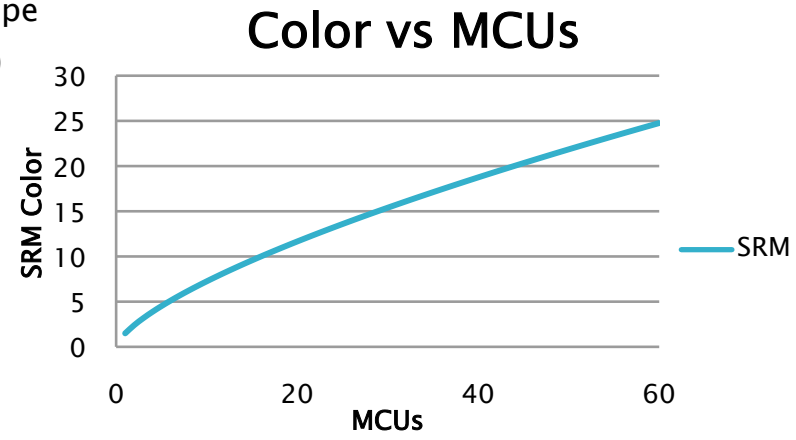
ASBC Grain Sensory Method

- Inspection– taste, color, condition
  - Can inspect, taste, smell dry or crushed grains
- ASBC Hot Steep Sensory Method
  - Weigh 50 grams (1.75 oz) base malt
    - Specialty malts: use 25g base malt, 25g specialty
    - For roasted malts, use 7.5g roast malt with 42.5g specialty malt
  - Mill grains in coffee grinder for ~10 sec
  - Heat 450 ml (1.9 cups) water to 65 C (149 F) and mix and shake for 20 seconds
  - Use filter paper (Alstrom 515) or coffee filter to separate grains
  - Let sample cool to room temperature, and sample within 2 hours
- This gives you the best sensory/flavor impression of a malt!

Color Prediction

- Color is estimated using Dan Morey Equation:
  - Calculate Malt Color Units (MCU) for each grain:
    - MCU = (Weight_grains x Color_Lovibond)/Vol_gals
    - Example: 10 lbs pale malt, 4 Lovibond in 5 gal wort:
      - MCU = 10 x 4/5 = 8 MCUs
      - BeerSmith totals MCUs for all grains in a recipe
  - SRM_Color = 1.4922 * (MCU ^ 0.6859)

For light beers, color of beer
Is close to MCUs (linear) but for
dark beers, SRM << MCUs



Base Malt Flavors

- Pale Ale Malt (2-4 L)
  - Clean, malty aroma with slight hints of toast. Variants like "Maris otter" offer a bit more character.
- Pilsner Malts (1.4-2.2 L)
  - Clean, malty aroma, white bread or cracker qualities
- Mild Ale Malt (3.5-5.5 L)
  - Dry, caramel like aroma, the British version of Munich malt
- Vienna Malt (3-4 L)
  - Clean, caramel character without toastiness

Carmel and Crystal Malts

- Cara-Pils (1.8-2.5L)
  - Neutral flavor – mainly adds body/foam
- Pale Caramel/Crystal (10-30L)
  - Intense caramel aroma, apricots, raisins, figs
- Medium Caramel/Crystal (40-80L)
  - Intense toasted, caramel, burnt sugar, toasted marshmallow, dried fruit (raisin, fig, prune)
- Extra Dark Caramel (100-140L) – Special B
  - Intense roast sugar, toasted raisins, Turkish coffee, bitter (use sparingly)

Caution: All caramel/crystal malts have strong assertive flavors (fruits and harshness) and also dextrins add weight!

Color Malts

- Munich Malt (6-12.5 L)
  - Malty, caramel with a cookie bite, sweet
- Amber Malt (20-30 L)
  - Amber biscuit with a sharp toasty, brown chocolate flavor – but lacks caramel notes
- Melanoiden Malt (15-33 L)
  - Soft cookie/cake maltiness, not toasty, light caramel notes but without fruity/ raisin flavor of caramel malt

Color Malts (cont…)

- Honey Malt (20-30 L)
  - Not really honey like. Some caramel but less heavy, less fruity than crystal malt. Closer to Munich.
- Brown Malt (50-65 L)
  - Deep toasty, mocha and chocolate overtones with some campfire character. Modern versions not smoked. Used in old English Porters.

Roasted Malts

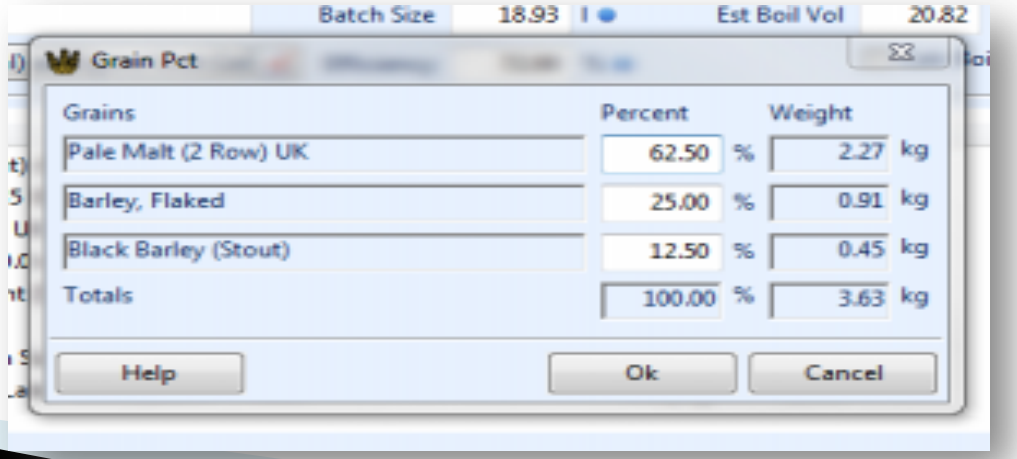
- Chocolate Malt (200-400 L)
  - Sharp, coffee like roastiness, more piercing than black malt.
- Carafa/Rostmalz (300-600 L)
  - Deep, bittersweet-chocolate. Smoother and creamier than black or chocolate malt.
- Black Patent Malt (475-600 L)
  - Deep, bittersweet chocolate with coffee or expresso notes. Smooth/mellow to bitter depending on maltster.
- Stout Roast, Roast Barley (Unmalted Black malt)
  - Drier more acrid flavor – typical of Irish Stout/Guinness

Non-Barley Malts

- Wheat Malt (1.5-2 L)
  - Lacks much flavor of its own but contributes creamy mouthfeel, foam and clean graininess. Can be cloudy.
- Oat Malt (2 L)
  - Little flavor, but adds creamy texture and head retention. Toasted version adds some cookie aroma. Can be cloudy.
- Unmalted Adjuncts (raw, flaked, torrified)
  - Unmalted wheat or barley adds significant body, texture and head retention, but is less fermentable, cloudy
  - Flaked or torrified versions can be single step mashed

Working Grain Bills in Practice

- Select your grains
- Use **Grain Pct** to set the grain percentages
- Use **Adjust OG** to set target gravity
- Enter hops and **Adjust Bitterness**



Hops

- Hop Intro
- Hop Specs
- Hop Bitterness
- Hop Oils and Thiols
- Hop Groups/Flavors
- Hop Forms and Hop Products
- Hop Storage and Usage considerations

Roles for Hops

- Bitterness (Isomerized Alpha acids)
- Preservative (anti-microbial)
- Flavor
- Aroma (aroma oils)
- Foam stability and lacing
- Long term flavor stability

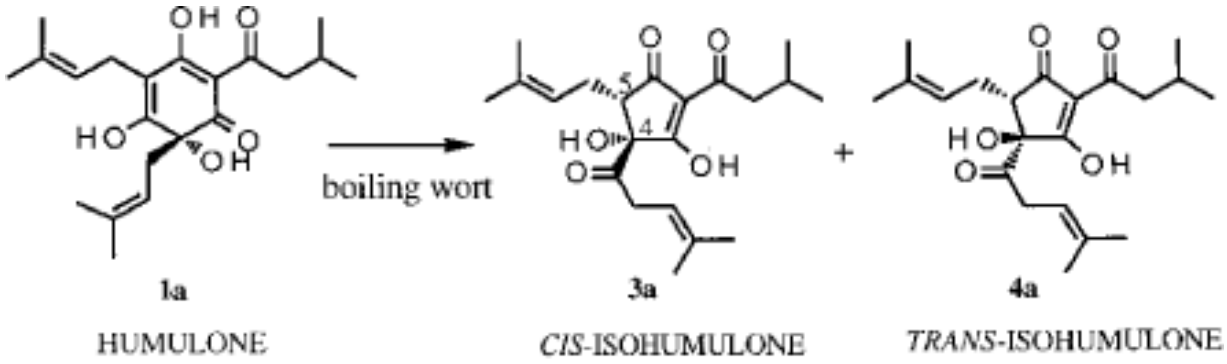
Hop Cone Composition

- Dried Hop Composition
  - 10% Water
  - 40-50% Cellulose
  - 8-10% Ash
  - 2% Pectin
  - 5% Lipids/Waxes
  - 2-5% Polyphenols
  - 0-10% Beta Acid (Lupulones)
  - 0-22% Alpha Acid (Humulones)
  - 0.5-4% Aroma Oils

