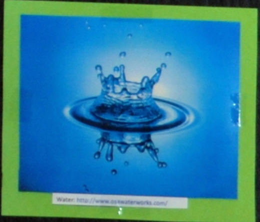
2012

From the Lab into the Kettle

Anthony McCauley
Parkland College

From the Lab Into the Kettle



Water: http://www.synesterworks.com/

Water

Many people seem to think that beer is just water, malted barley, hops, and yeast. While in general they are correct, what they don't know is how complex some of these things are. Water making up the most of what beer is has a huge impact on the end flavor. The composition of the water has got to be one of the most important things in brewing. The following is a look at ions commonly found in water across the nation. Brewers often have to keep mind that a change of location can change a flavor of a beer. You can take the same ingredients of the beer and make it in a different state, and because of the ambient bacteria and the composition of the water, the beer will taste completely different than the original beer.

Ca^{2+}: Calcium Ion

- Reacts with the Phosphates (K_2HPO_4 and KH_2PO_4) to form the precipitate Calcium Phosphate.
- Formation of these Calcium Phosphates precipitates release H^+ ions into the water which intern lowers the PH.
- $Ca^{2+}(aq) + 2HPO_4^{2-}(aq) \leftrightarrow 2H^+(aq) + Ca_3(PO_4)_2(s)$
- Having enough of the Calcium ion is necessary in order to counter-balance the buffering effect of the Phosphate Ions in the mash.
- Too much will cause the Phosphates to precipitate out and rob the yeast of a vital nutrient used during the fermentation process.
- If there is a Calcium deficiency in the water, then adding gypsum ($CaSO_4 \cdot 2H_2O$).
- Optimum concentration of the Calcium ion is $< Ca^{2+} > = 50 - 100\ mg/l$

Mg^{2+}: Magnesium Ion

- Magnesium Ion players an important role in several enzymatic reactions that take place throughout the entire brewing process.
- Optimum concentration of Magnesium is $< Mg^{2+} > = 10 - 15\ mg/l$.
- Exceeding 30mg/L will introduce a sharp-bitter and unwanted flavor to the beer.
- A deficiency in Magnesium ions can be corrected by the introduction of Epsom salt ($MgSO_4 \cdot 7H_2O$).
- However, Epsom salts have a pronounced bitterness and excessiveness amounts are more harmful to the mash than a deficiency.

CO_3^{2-} and HCO_3^-: Carbonate and Bicarbonate Ions

- Both the Carbonate and Bicarbonate ions can be problematic to brewers.
- The Carbonate ions seek to first form a Bicarbonate ion which intern seek to form carbonic acid, both do this by ripping an H^+ off of an H_2O molecule.
- $CO_3^{2-} + H_2O \leftrightarrow OH^- + HCO_3^-$
- $HCO_3^- + H_2O \leftrightarrow OH^- + H_2CO_3$
- The problem that occurs is the release of the OH^- (hydroxide ion). This can cause a rise in the PH and ultimately problems within the mashing process.
- When in the correct amounts, these reactions will help to balance the release of H^+ ions.
- The formation of the carbonic acid in the mash is irrelevant because the acid is harmless in mash.
- These ions also promote the harsh side of flavors introduced from the hops.
- Optimum levels of Bicarbonate are $< HCO_3^- > = 61 mg/l$. This equates to about 100 mg/l of $CaCO_3$.
- In short by balancing the Bicarbonate ions you balance the general Alkalinity of the water. This is shown by the following equation (the << and the >> means the concentrations are separate from each other)
- Alkalinity = $\ll HCO_3^- \gg + 2 \ll CO_3^{2-} \gg + \ll OH^- \gg - \ll H^+ \gg$
- The alkalinity should range between 25-50 mg/l. In that range any worry about levels of Bicarbonate should be taken care of.

Other Various Ions:

- Copper: Causes a haze and is toxic to yeast in levels higher than 10 ppm.
- Chloride: May hamper yeast flocculation (clumping and settling).
- Iron: May cause a haze in beer and can hamper yeast activity, this isn't wanted in brewing.
- Manganese: It's important for proper enzymatic action in the mash but the malt usually contains enough and is unwanted in the water.
- Nickel: Causes foaming, as well as a strong metallic taste in the beer, the less of it the better.
- Potassium: Can inhibit some enzymatic reactions as well and cause a salty taste to the beer.
- Sodium: In levels of 75 ppm to 150 ppm it can introduce a round smoothness to the beer, but when it's also in the presence of sulfate, it will create an unpleasant harshness.
- Sulfate: Imparts a sharp "dry" edge to well-hopped beers, in the presence of sodium or potassium it creates a harsh dryness.

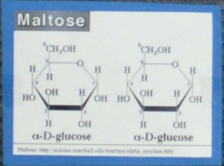
PH: a Necessity of Brewing

- PH is a rather important thing to monitor while brewing beer.
- Yeast thrives in an environment and close to a PH of 7 and can do its job down to a PH of 4.
- In the process of making beer, the wort should have a PH around 5.2 – 5.6. If everything including the composition of the water is correct, then achieving this will not be hard.
- Typically the Phosphates found in malted barley will achieve a mash's PH of about5.8 and once all the hops are in and the boil complete then the PH should drop to the appropriate range.
- This is assuming that you are working with pale and amber malts, when you deal with darker malts they are more acidic than previously mentioned malts. Depending on the amounts used there may have to be a compensation for the acidity but usually it will be fine.

