# The Science Of Brewing

presented by Thomas Reese of the Ghost Harbor Brewing Company

# In the brewing process

Barley, Hops, Water, and Yeast

Come together to make...


Woo-hoo!
Duff
BEER

# Reinheitsgebot
## "German Beer Purity Law"

- According to the law adopted in 1516 Bavaria, the only permitted ingredients in beer were Barley, Hops, and Water.
- Yeast was added in 1906

# BARLEY

## The "Heart of Beer"

# Barley Malting Process

During steeping water is absorbed by the raw barley kernel and germination begins. Raw barley is placed in steep tanks and covered with water. The barley spends a couple days in the steep tanks alternating between submerged and drained until it increases in moisture content of about 44%. The absorbed water activates naturally existing enzymes and stimulates the embryo to develop new enzymes. The enzymes break down the protein and carbohydrate matrix that encloses starch granules in the endosperm, opening up the seed's starch reserves.

Steeping is complete when the barley has reached a sufficient moisture level to allow uniform breakdown of the starches and proteins. One visual indicator that the maltster uses to determine the completion of steeping is to count the percentage of kernels that show the start of rootlets called "chit".

## STEEPING

# Barley Malting Process

## GERMINATION

The "chitted" barley is transferred from the steep tanks to the germination compartment. Here it will continue the germination process in which the barley kernel undergoes modification. Modification refers to the break down of the protein and carbohydrates, and the resulting opening up of the seeds' starch reserves. Germination is controlled by drawing temperature-adjusted, humidified air through the bed. Turners keep the bed from compacting and rootlets from growing together.

# Barley Malting Process

## KILNING

Four to Five days later germination is halted by drying. If germination continued, the kernel would continue to grow and all of the starch reserves needed by the brewer would be used to grow the plant. Base malts are kiln dried, typically with a finish heat of 180-190° F for 2-4 hours. This develops flavors ranging from very light malty to subtle malty. Specialty malts are dried in a kiln at higher temperatures for longer periods of time, roasted, or both. Varying the moisture level, time, and temperature of drying develops the flavor and color characteristics of specialty malts.

# When is all done we end of with malted barley resembling…

Base and various specialty malts

# The Mash

Converting starch to sugar

# Temp rests and enzymes

Phytase (86-126 F) - Lowers the pH of the mash. Lowering the mash pH has a number of benefits, though a Phytase rest is rarely used by modern brewers.

Debranching (95-112 F) - Helps to increase the solubility of starches resulting in increased extraction for certain malts.

Beta Glucanese (95-113F) - Breaks down the gummy heavy starches, which can help improve stability and extraction, particularly for mashes high in proteins and adjuncts such as wheat.

Pepidase (113-131F) - Produces free amino nitrogen, which can aid in fermentation.

Beta Amylase (131-150F) - Produces maltose, the main sugar fermented in beer.

Alpha Amylase (154-162F) - Produces a variety of sugars, including maltose and also some unfermentable sugars. Mashing at the higher end of this range produces more unfermentables and therefore more body in the finished beer.

# Collecting Wort

- After the starches have completely converted to sugar (~1 hour) you begin to collect the sweet infusion of ground malt and/or other grains known as Wort.
- Raise the temperature of the grain bed (known as mash out) to 170F to allow the sugars to dissolve and rinse easily.
- Vorlauf the wort until in runs clear (no grain particles) then begin to run the wort into the kettle.
- There are several sparge methods including batch and fly spare. Your equipment type will dictate which method to use.
- Efficiency is a measurement of potential fermentables converted into sugar in your wort. Grain type, grain crush, sparge method, mash temp and time are some of the many variables that affect efficiency.

# HOPS

From Pliny the Elder to Russian River with love

Hops were originally used in brewing for their antibacterial effect over less desirable microorganisms. Hops also have many other benefits, including balancing the sweetness of the malt with bitterness, and contributing a variety of desirable flavors and aromas. Historically, traditional herb combinations used to flavor and bitter beers were abandoned when beers made with hops were noticed to be less prone to spoilage.