Over 500 flavor compounds in hops, though brewers focus mainly on the last two items (Alpha acid and Aroma Oils)

Bitterness – Isomerization

- **Isomerization** – a process where a molecule is transformed into another molecule with exactly the same atoms (isomers)



- **Humulones (alpha acids)** are transformed by heat/boiling into cis- and trans-isohumulones. These are very soluble in wort.
- **Isohumulones (Isomerized alpha acids)** – provide bitterness

Bitterness – IBUs

- IBUs – International Bitterness Units
  - 1 IBU = 1 mg/liter (or 1 ppm) of isomerized alpha acid
  - In practice, spectrophotometry is used to measure it
    - Organic solution created, absorbance read at 275 nm
- Estimating IBUs

  IBUs = Weight x Utilization x Alpha_acid / Volume_wort

  - Several formulas for utilization (Tinseth, Rager, Garetz)
  - Utilization increases with boil or whirlpool time, decreases as the wort gravity increases or temperature decreases
  - Utilization also differs with hop form and altitude

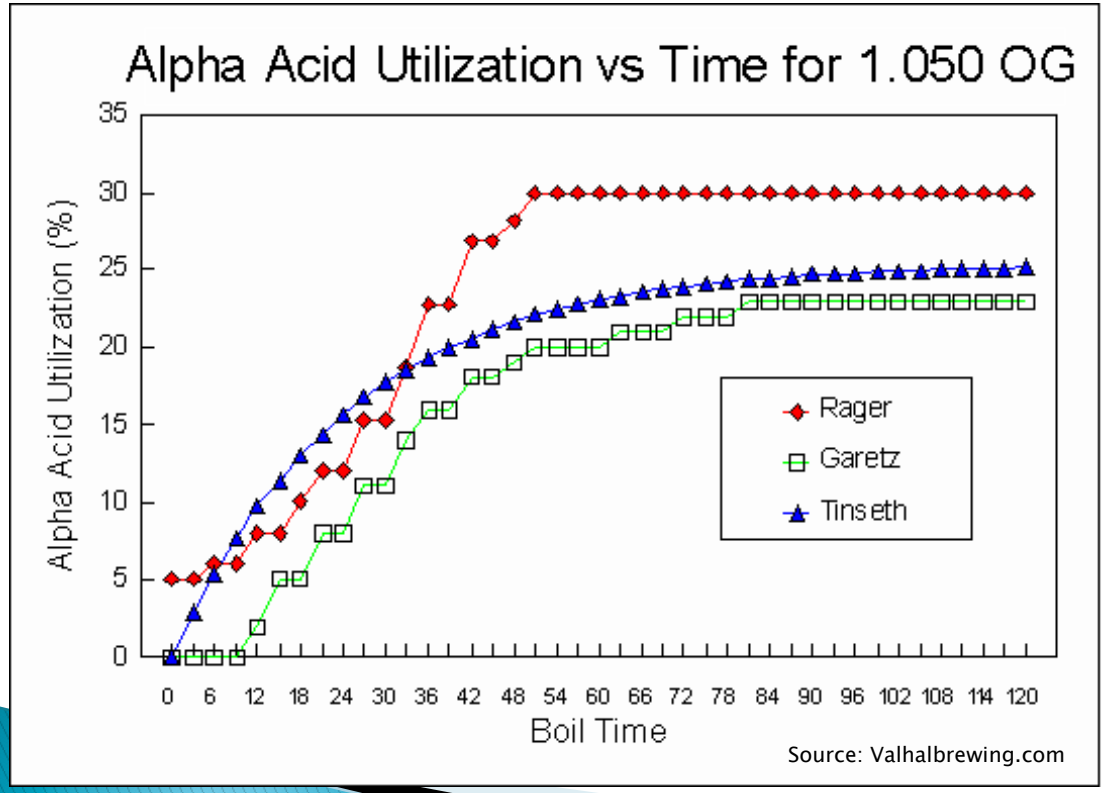
Hop Utilization Estimates

- Glenn Tinseth Equation

Utilization = Hop_grav_adj * Boil_time_factor
Hop_grav_adj = 1.65 * (1.25E-4)^(boil_grav – 1.0)
Boil_time_factor = (1.0– e^(–0.04 * boil_time)) / 4.15)

- Sample: 60 minute boil, 1.041 wort gives a utilization of 25%. 90 minute boil is only 27%
- Rager, Garetz have other utilization charts/tables

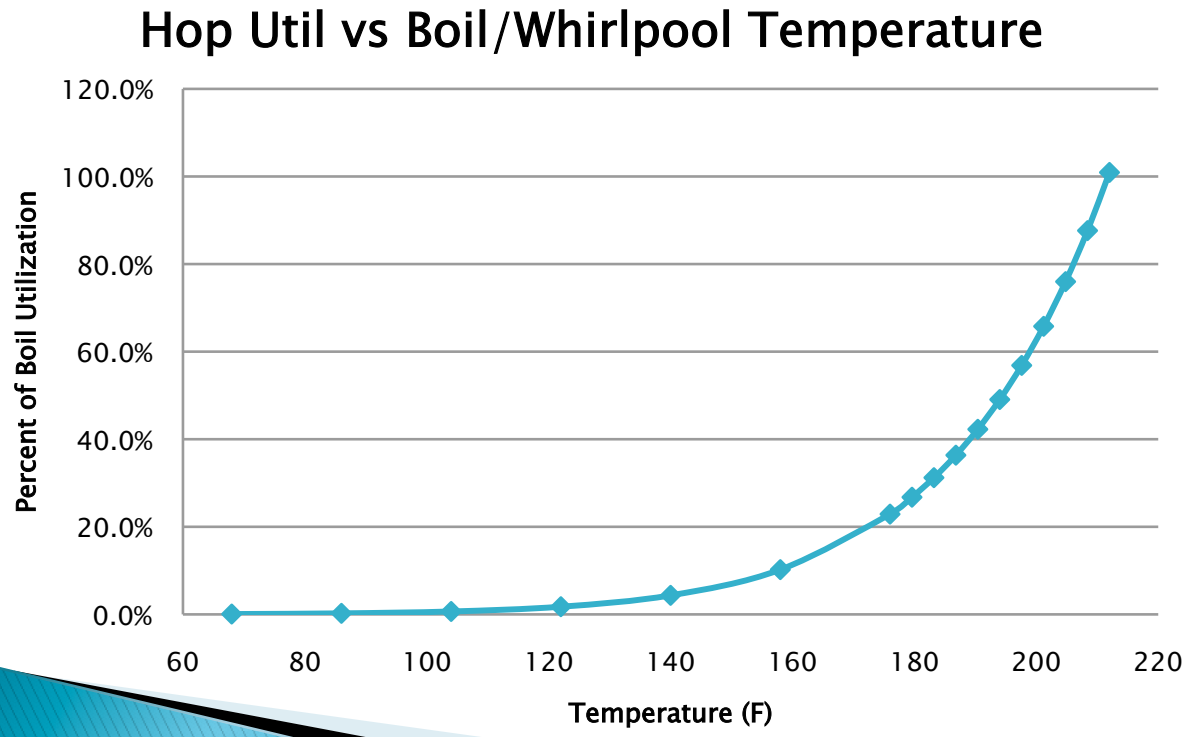
Hop Utilization vs Boil Time



Most all Grain Brewers Use Tinseth (BeerSmith default)

These are ESTIMATES that don't take into account many real world factors

Whirlpool/High Altitude Hops



- Isomerization continues during whirlpool
- Falls off rapidly below about 160F
- This can also be used for high altitude brewing, as the boiling point drops about 3C per 1000 meters
- At 5000 feet, boiling point is 95C which cuts utilization by almost 30% !
- These factors are in BeerSmith equpment/ whirlpool calcs