Beer: http://www.beer101.com/beercalories.htm

Barley

The next major ingredient used in the process of making beer is Barley. Now someone might just jump up and say all barley is the same however, that is not quite true. Starting out there are two types of Barley used in brewing Six-row Barley and Two-row Barley. There are several differences in between the two plants but for the sake of simplicity we'll keep it at Two-row is used in quality home and micro brews and contains less enzymes to break down starches. While Six-row has a higher enzyme content is more often used in lesser quality American pilsners (i.e. Miller, Coors, Bud etc.) along with corn, the extra enzymes help break the starch down in the corn. All biased opinions aside lets dive into the mystical world of brewing grains.



Maltose: http://science.marshall.edu/murraye/alpha_amylase.htm

Sugar: The sweet side of beer:

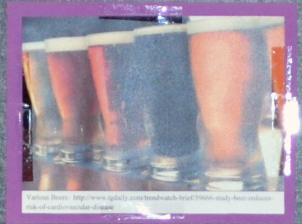
- The sugars that are extracted from the malt during the mashing process are mostly why beer is beer. Without sugars and starches the yeast would never have anything to consume, and then would never produce the Carbon-dioxide (CO_2) or the ethyl-alcohol (C_2H_6O).
- Yeast can most effectively consume and produce it's reactants with the monosaccharide's Fructose, Mannose, Galactose, and Glucose. All of those sugars save Fructose are Hexose's (they have six carbons) while Fructose is a pentose (it has 5 carbons).
- Glucose (the most common of the monosaccharaides in beer) only occurs 8-10% of barley sugars, in a pure state that is.
- Much more common is Maltose, a disaccharide composed of two glucose connected by a 1-4 bond (the 1 carbon on one molecule and the 4 carbon molecules are bonded)
- There is one final sugar related to maltose that is common in beer's mash and wort. This sugar is called Maltotriose, which is essentially Maltose with another glucose thrown on using a 1-4 bond.

Pale Barley: http://www.thebrewhouse.co.nz/webstore/

Barley: This is where the grain comes into play.

- The starch amylose is broken down into maltose, and maltotriose by α-Amylase.
- From the starch Amylopectin the Amylase breaks glucose and Amylodextrin.
- Amylodextrin will be broken down in time by the Amylase.
- A small trick that many brewers use to test when their mash is complete is to take a small sample and add a dash of iodine to it. The iodine will turn a color of blue or purple if there is any significant amounts of Amylodextrin in the mash.
- This is done because Amylodextrin is not fermentable or even consumable by yeast, but once broken down into its constituent parts then it's fully fermentable.
- Sugars are drawn from the Barley by a process called Mashing.
- This is when the grain is steeped in water between 150°-155°F much higher you'll kill the enzyme lower and the enzyme won't work.
- In this stage your drawing out the enzymes and the starches into the water into a sort of tea, letting it set at the pre-mention temperature the enzymes will soon go to work and leave you with solely fermentable sugars.
- At this point you sparge or draw off the malt-tea, drawing the water through the bed of grain as to draw off as much of the sugar as possible.

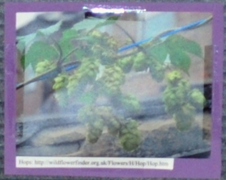
Mash: http://www.innerchanellerfinance.com/category/homebrew/



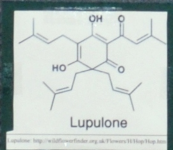
Various Beers: http://www.tgdaily.com/trendwatch-brief/59666-study-beer-reduces-risk-of-cardiovascular-disease

Hops

One of the most mysterious and well known ingredients of beer is hops. To start out with a hop is the female head of the plant Humulus Lupulus. This plant is strange in the fact that the female and male parts of the plant are grown on two separate plants. In certain countries the cutting of the male is head is illegal due propagation issues that occur (except those needed for the stimulation of the female plant). Hops were first introduced to beer in order to help the preservation of the beer. Over time the bitterness and various aromas that hops bring to beer became the standard flavor and even to today where the preservation aspect is no longer needed we still add hops for the flavors. Certain beer flavors have been shaped by the preservation ability of hops. One kind of beer call an IPA (India Pale Ale) was created in Britain in the 1790's. This beer was created in order to be able to withstand the long shipping times to India (at the time a British colony). As such a large amount of hops was added to aid in preservation of the beer. To this day IPA's still have a strong bitterness from hops.