# Types of hops

Whole-leaf Hops - Whole-leaf hops are simply the dried hop cones that have been compressed into bales. They are believed to have greater aromatic qualities than the other forms and are easier to strain from wort. However, because they retain more of the vegetative matter greater volumes must be used. They soak up more wort than other forms resulting in greater loss to the brewer. Their bulk also makes them more difficult to store and more susceptible to spoilage.

## Whole Leaf

# Types of hops

## Pellet Hops

Pellets - To make pellet hops the dried cones are shredded, compressed, and extruded into pellets that resemble rabbit food. The shredding process exposes the lupulin glands and removes a percentage of the vegetative matter, meaning smaller volumes can be used in the brewery. Their lighter weight and compressed state also makes them easier to store and less susceptible tospoilage. On the down side, they tend to lose some of their aromatic quality in processing and they create sludge at the bottom of the brew kettle that can be difficult to remove from the wort. The majority of hops used in the craft brewing industry are pellet hops.

# Types of hops

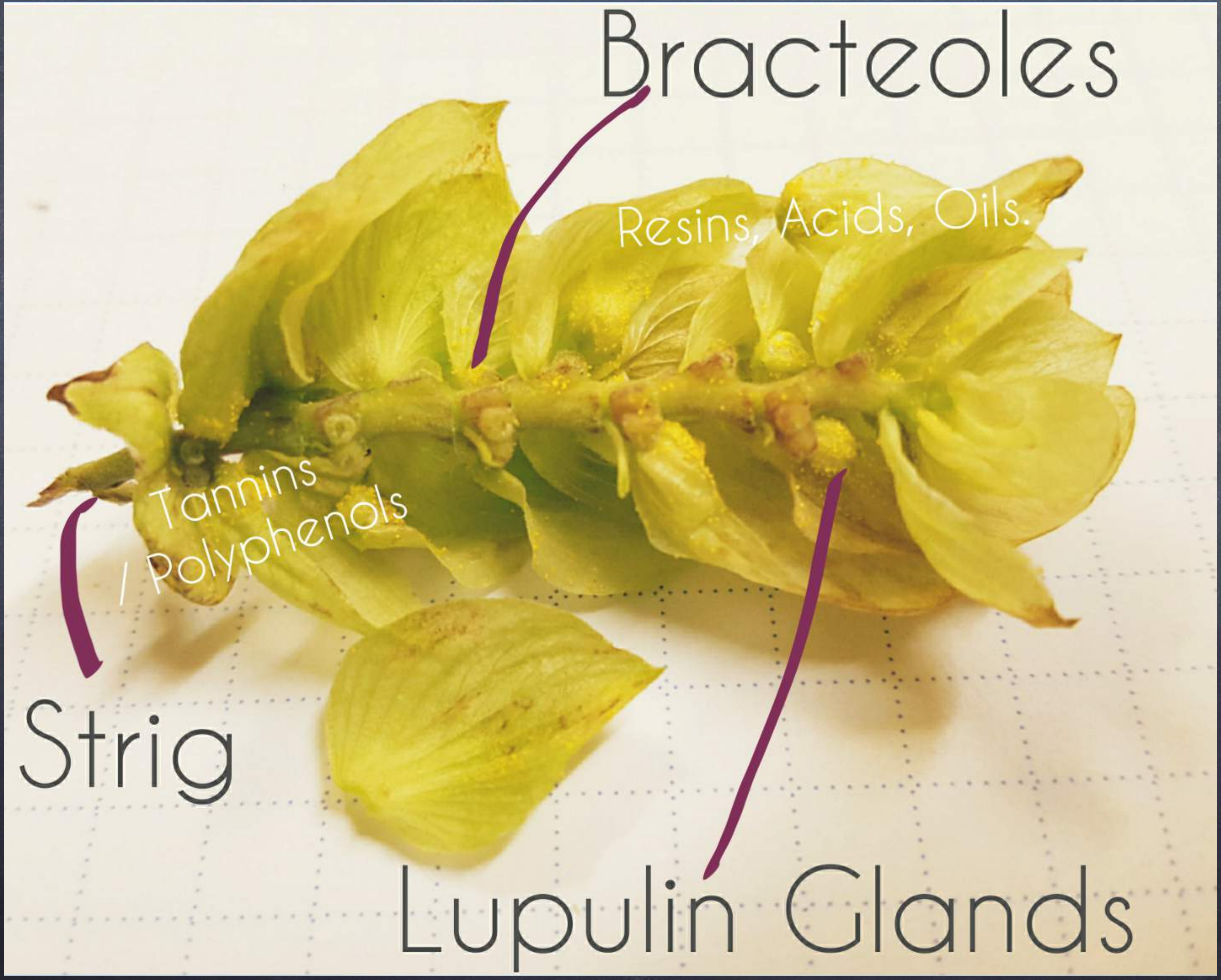
For hop extracts, the alpha acids and essential oils are pulled from the cones using heat and various solvents. These concentrated liquid extracts can be used in the brewing process just like hops. Wort loss is kept to a minimum due to lack of negative matter.