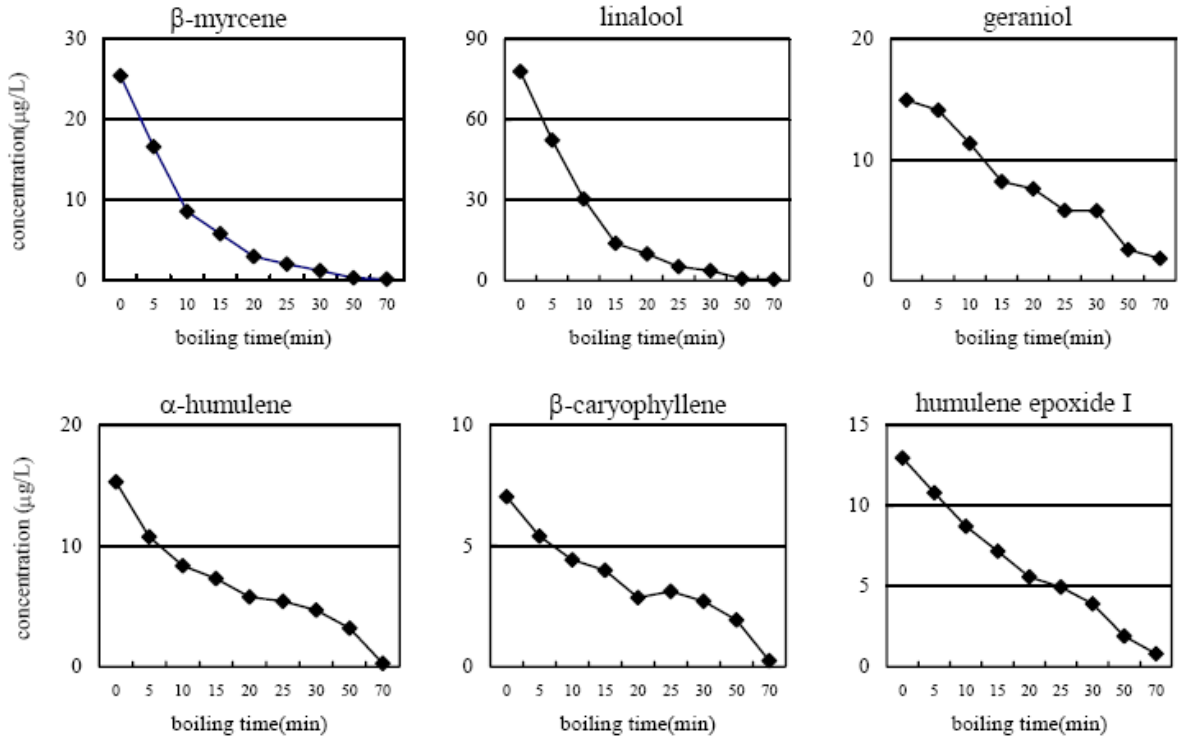
Aroma Compounds

- **Odor compounds, the short list**

Myrcene	**green, resinous, piney**
Caryophyllene	**woody**
Humulene	**woody, piney**
Farnesene	**floral**
Linalool	**floral, orange**
Geraniol	**floral, rose, geranium**
Cis-rose oxide	fruity, herbal
Citronellol	citrusy, fruity
Limonene	citrusy, orange
Nerol	rose, citrusy
Pinene	spicy, piney
3-mercaptohexan-1-ol (3MH)	black currant, muscat
4-mercapto-4-methylpentan-2-one (4MMP)	black currant, tropical

Source: Stan Hieronymus

Aroma Compounds Boil Quickly



Whirlpool or Dry Hop to Preserve Aroma

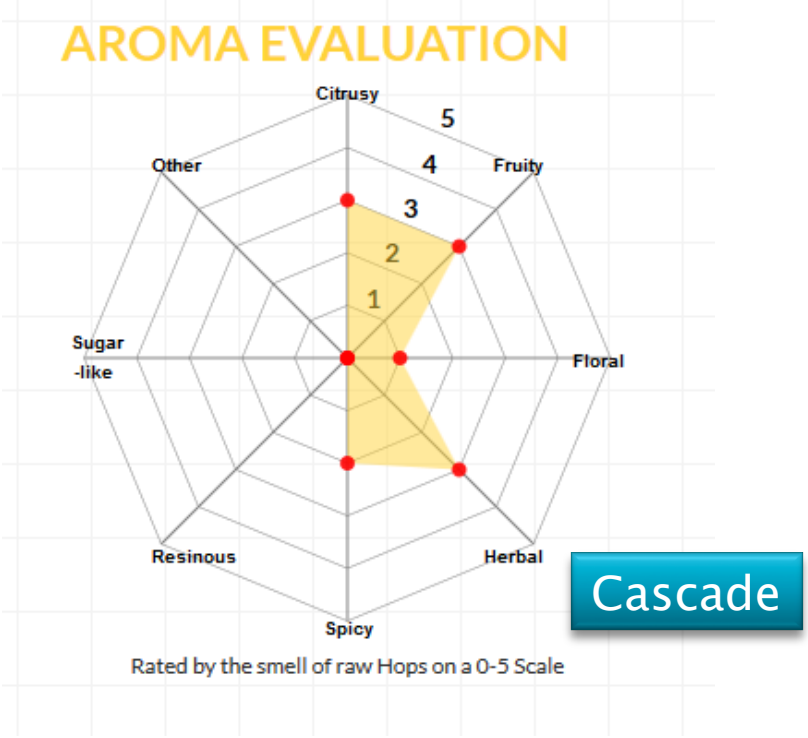
Source: Stan Hieronymus

"Flavor Additions" really are not flavor additions…

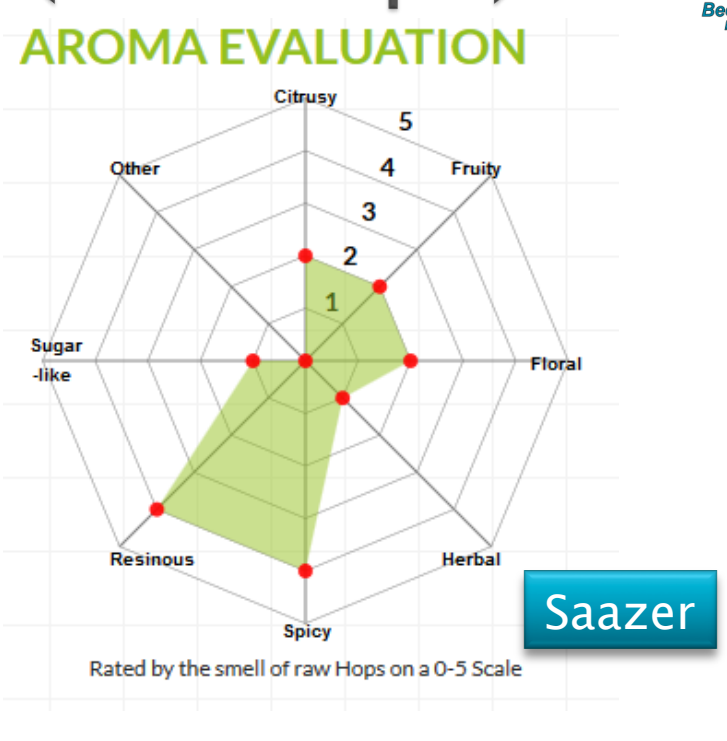
New Hop Products

- Hop Extracts:
  - CO2 Extract (Hop Shot, larger cans)
    - Contains ~65% alpha acids, but must be boiled to isomerize them for bittering – use in the boil
  - Isomerized Extract (Less common)
    - Pre-boiled then concentrated – can be added even at bottling to enhance bitterness
  - Aroma Oil Extracts (Very New)
    - Isolated aroma compounds from hops
    - Available in both "hop variety" or by compound (myrcene, linalool, etc…) – can be added at bottling "to taste"
  - Lupulin Powder (Cryo hops)
    - LupuLN2 is a dry powder extracted from the lipulin gland of the hop in a proprietary process (Yakima)
    - Best used for dry hopping

Aroma Evaluation (raw hops)



