All-grain Brewing Tutorial

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Contents

1 How to Use this Guide

First, gather the necessary equipment covered in the "Equipment" section. Secondly, choose a recipe, either from the "Recipes" section in this tutorial or from the endless online sources. With the necessary equipment and recipe acquired, including the required ingredients, simply follow the "step-by-step" section and come out on the other end with a delicious, bottled, home brew!

Additional Sections are included for further knowledge on the subject of home brewing, but are not necessary to brew. These sections are recommended in order to improve your next iterations of home-brew. Before delving into the more technical areas of text- "The 4 main ingredients of Beer" and "More on the Process"- I would recommend one iteration through the "step-by-step" section. This will provide a tangible experience to reference when reading about the technical specifics.

Furthermore, the "Calculations" section teaches the user how to calculate Alcohol by Volume (ABV), the amount of water used in each process, along with the International Bitter Units (IBUs) and Standard Reference Method value (SRM) of beer. Once again this section is not necessary to come out with a delicious beer and many recipes include these calculations.

Don't be afraid to dive in and make mistakes! And remember to invite friends to the brew day. They will lighten the cleaning/sanitizing load and will more than likely be happy to be repaid with some delicious home brew! Happy Brewing!

2 The 4 main ingredients of Beer

2.1 Grain

There are a multitude of grain - both malted and unmalted - used in brewing beer. These include barley, wheat, rice, corn, rye and oats. The most common is malted barley. Malt refers to grain once it has undergone the process of germination and subsequent drying. While brewers typically purchase the milled grain for their recipe from their local home brew store or online, the malting process is described next for the curious reader.

2.1.1 Malted Barley

Malted Barley is created by undergoing germination and kilning, creating diastase (enzymes which break down starch into sugar), soluble starch, and soluble sugar - all necessary for brewing.

Before the malting occurs, one must find suitable barley. There are a number of different varieties of barley, some more appropriate for making beer. Once chosen, the kernels of this variety are tested for degrees of moisture, ability to germinate and protein content (nitrogen level). Once suitable barley is chosen, it is steeped to different degrees for different desired malts.

For 40 hours the barley sits in fresh water tanks, with three periods (of about 8 hours) when the water drains, such that the barley is moisturized to around 40 to 45%. The barley is then dried and ventilated in germination rooms for about 5 days at around 60 °F, becoming "green malt." The malt is kilned for about 30 to 35 hours by slowly bringing up the temperature ranging from 122 °F (for lager malts) to 221 °F (for stronger malts).

After the kilning, the finished malt contains sugars, starches and enzymes crucial to the brewing process. Once the rootlets are separated from the malted barley mechanically, it is ready for the brewing process!

2.2 Hops

Hops are the conelike flowers that are used to counteract the sweetness of the malt. While brewers have utilized hops for thousands of years, they starting being used regularly in the 1800s[1]. The many varieties (currently over one hundred) of hops are native to temperate areas such as North America, Asia and Europe. Along with contributing bitterness, hops help to preserve beer, as well as add flavor and aroma. While no known pathogens can survive in finished beer (will never "spoil" in the way that other consumables will make you sick), old or stale beer is not pleasant to drink.

The lupulin glands contain both oils and resins. The hop oils add the "hoppy" aroma and flavor to beer. The resins impart bitterness to the beer by contributing both alpha and beta acids. The resins are not naturally soluble however. Alpha acids require isomerization - using the heat of the boil - in order to become soluble. Beta acids become soluble through oxidation. Brewers are primarily concerned with the alpha acids since those contribute more bitterness, and hops are advertised in terms of this concentration as a result.These acids are measured by their weight relative to the weight of the flower as a whole. Thus, a alpha acid concentration of 4% means that 4% of the flower's weight consists of alpha acids.

There is evidence that hop's ability to hinder bacterial growth - which spoils beer - is the reason, the super "hoppy" beer style, IPA (India Pale Ale) was created. Legend has it that the beer Britain sent their troops to India -during the colonization efforts - rutinely spoiled due to lack of refrigeration. Allegedly, Bow Brewery's George Hodgson created the first IPA: an unprecendented "hoppy" and highly alcoholic ale (both of which act as preservatives) in order to allow the beer to survive the long voyage [4].