Fresh hops are green, unprocessed cones, often added to the beer within hours of harvest. Wet hops give beers an intense, bright hop flavor and aroma. They lack the concentration that comes with drying, a much larger volume is needed to achieve the same result as from dried hops.

## Extract

## Wet Whole Cone

# Hop anatomy


Bracteoles
Resins, Acids, Oils.
Tannins
/ Polyphenols
Strig
Lupulin Glands

# Bittering Hops

Bitterness from hops comes from alpha acids found in the lupulin glands of the hop flowers. The main alpha acids are humulone and cohumulone and adhumulone. In order to become bitter these acids must be chemically altered, isomerized, by boiling. Isomerization is a chemical process in which a compound is changed into another form with the same chemical composition but a different structure. The percentage of the potential alpha acid that is isomerized is referred to as utilization. Because the length of the boil determines degree of utilization, bittering hops are usually added at the beginning of the boil or with at least 60- minutes of boiling time remaining.

# Flavor Hops

Flavor Hops - Hop flavor and aroma are derived from essential oils found in the lupulin glands. These oils include humulene, myrcene, geraniol, and limonene, among others. The flavors are released as these oils become dissolved into the wort during the boil. However, these oils are highly volatile and are to a large degree lost to evaporation. For this reason flavor hops are added with twenty to forty minutes remaining in the boil. This provides a compromise between isomerization of the alpha acids and loss of essential oils.

# Aroma Hops

Aroma Hops - Because the aromatic essential oils are highly volatile, aroma hops are added in the last minutes of the boil to minimize their loss to evaporation. Aroma hops are also often used in dry hopping. A method in which hops are added to beer that has been fermented.

# Experimental Hops


# Water

90% of beer 99% boring

# Brewing Water

Brewing water affects the beer in three ways: It affects the pH of the beer, which affects how the beer flavors are expressed to your palate; it provides "seasoning" from the sulfate-to-chloride ratio; and it can cause off-flavors from chlorine or contaminants.

# Water and "Salt"

Calcium chloride and calcium sulfate are essential parts of good brewing water. Chloride acts to make the beer seem fuller and sweeter. It has the opposite effect of sulfate. Sulfate accentuates hop bitterness, making it seem drier and crisper. In fact, the sulfate-to-chloride ratio is a good way to gauge the effect of the brewing water on the balance of the beer. For example, a sulfate-to-chloride ratio of 2:1 or higher will tend to give the beer a drier, more assertive hop balance, while a beer with a ratio of 1:2 will tend to have a less bitter, rounder, and maltier balance. However, this effect is just like salting and seasoning your food; it helps accentuate the flavors that are there but will not fix a bad recipe. Finally, you should understand that chloride is not the same as chlorine, which is used as a disinfectant. Chlorine and chloramines need to be removed from the brewing water.