Cascade

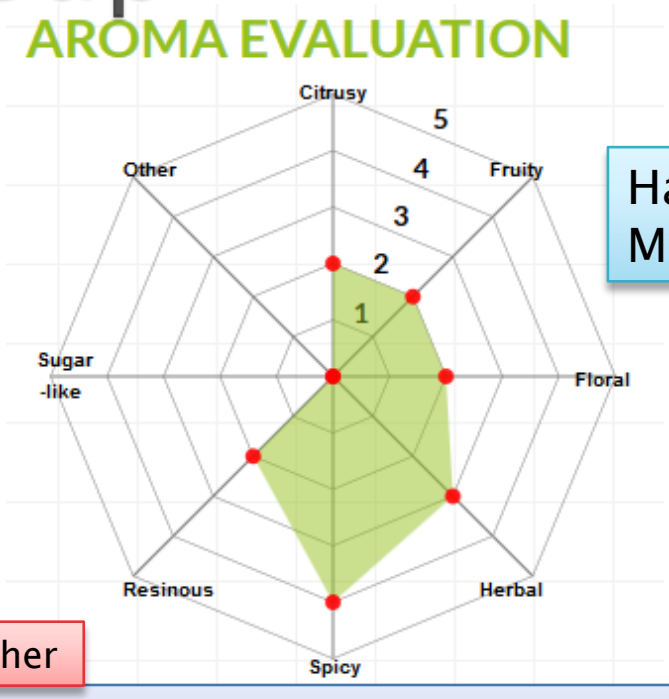


Saazer

http://www.hopsteiner.com/variety-data-sheets/

Noble Hops Group

- Germanic, low alpha hops bred for aroma
- Varies from dry, herbacious to minty and spicy
- Sometimes citrus, fruity, piney notes



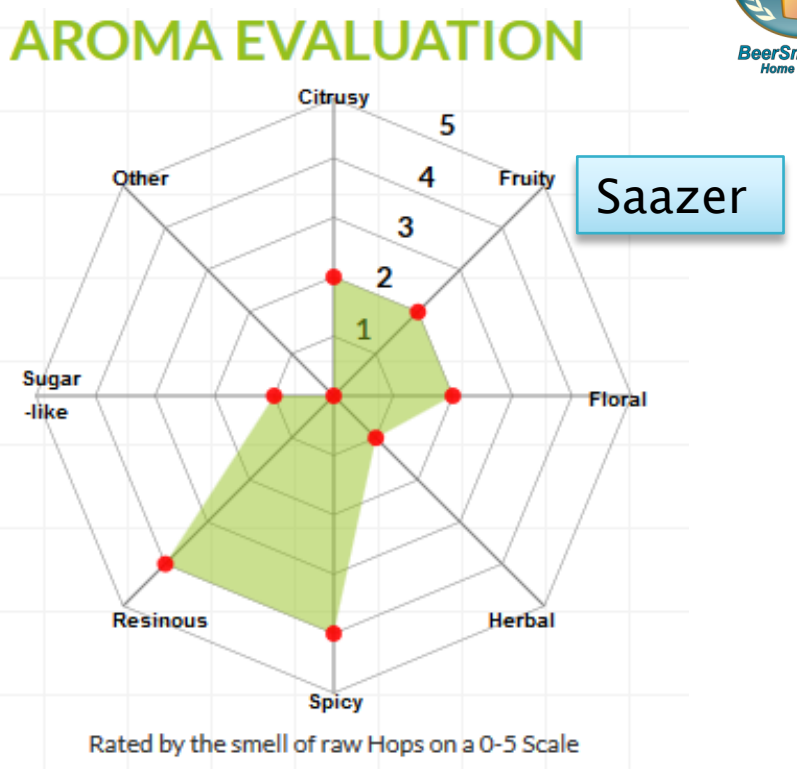
Hallertauer Mittelfruh

Credit: Mastering Homebrew – Randy Mosher

Hallertauer Mittelfruh, Hallertauer, Liberty, Saphir, Smagard, Vanguard, Hersbrucker, Strisselspalt, Perle, Santiam, Mount Hood, Crystal, Spalter, Tettnanger, Mount Ranier, Pacifica

Saaz Group

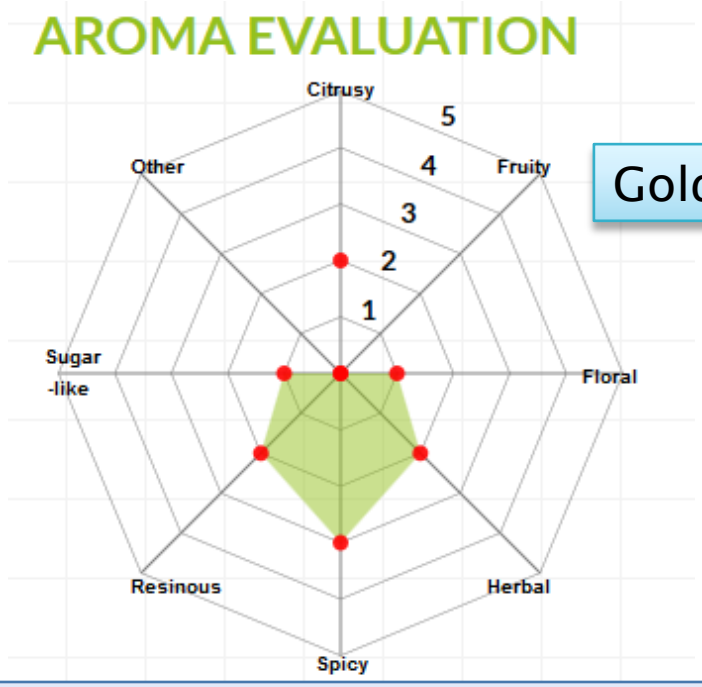
- Also Noble, variants of Saaz
- Spicy, Resinous with hints of fruit, lemongrass and other complex aromas



Saaz, Saazer, Lublin/Linbelski, Ultra, Sterling, Riwaka, Shinsu Wase

Britannic Group

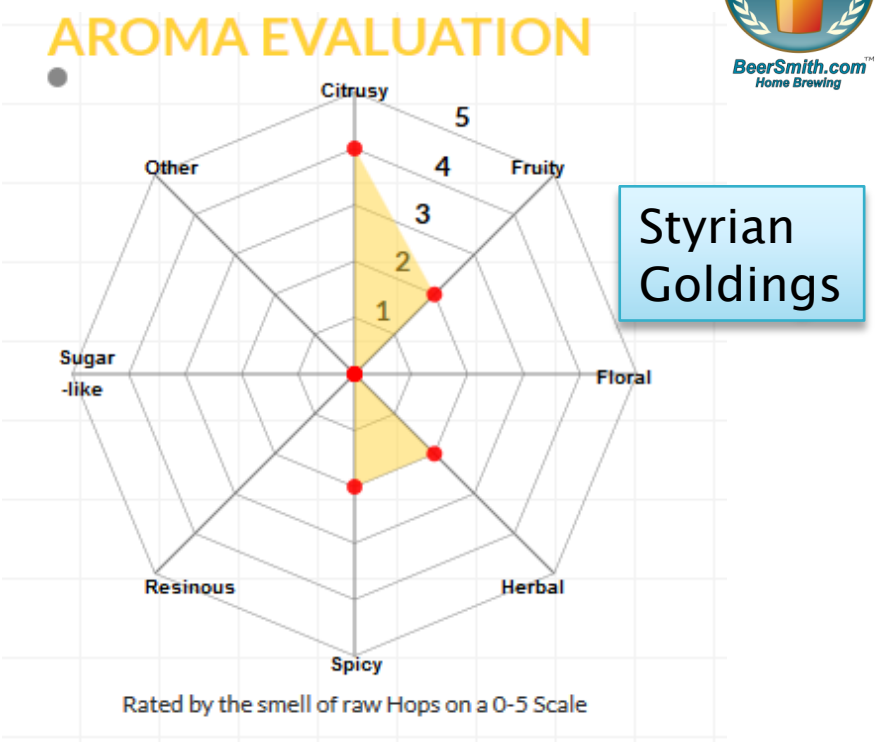
- English hops – spicy, earthy, herbal, woody, grassy, green, tangy
- Critical for IPAs, pale ales, milds
- East Kent Goldings is the defining example



Kent Goldings, First Gold, Golding, Whitbread, Pioneer, Phoenix, Pilgrim Challenger, Progress, Fuggle, Willamette, Palisade, Bramling Cross, Northdown, Northern Brewer