2.3 Water

Water makes up roughly 90 to 95% of beer. It interacts with all processes in brewing: malting, mashing, boiling, fermenting, and therefore the characteristics of the water will affect the flavor of the beer. The rule of thumb is that if the water is suitable for drinking than it is suitable for brewing. However if you know your water to contain high levels of iron, bicarbonates or sulfur then it is advised to use bottled water.

The simplest way to begin improving your beer is to remove the excess chlorine. One can do this by boiling the water beforehand or by using a filter. Any mineral in excess will ruin your beer. Before water could be treated with modern technology (changing the water profile), the water in an area determined what styles of beer were developed as it affected what would taste good.

The more significant mineral reactions occur during the mash and an understanding of water chemistry can greatly improve the quality of your beer. When minerals salts are added to water they dissolve and "dissociate" (ions separate from each other). For example, when the calcium sulfate ($CaSO_4$) is added the calcium dissociates improving the clarity of the beer. As you get more advanced you may want to send your water to a lab. This fairly cheap analysis will allow you to adjust the minerals of your water to match nearly any water profile found around the world.

2.4 Yeast

A favorite saying of brewers is that "brewers make wort, yeast makes beer." Yeast is a fungus: a living organism. It consumes sugar in order to create more yeast cells and in the process creates the awesome "waste" products that make beer so great: carbon dioxide and alcohol!

For brewing purposes, yeast is primarily broken down into two categories: ale yeast and lager yeast (but there are hundreds of varieties within these categories). While it is completely possible to make great beer at room temperature with both varieties, ale yeast works best if used at temperatures between 55 and 75°F. Ale yeast is inhibited at lower temperatures: below 50°F many strands will be unable to ferment. Lager yeast is most effective when the fermenting beer is kept between 32 to 55°F, and is typically kept below 45°F.

The process of making lager beers takes much longer than ales and is called "lagering." While ale will be done fermenting after around two weeks, lagering can go on many months but the length depends on the recipe and variety.

Yeast has a massive effect on the taste of the finished beer, and different strands will create different characteristics in your final beer. For example another by-product form yeast are "fruity" esters. A strand that produces a high amount of these can be used to impart a fruity flavor to your finished beer.

3 Equipment for this Guide

The following equipment (and images) can all be found at northernbrewer.com. Similar products can be found at your local home brew store.

3.1 For Brew Day

1) Boil Kettle

Fig. 1: Heats strike water, sparge water and used to boil your extract.

2) Propane Burner

Fig. 2: Used to heat your boil kettle. You will also need a propane tank (available at many gas stations and hardware stores.

3) MLT

Fig. 3: Mash/Lauter Tun.

4) Bucket

Fig. 4: Large enough to hold pre-boil volume.

5) Sparge Arm

Fig. 5: Plastic rectangle sits on top of MLT, dispersing water over the grain. The tube connects to your boil kettle holding your sparge water.

6) Fermenter

Fig. 6: Bucket or Carboy with Airlock.

7) Cleaning Solution

Fig. 7: PBW: Powdered Brewery Wash.

8) Sanitizer

Fig. 8: I use "Star San" to sanitize everything. Works in 1-2 minutes and does not require rinsing. Bleach works as well but must be thoroughly rinsed off prior to use.

9) Thermometer

Fig. 9: It is important to monitor temperatures throughout the process and to calibrate your thermometer before brewing.

10) Hydrometer

Fig. 10: For calculating Specific gravity (density) and in turn the amount of alcohol present in your finished beer.

11) Immersion Chiller

Fig. 11: One of many ways to quickly cool you wort post boil. Put directly into the boil kettle and run hose water through.

3.2 For Bottling Day

1) Bottles

Fig. 12: About 48 for 5 gallons. Best to buy these full of your favorite commercial beer, drink, save and clean!

2) Bottle Caps

Fig. 13: Bottles must be sealed with caps. These you must buy new.

3) Bottle Capper

Fig. 14: Used to seal caps onto the bottles.

4) Bottle Priming Sugar

Fig. 15: Dry Malt Extract. More sugar added prior to bottling in order to "bottle condition" (carbonate the beer in the bottle). Many different types of sugar can be used: cane, DME, etc.