# Water pH in the mash

Proper Mash pH benefits include

- Improved enzyme activity during the mash, leading to better conversion of starches to sugars
- Lower pH in the finished wort which improves yeast health during fermentation, and also inhibits bacteria growth
- Improved hop extraction rates in the boil
- Better protein and polyphenol precipitation both during the cold break and post fermentation
- Improved clarity in the finished beer with reduced chill haze
- Improved flavor and clarity stability as the beer ages


# Yeast

Louis Pastuer had a magnificent eye!

Yeast is in the fungus family and, because of its cell-splitting capabilities, is self-reproducing. Yeast has a voracious appetite for sweet liquids and produces abundant quantities of alcohol (ethanol) and carbon dioxide in exchange for a good meal. Brewers Yeast reproduces asexually by budding.

Yeast can also take credit for the classification of the beer style. Brewmasters pick a yeast according to the recipe or the style of beer they want to make. Yeast is identified as either an ale yeast or a lager yeast.

# Ale Yeast

## Saccharomyces Cerevisiae

Saccharomyces cerevisiae is used when brewing an Ale. It is referred to as a top-fermenting or top-cropping yeast. The reason for this is during the fermentation process its hydrophobic surface causes the flocs to adhere to Co2 and rise to the top of the fermentation vessel. Top-fermenting yeasts are fermented at higher temperatures (60-70f) and have a "fruitier flavor" than lager yeasts. Examples include India Pale Ale, Stout, Porter, and ESB.

# Lager Yeast

## Saccharomyces Pastorianus

Saccharomyces Pastorianus is used when brewing Lagers. It is cold-tolerant and has a sulfite-metabolizing characteristics that manifest in the distinctive flavor and character of lager beer. Lager beer is fermented between 45F and 55F and then "lagered" (stored) for a period of weeks or months at temperatures hovering just above freezing. This low-and-slow fermentation means that lagers taste "clean" and lack the fruity esters characteristic of ales. Further, because of the sulfite metabolism, lager beers usually smell a lot like rotten eggs during fermentation. Lager examples include Pilsner, Bock, Oktoberfest.

# Fermentation

Yeast are unusual in that they can live and grow both with or without oxygen. Yeast can live without oxygen by a process that we refer to as fermentation. The yeast cells take in simple sugars like glucose and maltose and produce carbon dioxide and alcohol as waste products. Yeast also produce many other compounds, including esters, fusel alcohols, ketones, various phenolics and fatty acids. Proper wort nutrition, initial oxygen levels, yeast pitching rate, and temperature control are essential to a good, clean fermentation which is the hallmark of great beer!

# Fermentation Phases

## Lag Phase: Three to 15 Hours After Pitching Yeast

- Yeast begin to uptake minerals, oxygen, vitamins and amino acids from the wort to prepare for growth and reproduction.

## Exponential Growth Phase: One to Four Days

- Occurs because the yeast begin to consume sugars. Starting with simple sugars like glucose and finishing with the complex sugar maltose. During this phase, the cell count increases rapidly and ethanol, CO2, and flavor compounds are produced. Also known as high kraeusen.

## Stationary Phase of Yeast Growth: 3 to 10 Days

- Beer is matured in the stationary phase of growth, also known as the conditioning phase. Yeast reabsorb diacetyl that was produced during fermentation. The kraeusen falls and the yeast begins to flocculate. Check the degree of attenuation to confirm fermentation is complete.