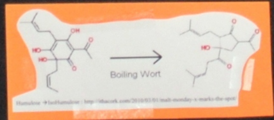
Hops: http://wildflowerfinder.org.uk/Flowers/H/Hop/Hop.htm



Lupulone: http://wildflowerfinder.org.uk/Flowers/H/Hop/Hop.htm

- Hops contain three kinds of acids alpha-acids (α-acids), beta-acids (β-acids), and gamma-acids (γ-acids).
- Both the alpha and beta acids are found in soft resins in the hop flower.
- The gamma-acids are hard resins that as such are insoluble, thus they do not add nor take away any particular flavors to the beer.
- The alpha and beta acids are also known as Humulone and Lupulone.
- Both Humulone and Lupulone both have three isomers found in the hop's resins.
- These isomers have the prefix's Co- and Ad- (along with the original compound. Co-Humulone, Ad-Humulone, and Humulone).

- Brewers concern themselves with Alpha-acid content of the hop, seeing as that is the where the flavor they wish to create comes from.
- Beta acids create a strong unpleasant bitterness to the brew that is unwanted but most hops contain so little of this type of acid that it's usually irrelevant.
- The Alpha-acids provide the main part of the bitterness associated with beers.
- Hops that have a higher amount of Co-Humulone will actually provide a slightly more bitter taste than a lower Co-Humulone hop.
- Most High Alpha-acid hops also have a high Co-Humulone content, so this doesn't quite matter all that much.
- The solubility of alpha acids in wort is rather poor. During the boiling of the wort, the alpha acids undergo Isomerization and turn into far more soluble iso-alpha-acids.
- One of these iso-alpha-acids Isohumulone is the reason for the hops having such strong ability to preserve beer. It provides protection from bacteria such as *Lactobacillus*.
- Hops also bring a verity of essential oils that are used in the flavoring of the beer. Such as Humulene which provides a flavor best described as "Elegant" and Myrene which provides a strong and intense flavor often described as "Pungent".



Humulone → IsoHumulone

Yeast and Bacteria

Probably the important ingredient of all beer making is yeast. Technically speaking the Wort doesn't become beer until you have added yeast, so without yeast, you can't make beer at all. From the outside it just looks like yeast is yeast there is no difference. However, this is why there are several hundred different types of beer. Two beers can have the same composition but use different yeasts and come out with different final flavors. In modern day you can get any type of yeast anywhere and replicate virtually any beer except for a few brews with specific methodology that is reliant on ambient bacteria and yeast. Back when brewing beer had started you only used the yeast that you had in your region of the world and this is where the regionalism of beer started.

Yeast: http://www.mahalyer.com/?p=1816

- All yeast are fungi, not meaning he gets to go to all the best parties but that it's a part of the fungus family.
- In the case of beer Yeast take the sugars that are collected from the grain during the mashing process and releases Ethyl-Alcohol (C_2H_5O), and Carbon-dioxide (CO_2).
- $C_6H_{12}O_6 \rightarrow C_2H_5O + CO_2$
- For a simple home brewer this is all that they have to worry about, you add the yeast and it makes the alcohol and carbon dioxide. But when you get to large scale brewing and working with one to three hundred gallon batches, you have to consider one more aspect, this reaction is exothermic.
- When home brewing the heat doesn't add up, but large scale brewing has to worry about the heat of large batches or else the heat could kill the yeast causing a failed fermentation, or causing the formation of haziness and off-flavors often referred to as skunkiness by beer drinkers.
- Now yeast are a funny little critter, they are surprising resistant to a lot of stuff. Compared to other bacteria and other microbial organisms they have a huge PH range they can live in, but one that can be easily be exceeded by brewers.
- So why is it that they die, seeing as the end conditions of beer are still suitable for the thriving of the yeast, well it has more to do with killing of the enzymes in the yeast by the alcohol.
- Once those guys are killed you basically have little fungus that can no longer produce the food that they need so, the little buggers die.

Lactobacillus: http://www.sciencephoto.com/media/

Bacteria:

- As was said in the intro to this section, certain beers can only be made in certain regions of the world due to the ambient yeast and bacteria.
- An example of this would be what is referred to as Belgium attic beers. This is a style of beer from the Belgian region of the world where brewers would take their beer and put it in a large open vat and let the yeast and bacteria in the air and in the attic go to town.
- Now this seems unsafe because there is a chance of pathogenic bacteria floating around, but between hops and yeast, wort is such a un-bacteria friendly place that very few strains of pathogenic bacteria will ever survive the brewing process.
- Bacteria such as Lactobacillus, Pediococcus, and Brettanomyces will thrive in wort, and eventually be killed off by the increasing acidity, lack of oxygen, and increased alcohol content.
- These beers that use these bacteria are referred to as sour beers; this is because they have a sour taste to them from the lactic acid the bacteria produce.
- The same exact process is used is making open air pickles, and sauerkraut.

Attic Beer: http://knittles.ticklefish.org/

BIBLIOGRAPHY

Noonan, G. J. Brewing Lager Beer; Brewers Publication; Boulder Colorado, 1986.

Miller, D. The Complete Handbook of Home Brewing; The Garden Way Publishing; Pawnat, Vermont 1988.

Fix, G. Principles of Brewing Science; Brewers Publication; Boulder Colorado, 1989.