Styrian Group

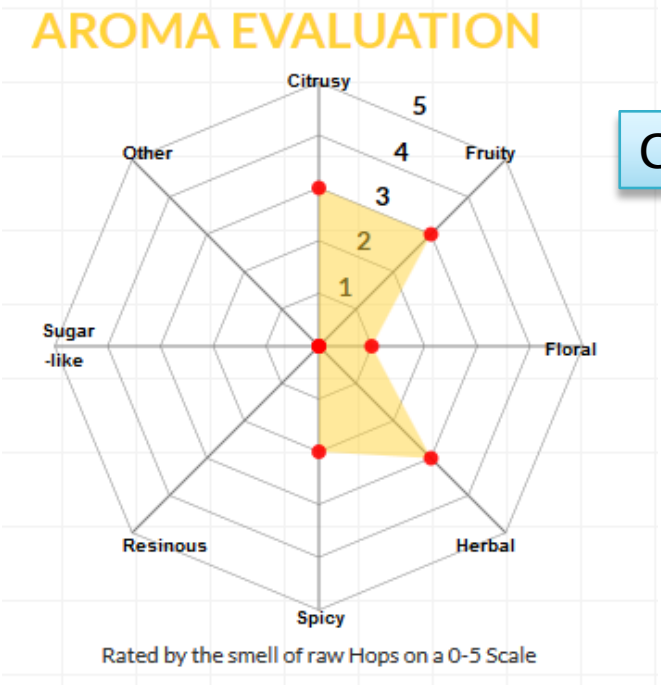
- Region in Slovenia where Fuggles variant grown
- Aromatic, herbal, ethereal, citrusy, bright, elegant, green tea, lemon hints
- Some variants earthy and spicy



Styrian Goldings, Glacier, Opal, Celeia, Aurora, Green Bullet, Bobek

Cascade Group

- Pacific NW – Soul of American Pale Ales
- Piney and Citrusy!
- Floral, herbal, pungent, some spice
- Led to Anchor Liberty Ale, Sierra Nevada Pale Ale, American IPAs

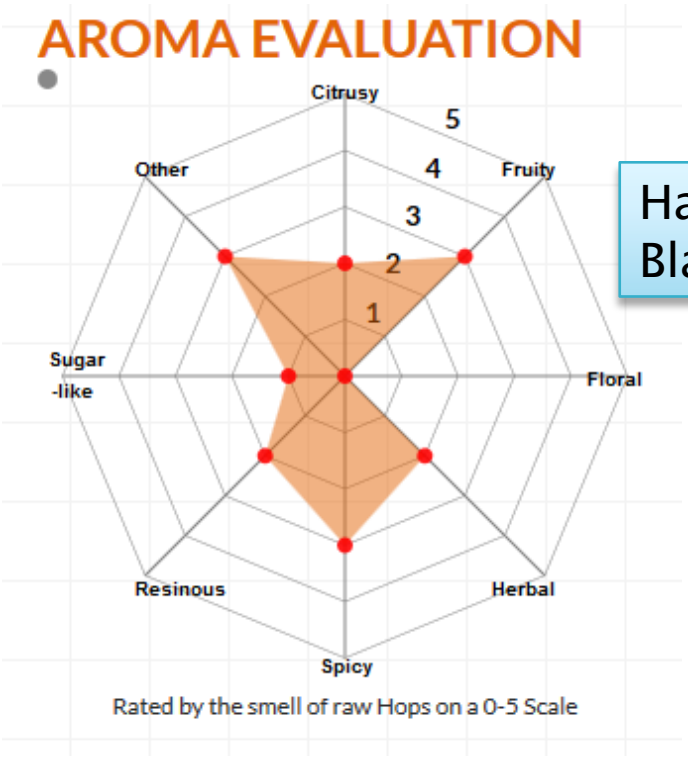


Cascade

Cascade, Centennial, Antanum, Falconer's Flight, Chinook, Columbus, Tomahawk, Zeus, Zythos, Amarillo, Mosaic, Rakau, Simcoe, Lemondrop

Pacific Group

- Newer hops with distinct personalities
- Fruity, apricot, passion fruit, grapes, gooseberry, white wine, other fruits



Hallertau Blanc

Citra, Galaxy, Motueka, Sorachi Ace, Nelson Sauvin, Hallertau Blanc, Aramis, Pacific Jade, Wakatu

Flavors from Yeast

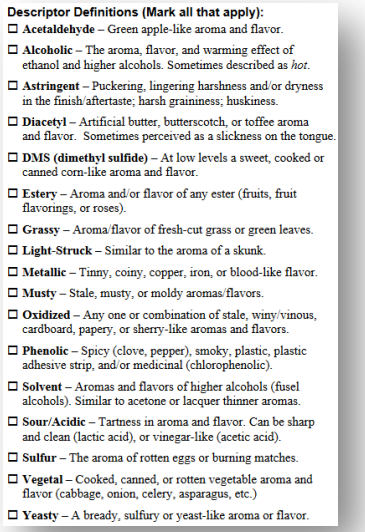
- Some possible flavors and off flavors
  - Attenuation may accent malt, hops or clean fermentation
  - Flocculation may enhance clarity or yeast flavors
  - Alcohol (mild warmth to moonshine/solvent)
  - Acetaldehyde (green apple)
  - Diacetyl (butter, butterscotch)
  - Clove (spicy, clove to phenolic)
  - Fruity/estery (plums, pears, banana, strawberry)
  - Medicinal (phenolic, band-aids, smoke, cloves)
  - Solvent (acetone, lacquer thinner)
  - Sulfur (rotton eggs, burnt matches)
  - Sour (lactic acid, acetic acid) from bacteria

Off Flavors (BJCP Score Sheet)

- Acetaldehyde – Yeast
- Alcoholic – Yeast
- Diacetyl – Yeast
- DMS – Process
- Esters – Yeast
- Grassy – Process
- Skunky – Process
- Metallic – Equipment
- Musty – Process
- Oxidized – Process
- Phenolic – Yeast
- Solvent – Yeast, Water
- Sour– Yeast/Bacteria
- Sulfur – Yeast
- Vegetal – Process
- Yeasty – Yeast

Most Serious Off Flavors are Related to Yeast!
Process Issues (sanitation, oxygen, DMS, mold) are Second

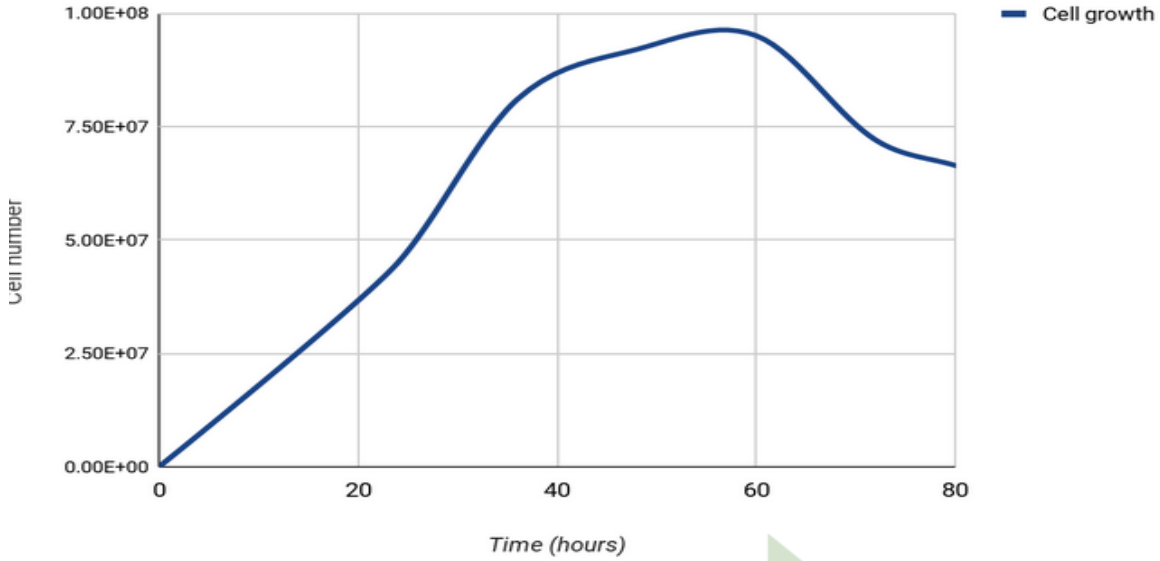
BJCP Scoring



Descriptor Definitions (Mark all that apply):