# Recipe Formulation

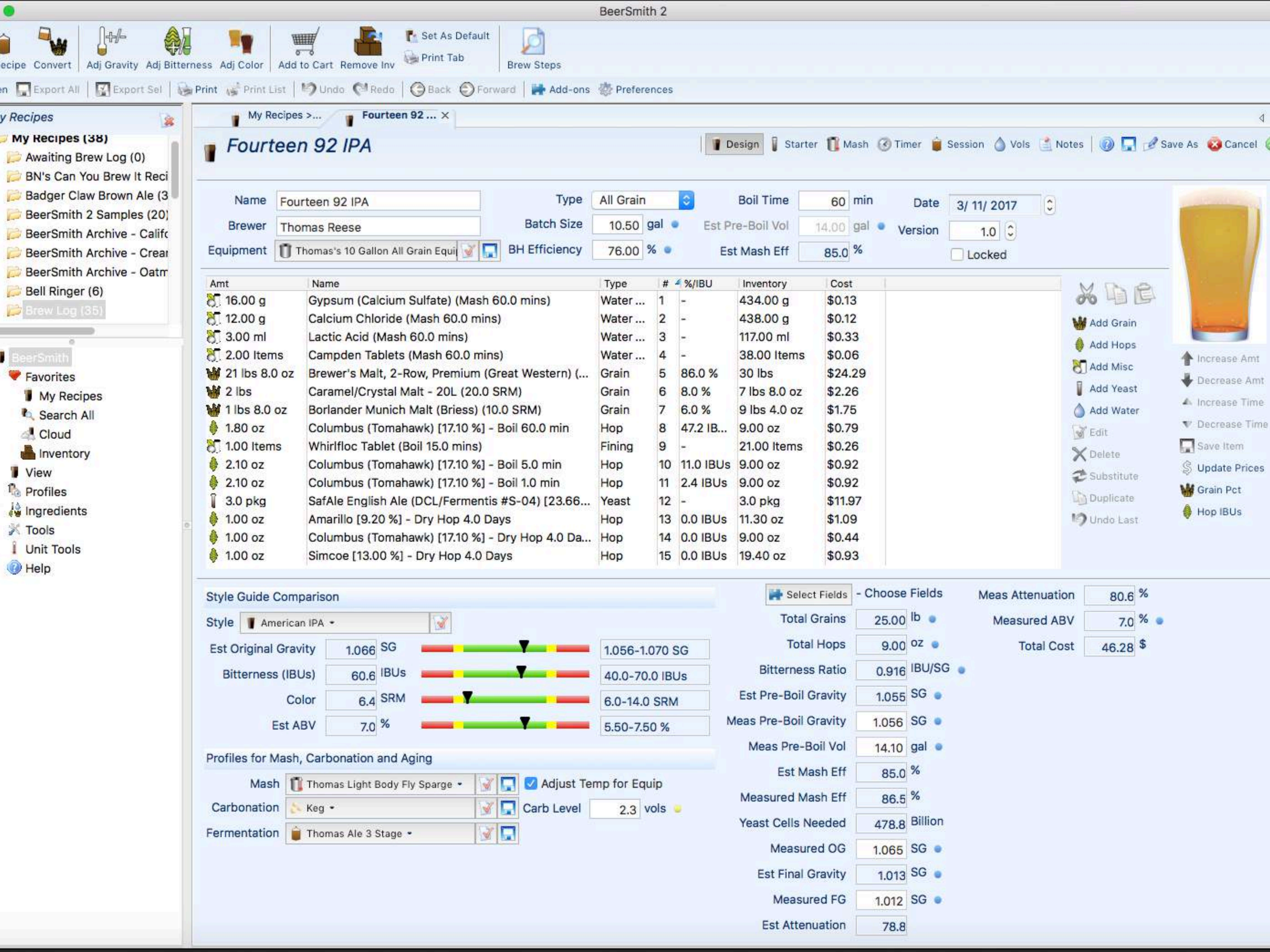
Art meet Science, Science meet Art

# Ingredients

American 2 row, Maris Otter, Pilsner, Pale, Vienna, Munich, Victory, C10-120, Carapils, Honey, Special B, Aromatic, Chocolate, Roasted Barley, Black Patent, Wheat, Flaked Barley, Rice, Corn, Oats

Chinook, Horizon, Columbus, Simcoe, Magnum, Northern Brewer, Amarillo, Cascade, Centennial, Citra, Mosaic, Galaxy, Falconer's Flight, Huell Melon, Nelson Sauvin, EKG, Willamette, Fuggle, Liberty, Hallertau, Saaz,

WLP001 Cal Ale, WLP002 English Ale, WLP007 Dry English Ale, WLP090 San Diego Super, WLP004 Irish Ale, WLP400 Belgian Wit, WLP565 Saison, Safale US-05, Safale S04, WLP840 American Lager, WLP810 San Francisco Lager, WLP830 German Lager, Saflager S23