5) Bottling Bucket

Fig. 16: Bucket with hole and spout used during bottling process.

6) Bottle Filler

Fig. 17: Attaches to Bottling Bucket spout. Automatically leaves perfect amount of head space in bottle.

4 Step by Step Brew Day

4.1 Cleaning and Sanitizing

Every equipment item used should be cleaned. Everything that comes in contact with the wort after the boil must be sanitized. Neglecting this step is the quickest way to a contaminated, disappointing brew.

4.2 Mashing

1) Heat up water (called Strike Water) for mash in the boil kettle (volume calculation included “Calculation Section,” but often included with recipe) to about 170°F.
2) “Dough in”: Add grist (crushed grain) and strike water into MLT (Mash/Lauter Tun). Stir and cover
3) Start 60 minute timer for the mash.
4) Stir occasionally, and keep the mash as close to the exact temperature described in recipe (150-160°F) by adding small amounts of boiled water if raise is needed.
5) Heat the sparge water in the boil kettle. Try to time this so that the sparge water reaches the desired tempurature at the end of the mash. Many recipes will inlclude both the volume and tempurature of these (though included in the “Calculation” section). Typically the strike water will brought to about 170°F and will be the same volume as was added to the mash.

4.3 Lautering

1) Do not stir once you begin to lauter, as you want to disturb the grain bed as little as possible.
2) Lift Boil Kettle (with the heated sparge water) to height above the mash tun, and bring the bucket (receiving the extract) below the mash tun.
3) Set up draining tube from mash tun to bucket and the sparge arm from the boil kettle into the top of the MLT
4) Recirculate: drain some wort from the MLT into a pitcher (or some other receptacle) and pour back into the top of the MLT, repeating this process until the drained wort is relatively clear (eliminating grain from the extract).
5) Begin Lautering: slowly drain the wort from the MLT into the bucket.
6) Take a hydrometer reading of the “first runnings” as you begin lautering. Potentially adjust the speed of the lauter based on this reading (remember to adjust for tempurature). The slower you lauter, the more dense your extract will be (also remember the water from evaporation during the boil will also increase the specific gravity).

7) Begin Sparge: slowly drain from the boil kettle into the top of the MLT. Try to match the speed of the lauter.
8) Take hydrometer readings periodically to ensure you are not lautering too quickly.
9) In case of a stuck sparge: stop lauter, stir, recirculate until clear (clearing out tubing/valve if necessary).

4.4 Boiling

1) Pour extract from bucket into Boil Kettle.
2) Begin heating the Boil Kettle.
3) Know the timing and amount of your hop additions as stated in recipe
4) Start the timer upon the first bubble indicating the start of the boil. Typically the boil is an hour long but it can change as indicated by the recipe.
5) Add hops throughout boil as recipe indicates.
6) Put the immersion chiller into the boil with about ten minutes left in the boil (to sanitize) and hook up to I/O hoses. You will probably have to turn up the flame to return the wort to a boil.
7) If using Irish Moss to aid in the clarification of the beer, add with about 5 minutes left in the boil, along with yeast nutrient.

4.5 Cooling

1) Flameout (turn the heat off), and begin running water through the immersion chiller.
2) Note: Everything that comes in contact with the wort after the heat is turned off must be sanitized.
3) Once temperature is below 80°F, measure the specific gravity (called Original Gravity at this stage) reading using the hydrometer and record this value.

4.6 Pitching Yeast

1) Pour wort into your fermenter.
2) Wait for temperature to be a few degrees below the recipe's fermentation temperature (the active yeast will raise it).
3) Add yeast to the fermenter and stir with a sanitized spoon.

4.7 Fermenting

1) Put fermentor in a dark place where the fermentation tempurature, as indicated by the recipe, can be reached.
2) Take specific gravity readings periodically to monitor the fermentation process. Once the specific gravity has stabilized(stayed the same for multiple days in a row) primary fermentation is complete.