- ☐ **Acetaldehyde** – Green apple-like aroma and flavor.
- ☐ **Alcoholic** – The aroma, flavor, and warming effect of ethanol and higher alcohols. Sometimes described as *hot*.
- ☐ **Astringent** – Puckering, lingering harshness and/or dryness in the finish/aftertaste; harsh graininess; huskiness.
- ☐ **Diacetyl** – Artificial butter, butterscotch, or toffee aroma and flavor. Sometimes perceived as a slickness on the tongue.
- ☐ **DMS (dimethyl sulfide)** – At low levels a sweet, cooked or canned corn-like aroma and flavor.
- ☐ **Estery** – Aroma and/or flavor of any ester (fruits, fruit flavorings, or roses).
- ☐ **Grassy** – Aroma/flavor of fresh-cut grass or green leaves.
- ☐ **Light-Struck** – Similar to the aroma of a skunk.
- ☐ **Metallic** – Tinny, coiny, copper, iron, or blood-like flavor.
- ☐ **Musty** – Stale, musty, or moldy aromas/flavors.
- ☐ **Oxidized** – Any one or combination of stale, winy/vinous, cardboard, papery, or sherry-like aromas and flavors.
- ☐ **Phenolic** – Spicy (clove, pepper), smoky, plastic, plastic adhesive strip, and/or medicinal (chlorophenolic).
- ☐ **Solvent** – Aromas and flavors of higher alcohols (fusel alcohols). Similar to acetone or lacquer thinner aromas.
- ☐ **Sour/Acidic** – Tartness in aroma and flavor. Can be sharp and clean (lactic acid), or vinegar-like (acetic acid).
- ☐ **Sulfur** – The aroma of rotten eggs or burning matches.
- ☐ **Vegetal** – Cooked, canned, or rotten vegetable aroma and flavor (cabbage, onion, celery, asparagus, etc.)
- ☐ **Yeasty** – A bready, sulfury or yeast-like aroma or flavor.

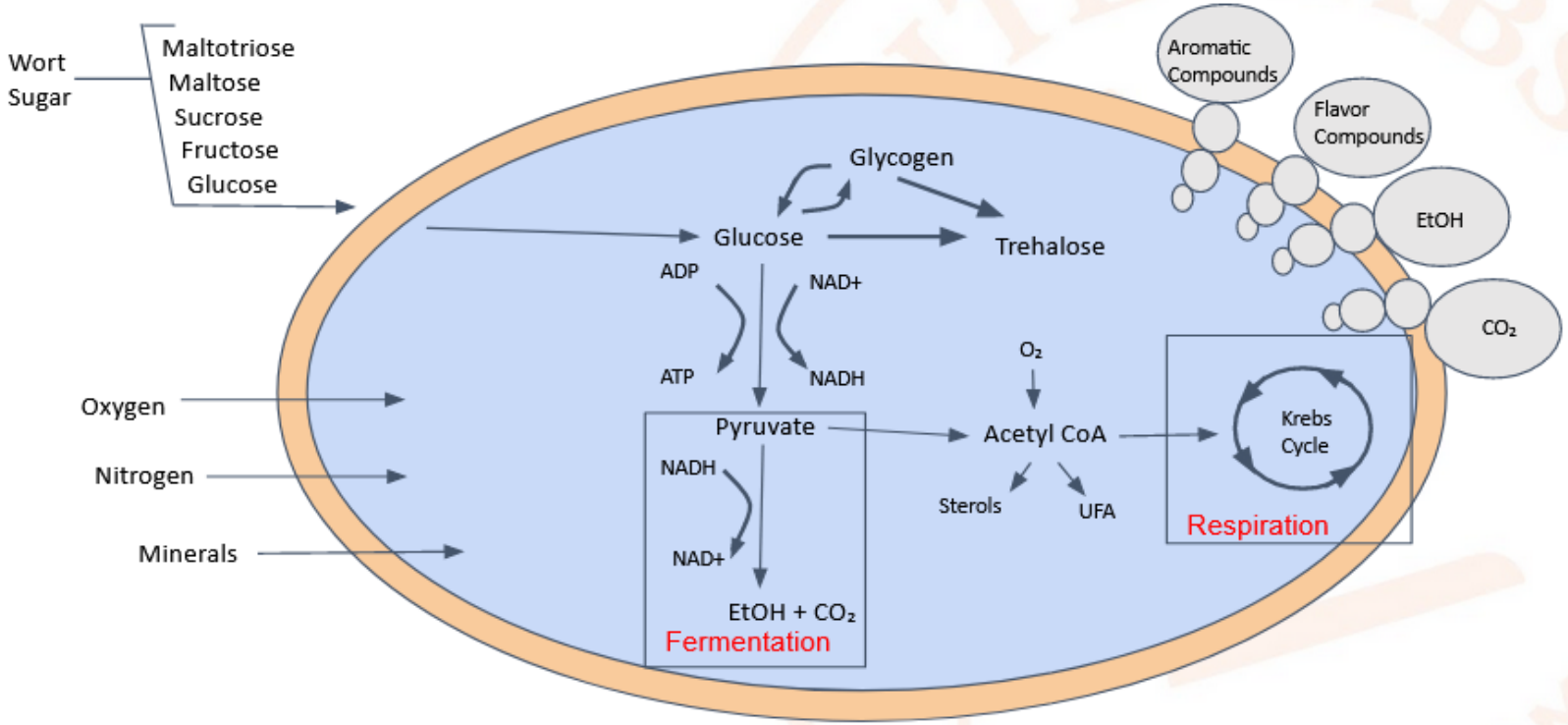
Fermentation Phases



Lag Phase | Exponential Phase | Stationary Phase | Death Phase

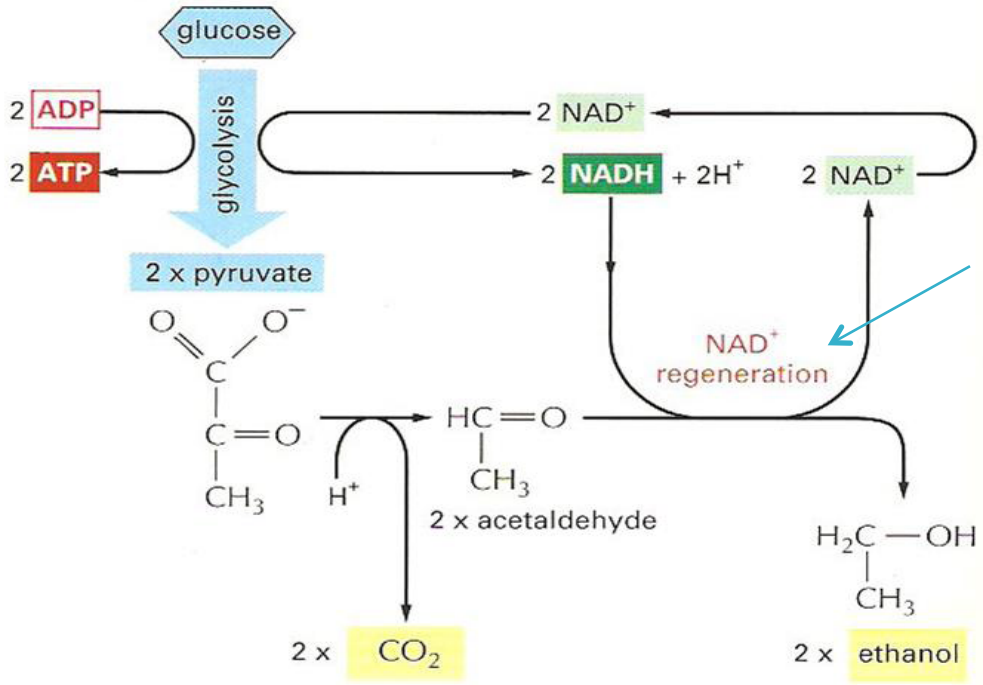
Source: White Labs: Life of Brewers Yeast