BeerSmith 2
Convert
Adj Gravity
Adj Bitterness
Adj Color
Add to Cart
Remove Inv
Set As Default
Print Tab
Brew Steps
Export All
Export Sel
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Undo
Redo
Back
Forward
Add-ons
Preferences
My Recipes (38)
Awaiting Brew Log (0)
Badger Claw Brown Ale
BeerSmith 2 Samples (20)
Bell Ringer (6)
Brew Log (35)
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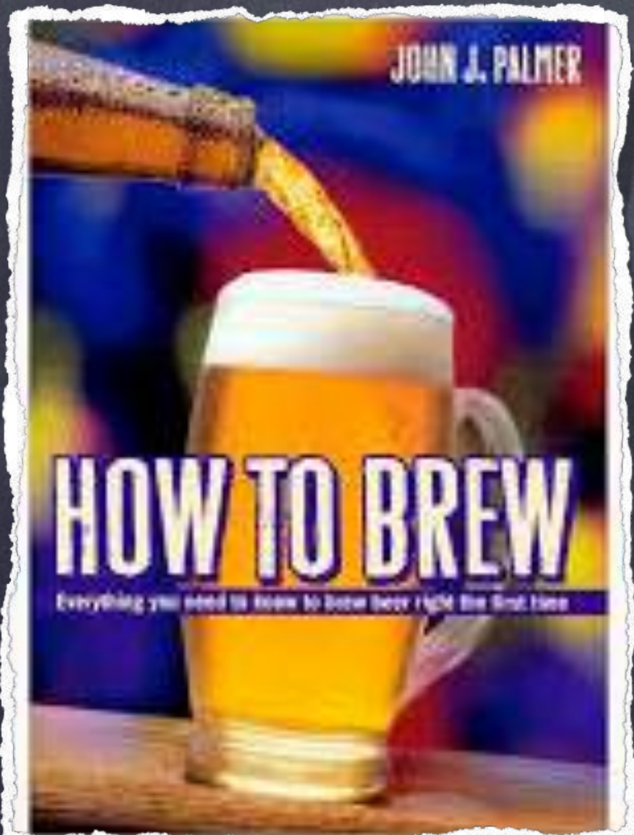
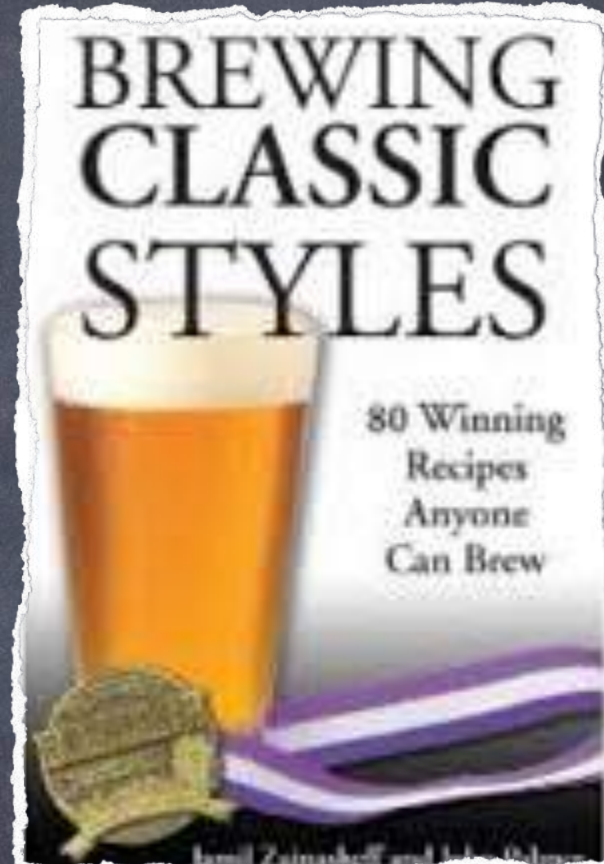
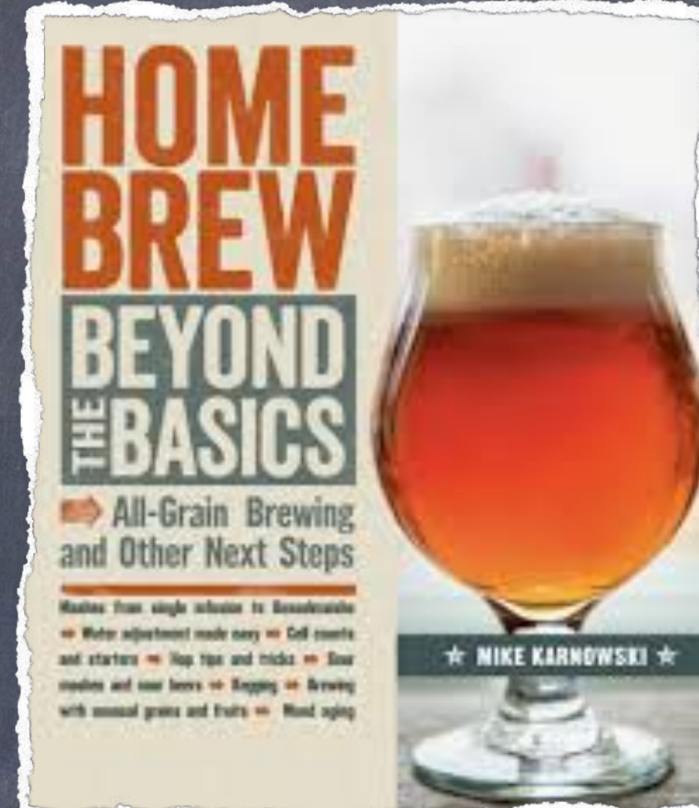
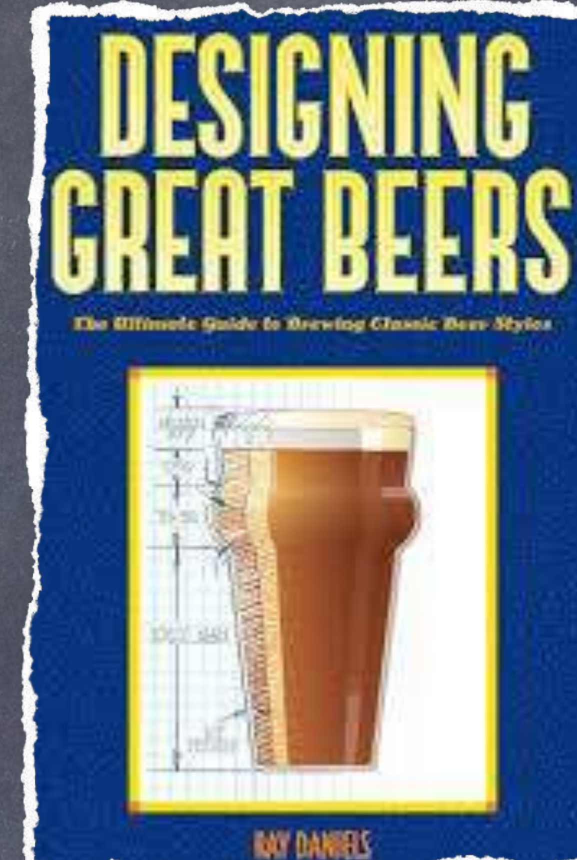
View
Profiles
Ingredients
Tools
Unit Tools
Help
Fourteen 92 IPA
Design
Starter
Mash
Timer
Session
Vols
Notes
Save As
Cancel
Name Fourteen 92 IPA
Brewer Thomas Reese
Equipment Thomas's 10 Gallon All Grain Equi
Type All Grain
Batch Size 10.50 gal
BH Efficiency 76.00 %
Boil Time 60 min
Est Pre-Boil Vol 14.00 gal
Est Mash Eff 85.0 %
Date 3/ 11/ 2017
Version 1.0
Locked
Amt | Name | Type | # | %/IBU | Inventory | Cost
16.00 g | Gypsum (Calcium Sulfate) (Mash 60.0 mins) | Water ... | 1 | - | 434.00 g | $0.13
12.00 g | Calcium Chloride (Mash 60.0 mins) | Water ... | 2 | - | 438.00 g | $0.12