5 Bottling Day

1) For a five gallon batch of beer you will need around 48 twelve-ounce bottles. Clean and Sanitize.
2) Add bottling sugar to the beer: (usually about 5oz of DME for a 5 gallon batch) boil sugar with a cup of water for ten minutes and mix into bottling bucket.
3) Fill Bottles and cap, leaving the trub (thick sediment at the bottom) in the fermenter.
4) Store bottles in a dark place between 60 and 70°F for at least 2 weeks.
5) Chill and enjoy! Cheers!

6 About the Process

6.1 Mash

The mash is the process of steeping the grist (milled grain) in hot water for about 60 minutes (can change depending on recipe). The type of mash described in the "Step by Step" section of the this tutorial is known as a single step infusion mash, since a single temperature is maintained throughout. The strike water is heated to 10 to 15°F above the mash temperature since the addition of the grist will lower the temperature.

The mash activates both starch degrading (diastase) and protein degrading (proteases) enzymes. The diasatic enzymes break down starch molecules into fermentable sugars, and unfermentable dextrins (lending to a fuller, creamier body). The proteolytic enzymes break down long chains of protein into smaller ones. This protein degradation improves fermentation characteristics, including attenuation (the amount of fermentable sugar that is converted to alcohol by the yeast) since the smaller strands of protein act as yeast nutrient. The diastic enzymes (alpha-amylase and beta-amylase) as well as proteolytic enzymes are activated at different temperatures.

Different mash temperatures will activate different enzymes in the grain which allows the brewer to control how much fermentable sugar and complex unfermentable sugar ends up in the wort. The more unfermentable sugar that ends up in the wort, the sweeter the final beer.

6.2 Lauter

Lautering is the process of draining the extract from the mash. With our equipment we will be utilizing the false bottom of the MLT to do so.

Sparging, done concurrently with lautering, involves rinsing the grain with hot water to ensure that as many of the sugars as possible are rinsed off the grain. Brewers attempt to get 75% of the mash sugars into the extract, since 100% efficiency is practically impossible although commercial brewers do approach this figure with technologically advanced brewing equipment.

The faster the extract is drained from the mash the lower the density.

6.3 Boil

The boil both kills all beer spoiling bacteria that may be present in the extract as well allows hops to impart their bitterness. The alpha resins in the lupulin glands of the hop flower are not naturally soluble in water naturally. By adding hops during the boil, the chemical reaction called isomerization can occur, allowing the alpha acids to become soluble in water.

Hops are added at different times throughout the boil based on the amount of bitterness the recipe is trying to extract from them. The early additions are primarily added for the amount of bitterness they add to the beer, while the later additions are exclusively to add the oils from the lupulin glands to the brew. These oils simply add aroma and "hoppy" taste while contributing no bitterness. The flavor will be dissipated if the oils spend longer then 10 minutes in the boil, thus the "finishing hops" are added in the final 10 minutes of the boil. Hops can also be added during fermentation ("dry hopping").

The foam that arises during the boil is due to the coagulation of proteins. The addition of hops typically results in intense foaming. To avoid boiling over, turn down the heat, or spray the pot with a spray bottle. While covering the pot will quicken the time it takes to achieve the boil, once attain, refrain from doing so. During the boil sulfur compounds boil off and the lid will block this, leaing to off-flavors like cooked cabbage or corn [2].

Adding Irish moss (simply a quarter teaspoon for a 5 gallon batch) in the last 5-10 minutes of the boil will help settle some of the proteins in the brew (becoming sediment at the bottom of the fermenter called "trub"), clarifying the beer. The boil also coagulates some of these unwanted proteins, improving fermentation, flavor and clarity.

6.4 Cooling

It is necessary to cool the wort before pitching the yeast as high temperatures will kill the yeast cells. After the boil, you want to cool the wort as quickly as possible to minimize contamination.

Quick cooling also helps to eliminate "chill haze": haze that occurs when a beer is chilled due to the precipitation of proteins. Rapid cooling after the boil is creates the "cold break" which precipitates these proteins out of the wort. If cooled slowly, the beer proteins will redissolve when the beer warms.