Yeast Metabolism



Source: White Labs: Life of Brewers Yeast

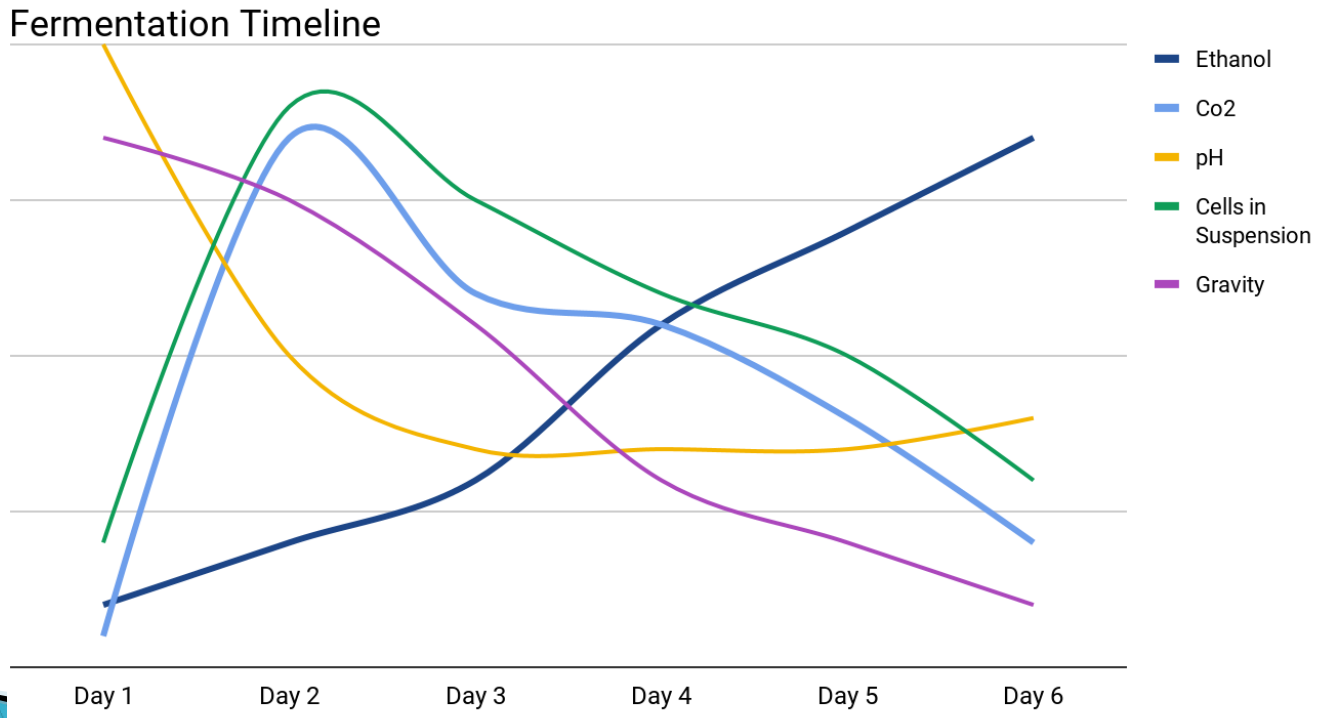
Fermentation



Keeps glycolosis going

Source: White Labs: Life of Brewers Yeast

Fermentation over Time



Source: White Labs: Life of Brewers Yeast

Yeast Data Sheet: WLP-001

- California Ale Yeast
  - Type: Ale
  - White Labs: WLP001
  - Attenuation: 73-80%
  - Temp: 68-73 F
  - Flocculation: Medium
  - Alcohol Tolerance: 10-15%

Fermenation Data:

- Isoamyl Alcohol: 90.18ppm
- Acetaldehyde: 14 ppm
- Ethyl Acetate: 17.4 ppm
- 2.3 Pentainedione: 8.6 ppb
- Diacetyl: N/A
- 1-Propanol: 37.23 ppm
- Ethanol: 4.825% ABV
- Hours to 50%: 40 hours

Description: Our best-selling yeast, famous for its clean flavors and hardy fermentations. Known for its use in hoppy beers, it accentuates hop flavors and aromas and attenuates well, even for high gravity beers.

Yeast Data

- Basic Yeast Stats:
  - **Attenuation** – The percent of the sugars (gravity points) you can expect to ferment into alcohol – usually quoted as "apparent attenuation"
  - **Temperature** – The recommended fermentation range for the yeast
  - **Flocculation** – An indication of how quickly the yeast "falls out" of beer after fermentation
  - **Alcohol Tolerance** – Highest alcohol percentage the yeast can tolerate before it goes dormant
    - Need to factor this in when designing high gravity beers!

Yeast Data

- Fermentation Stats:
  - **Isoamyl Alcohol/Acetate**: (Ester) The banana flavor in Wheat beer (circus peanuts)
  - **Acetaldehyde**: Intermediate compound produced during fermentation (green apples)
  - **Ethyl Acetate**: (Ester) Strongest of the common esters (fruits, pears, solvents if too much)
  - **2.3 Pentainedione**: Vicinel Diketone (VDK like diacetyl) gives a honey flavor, but has 10x lower flavor threshold
  - **Diacetyl**: (VDK) Buttery/popcorn like flavor
  - **1-Propanol**: Fusel alcohol can give off alcoholic odor to a strong solvent like flavor at higher concentration
  - **Ethanol**: Simply the alcohol percentage of the test batch
  - **Hours to 50%**: Time it takes to reach 50% fermented – indication of how quickly the yeast ferments out

Comparison: WLP001 and 002

- California Ale Yeast
  - Type: Ale
  - White Labs: WLP001
  - Attenuation: 73-80%
  - Temp: 68-73 F
  - Flocculation: Medium
  - Alcohol Tolerance: 10-15%

- English Ale Yeast
  - Type: Ale
  - White Labs: WLP002
  - Attenuation: 63-70%
  - Temp: 65-68 F
  - Flocculation: Very High
  - Alcohol Tolerance: 5-10%

Attenuation and alcohol tolerance significantly lower for the English Ale Yeast – will result in a malty finish

Comparison: WLP001 and 002

California Ale: WLP001

- Isoamyl Alcohol: 90.18ppm
- Acetaldehyde: 14 ppm
- Ethyl Acetate: 17.4 ppm
- 2.3 Pentainedione: 8.6 ppm
- Diacytl: N/A
- 1-Propanol: 37.23 ppm
- Ethanol: 4.825% ABV
- Hours to 50%: 40 hours

English Ale: WLP002

- Isoamyl Alcohol: 122.7 ppm
- Acetaldehyde: 12.5 ppm
- Ethyl Acetate: 24.1 ppm
- 2.3 Pentainedione:33.9 ppb
- Diacetyl: N/A
- 1-Propanol: 29.41 ppm
- Ethanol: 4.5% ABV
- Hours to 50%: N/A

Fruity Esters (Isoamyl, Ethyl Acetate) much higher as is Pentainedione (Honey) and likely Diacetyl (Buttery) for the English Ale Yeast.

Comparison: WLP001 and 530

- California Ale Yeast
  - Type: Ale
  - White Labs: WLP001
  - Attenuation: 73-80%
  - Temp: 68-73 F
  - Flocculation: Medium
  - Alcohol Tolerance: 10-15%

- Abbey Ale Yeast
  - Type: Ale
  - White Labs: WLP530
  - Attenuation: 75-80%
  - Temp: 66-72 F
  - Flocculation: Med to High
  - Alcohol Tolerance: 10-15%

Both are high attenuation yeasts, and both are capable of tolerating high alcohol levels

Comparison: WLP001 and 530

California Ale: WLP001

- Isoamyl Alcohol: 90.1 ppm
- Acetaldehyde: 14 ppm
- Ethyl Acetate: 17.4 ppm
- 2.3 Pentainedione: 8.6 ppm
- Diacytl: N/A
- 1-Propanol: 37.23 ppm
- Ethanol: 4.825% ABV
- Hours to 50%: 40 hours

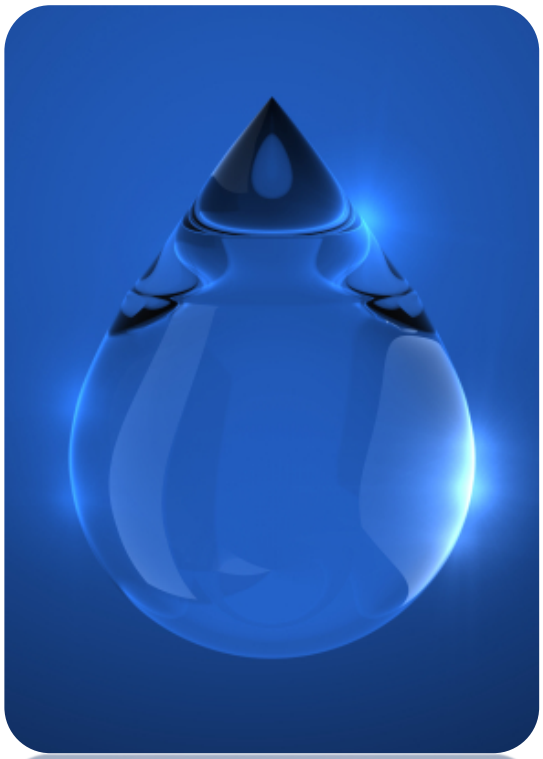
Abbey Ale: WLP530

- Isoamyl Alcohol: 142 ppm
- Acetaldehyde: 13.6 ppm
- Ethyl Acetate: 35.4 ppm
- 2.3 Pentainedione:16.4 ppb
- Diacetyl: 53.5 ppb
- 1-Propanol: 28.2 ppm
- Ethanol: 5% ABV
- Hours to 50%: 30 hours

Fruity Esters (Isoamyl, Ethyl Acetate) much higher for Abbey Ale,
But it lacks the pentainedione/diacetyl of earlier English Ale Yeast.