3.00 ml | Lactic Acid (Mash 60.0 mins) | Water ... | 3 | - | 117.00 ml | $0.33
2.00 Items | Campden Tablets (Mash 60.0 mins) | Water ... | 4 | - | 38.00 Items | $0.06
21 lbs 8.0 oz | Brewer's Malt, 2-Row, Premium (Great Western) (... | Grain | 5 | 86.0 % | 30 lbs | $24.29
2 lbs | Caramel/Crystal Malt - 20L (20.0 SRM) | Grain | 6 | 8.0 % | 7 lbs 8.0 oz | $2.26
1 lbs 8.0 oz | Borlander Munich Malt (Briess) (10.0 SRM) | Grain | 7 | 6.0 % | 9 lbs 4.0 oz | $1.75
1.80 oz | Columbus (Tomahawk) [17.10 %] - Boil 60.0 min | Hop | 8 | 47.2 IB... | 9.00 oz | $0.79
1.00 Items | Whirlfloc Tablet (Boil 15.0 mins) | Fining | 9 | - | 21.00 Items | $0.26
2.10 oz | Columbus (Tomahawk) [17.10 %] - Boil 5.0 min | Hop | 10 | 11.0 IBUs | 9.00 oz | $0.92
2.10 oz | Columbus (Tomahawk) [17.10 %] - Boil 1.0 min | Hop | 11 | 2.4 IBUs | 9.00 oz | $0.92
3.0 pkg | SafAle English Ale (DCL/Fermentis #S-04) [23.66... | Yeast | 12 | - | 3.0 pkg | $11.97
1.00 oz | Amarillo [9.20 %] - Dry Hop 4.0 Days | Hop | 13 | 0.0 IBUs | 11.30 oz | $1.09
1.00 oz | Columbus (Tomahawk) [17.10 %] - Dry Hop 4.0 Da... | Hop | 14 | 0.0 IBUs | 9.00 oz | $0.44