6.5 Fermentation

During fermentation, yeast - a living organism - converts sugar into alcohol and carbon dioxide along with other by-propducts that affect flavor. After adding yeast, place the fermenter in a dark area since light will react with the hops to create a "skunky" off-flavor. Once the yeast is pitched, signs of fermentation will be noticeable within 24 hours. After about 36 hours Krausen - the foamy head - will appear alongside the high degree of bubbling activity. One can remove this kraeuusen to lessen the bitterness of the beer, and help to reduce "beer headaches" as many of the "fusel" oils will be removed [1]. Between the third and sixth day, the kraeusen will fall back into the beer indicating the brewer can transition the beer to the secondary fermenter.

Primary fermentation should be started at 70-76°F and kept at 60-70°F for ale yeast. Lager yeast should be started at 50-60°F and then kept at 35-55°F after fermentation begins.

While secondary fermentation is not necessary, removing the beer from the trub (sediment that forms gathers at the bottom of the fermenter) will improve flavor. Many brewers will also "dry hop" the beer during this transition - adding additional hops - for a greater floral aroma and taste.

6.6 Yeast Starter

If the cell count is low in the yeast you have purchased, or you are making a beer with a high OG (Original Gravity) you may want to make a yeast starter. A minimum of 1 billion yeast cells is recommended for a 5 gallon batch. If the Original Gravity is over 1.070 I would recommend using even more yeast. Create a yeast starter 24-48 hours prior to your brew day to boost your otherwise slow fermentation:

1) mix 10g of DME per 100mL of water. Total Volume will be based on a calculation of your target cell count.
2) boil for 10-15 minutes
3) add yeast nutrient
4) cool down to under 80°F and pitch yeast
5) put in sanitized container, shake to aerate, and cover with sanatized tin foil
6) let it sit for 24-48 hours, stirring occasionally

6.7 Specific Gravity

The hydrometer is used to measure the specific gravity of your beer. This refers to its density. Distilled water has a specific gravity of 1, so if you float your hydrometer in water, it should read as such. Adding sugar to water increases the density so your wort will have a specific gravity higher than 1. Alcohol is less dense than water, so as the yeast cells convert sugar to alcohol during fermentation the specific gravity of the beer will decrease. The stabilization of this specific gravity reading will indicate that the yeast cells have become dormant and that the fermentation is complete.

The specific gravity reading you will take as you pitch the yeast is called the "Original Gravity." When the reading stabilizes you have attained what is called the "Final Gravity." The difference in these two densities can be used to calculate the amount of alcohol in your beer. Since heat expands, a high temperature wort will be less dense. Make sure to account for the temperature when making specific gravity readings. Read the instructions of your hydrometer to find the temperature (typically 60°F) that it is calibrated for. A 10°F raise in temperature usually lowers the specific gravity reading by about 0.001 but temperature calculators can be found online.

7 Calculations

7.1 Water Volumes

While many recipes include the different volumes of water you will use throughout the process, some don't so it useful to know how to calculate them. The first step is to know the final target volume of your brew. IT is also simple enough to calculate the strike and sparge water volumes based upon your recipe. With these beginning and end volumes we will meet in the middle to find the pre and post boil volumes based and the losses in water that occur.

7.1.1 Fermenter Volume

During fermentation some beer is absorbed by hops and yeast, evaporated, and left in the equipment. The goal is to figure out the final beer volume you achieve based on the amount that goes into the fermenter.

7.1.2 Strike Water Volume

The amount of mash water depends on the amount of grain and the desired mash thickness, both dependent on the recipe. Typically, the ratio is about 1 quart of water for every pound of grain.

7.1.3 Sparge Water Volume

Typically, brewers aim for the sparge water volume to equal that of the strike water present in the mash.

7.1.4 Boil Volume

There is both the pre-boil and post-boil volume. Here we must take into acount the amount of water lost to evaporation as well as how much the volume of the wort increases based on the heat. It is up to the brewer to determine the efficiency of their individual setup. It is the Post boil wort that ends up in the fermenter.

7.2 ABV (Alcohol By Volume)

Using your hydrometer to measure the "Original Gravity" and "Final Gravity" (specific gravity readings) the simplest way to calculate the ABV (Alcohol by Volume) of your beer is to navigate to an online calculate and input these values.