Water

- 90-95% of your Beer!
- Brulosopher.com experiments
- Water drives
  - Taste of the beer
  - Perception of Bitterness
  - Chemistry (pH) of the Mash
  - Fermentation
  - Off flavors
  - Long term stability
- Water Chemistry is Complex!



Know Your Water Source

- You need to test your water to know what you are working with
  - Local water reports (sometimes)
    - Many don't have detail needed
  - Brewing Water Test Kit (LaMotte, SmartBrew)
    - Great solution for a club/group
  - Lab test (Ward, White labs, etc…)
    - Send in a sample – cheaper than a test kit but provides only a single data point
    - Make sure you get a "brewing water" test
- Challenges:
  - In many areas your water source may change
  - Many brewers eliminate the problem entirely by starting with distilled/RO water and building water up with salts

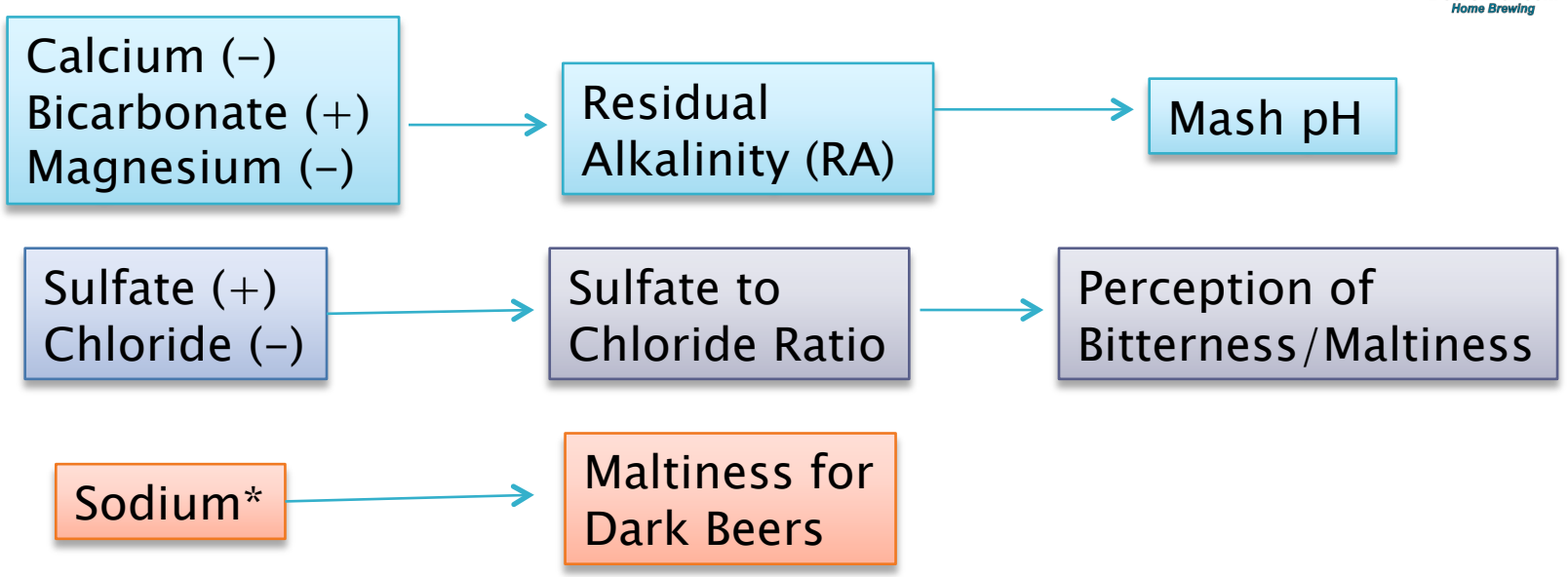
Big Six Ions – Water Reports

- **Calcium (Ca) [50-150 ppm]** – Acidifies mash, precipitates phosphates, improves stability, large role in mash pH balance
- **Magnesium (Mg) [10-40 ppm]** – Small amounts needed for fermentation, slightly acidic. Minor role in mash pH
- **Sodium (Na) [0-150 ppm]** – Enhances sweetness, body in dark beers, but largely mash-neutral

Big Six Ions – Water Reports

- **Sulfate (SO4) [50-250 ppm]** – Enhances bitterness, lightens color – often added as gypsum (CaSO4)
- **Chloride (Cl) [0-250 ppm]** – Affects bitterness perception, mash neutral
- **Bicarbonate (HCO3) [0-250 ppm]** – Strongly alkaline, impedes cold break, emphasizes bitterness but harshly, plays a major role in mash pH balance

The Role of Water Ions



Getting ions in the proper range supports mashing, fermentation, taste balance, proper beer ph, and long term stability

* Too much sodium can result in a salty perception

Residual Alkalinity

- Water pH not that important
- Residual Alkalinity (RA): Measure of the buffering capacity of water or how hard it is to change your pH:

RA = Alkalinity– Ca/1.4 – Mg/1.7
Alkalinity = Bicarb * 50/61

Ref: Kolbach
Palmer: How to Brew

  - Where Bicarb, Ca and Mg ion concentrations come from water report (in ppm). Gives RA in ppm as CaCO3
- Example: Los Angeles: Ca=70ppm, Mg=30ppm, Bicarb=147ppm
  - Gives RA=53 ppm (as CaCO3), and Alkalinity=120 ppm

High RA means more acid from malts or acid additions needed
Generally your bicarbonate (alkalinity) and Carbonate dominate

Sulfate to Chloride Ratio

- Simply Divide

  Ratio = Sulfate/Chloride

  - Where sulfate and chloride values are in ppm
- Sulfate will enhance malty perception, while chloride will do the opposite
- Does not apply for ion values well outside the "good" range

"Water": Palmer and Kaminski*:

0-0.4: Too malty
0.4-0.6: Very malty
0.6-0.8: Malty
0.8-1.5: Balanced
1.5-2.0: Slightly bitter
2.0-4.0: Bitter
4.0-9.0: Very bitter
9+: Too bitter

*Source: "Water a Comprehensive Guide for Brewers" Palmer and Kaminsky

Water Salts

- Any water adjustment adds at least two ions
- You can't match a given water profile exactly with salts
  - Chalk is not very soluble – some brewers avoid using it at all

Gypsum (CaSO4)
Salt (NaCl)
Epsom Salt (MgSO4)
Calcium Chloride (CaCl)
Baking Soda (NaHCO3)
Chalk (CaCO3)

BeerSmith has a "least squares" calculator in both the recipe builder and the Water Profile Tool that can help you match water profiles

Water Adjustment Strategies

- Water Sources:
  - Use your local water
    - Dilute with RO/Distilled if you want to reduce ions
    - Add water salts if you want to increase ions
  - Use RO or distilled water and build it to target with salts

- Target Water Profiles:
  - Target a particular “city” water profile
  - Target a water profile that fits a given “style” of beer
  - Build a “custom” water profile for your beer

Water Profiles – Dublin

Dublin, Ireland (Guiness Stout)

- Calcium: 115ppm [50-100]
- Magnesium: 4 ppm [10-40]
- Sodium: 12 ppm [0-150]
- Sulfate: 55 ppm [50-200]
- Chloride: 19 ppm [0-250]
- Bicarbonate: 200 ppm [0-250]

Analysis

- Alkalinity: 164 ppm
- Residual Alk: 84 ppm
- Sulfate/Chloride Ratio: 2.9

Actually a pretty average water. Residual alkalinity not excessive, and Large amount of bicarbonate probably helps offset acidic grains. Sulfite/Chloride ratio will accentuate bitterness.

Water Profiles – IPA/Hoppy

IPA or Hoppy Beer Style

- Calcium: 140 ppm [50-100]
- Magnesium: 18 ppm [10-40]
- Sodium: 25 ppm [0-150]
- Sulfate: 300 ppm [50-200]
- Chloride: 55 ppm [0-250]
- Bicarbonate: 110 ppm [0-250]

Analysis

- Alkalinity: 90 ppm
- Residual Alk: 111 ppm
- Sulfate/Chloride Ratio: 5.5

Overall a fairly moderate profile, except a large amount of Gypsum (CaSO4)
And Epsom Salt (MgSO4) is used to drive the sulfate levels way up.
This gives us a very high sulfate/Chloride ratio to accentuate bitterness.