1.00 oz | Simcoe [13.00 %] - Dry Hop 4.0 Days | Hop | 15 | 0.0 IBUs | 19.40 oz | $0.93
Add Grain
Add Hops
Add Misc
Add Yeast
Add Water
Edit
Delete
Substitute
Duplicate
Undo Last
Increase Amt
Decrease Amt
Increase Time
Decrease Time
Save Item
Update Prices
Grain Pct
Hop IBUs
Style Guide Comparison
Style American IPA
Est Original Gravity 1.066 SG 1.056-1.070 SG
Bitterness (IBUs) 60.6 IBUs 40.0-70.0 IBUs
Color 6.4 SRM 6.0-14.0 SRM
Est ABV 7.0 % 5.50-7.50 %
Profiles for Mash, Carbonation and Aging
Mash Thomas Light Body Fly Sparge
Adjust Temp for Equip
Carbonation Keg
Carb Level 2.3 vols
Fermentation Thomas Ale 3 Stage
Select Fields - Choose Fields
Total Grains 25.00 lb
Total Hops 9.00 oz
Bitterness Ratio 0.916 IBU/SG
Est Pre-Boil Gravity 1.055 SG
Meas Pre-Boil Gravity 1.056 SG
Meas Pre-Boil Vol 14.10 gal
Est Mash Eff 85.0 %
Measured Mash Eff 86.5 %
Yeast Cells Needed 478.8 Billion
Measured OG 1.065 SG
Est Final Gravity 1.013 SG
Measured FG 1.012 SG
Est Attenuation 78.8
Meas Attenuation 80.6 %
Measured ABV 7.0 %
Total Cost 46.28 $

# Thank You!




THE BREWING NETWORK