(1)

7.3 IBU (International Bittering Units)

IBUs are calculated based upon the amount of alpha acids present in the hops you add to your beer. Alpha acids content is measured relative to the weight of the hop flower as a whole. IBU measurements are the estimations of how much of these alpha acids are isomerized and subsequently dissolved in your beer. The calculation involves the AAUs (Alpha Acid Units), and boiling gravity, volume and time:

$$IBU = AAUxUx75/V \tag{2}$$

AAU	Alpha Acid Units	% weight of hop
U	utilization	boil time and gravity
V	recipe volume	

Utilization is the percentage of alpha acids that isomerize over time. The following utilization table approximates this value based on boil time and specific gravity readings:

Utilization: Function of Time vs. Boil Gravity

Gravity vs. Time	1.030	1.040	1.050	1.060	1.070	1.080	1.090	1.100	1.110	1.120
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.055	0.050	0.046	0.042	0.038	0.035	0.032	0.029	0.027	0.025
10	0.100	0.091	0.084	0.076	0.070	0.064	0.058	0.053	0.049	0.045
15	0.137	0.125	0.114	0.105	0.096	0.087	0.080	0.073	0.067	0.061
20	0.167	0.153	0.140	0.128	0.117	0.107	0.098	0.089	0.081	0.074
25	0.192	0.175	0.160	0.147	0.134	0.122	0.112	0.102	0.094	0.085
30	0.212	0.194	0.177	0.162	0.148	0.135	0.124	0.113	0.103	0.094
35	0.229	0.209	0.191	0.175	0.160	0.146	0.133	0.122	0.111	0.102
40	0.242	0.221	0.202	0.185	0.169	0.155	0.141	0.129	0.118	0.108
45	0.253	0.232	0.212	0.194	0.177	0.162	0.148	0.135	0.123	0.113
50	0.263	0.240	0.219	0.200	0.183	0.168	0.153	0.140	0.128	0.117
55	0.270	0.247	0.226	0.206	0.188	0.172	0.157	0.144	0.132	0.120
60	0.276	0.252	0.231	0.211	0.193	0.176	0.161	0.147	0.135	0.123

Fig. 18: Palmer [2]

7.4 SRM value (Standard Reference Method)

The many varieties of beer result in a great variability in color, ranging from the very pale light lagers to black stouts. The brewing color Scale SRM (Standard Reference Method) uses light meter-analyzers to reach a value (degree of SRM) of light intensity. While there exist very complicated equipment to measure the exact SRM value, most home brewers simply use references to approximate:

Degree SRM	Color
2.0-4.2°	yellow-gold
10°	amber
17°	brown
35°+	black

[1]

SRM Chart

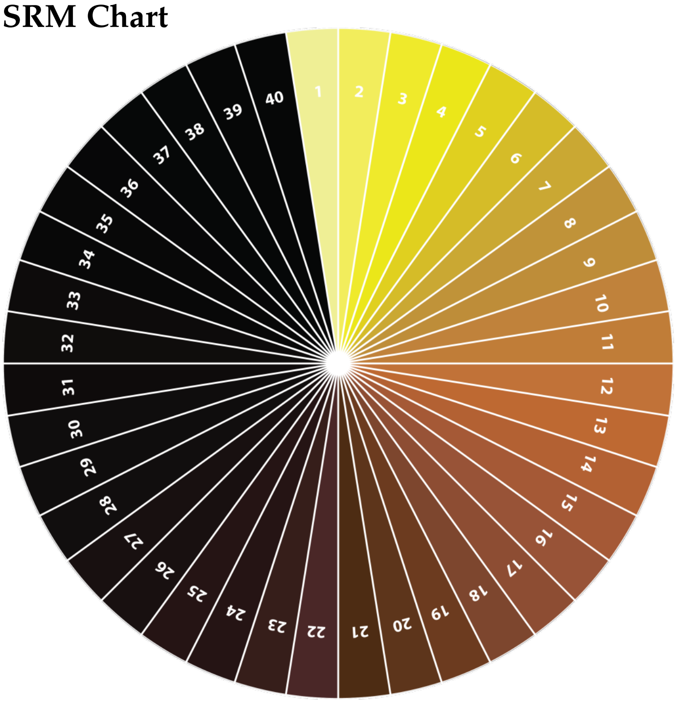

Fig. 19: [6]

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