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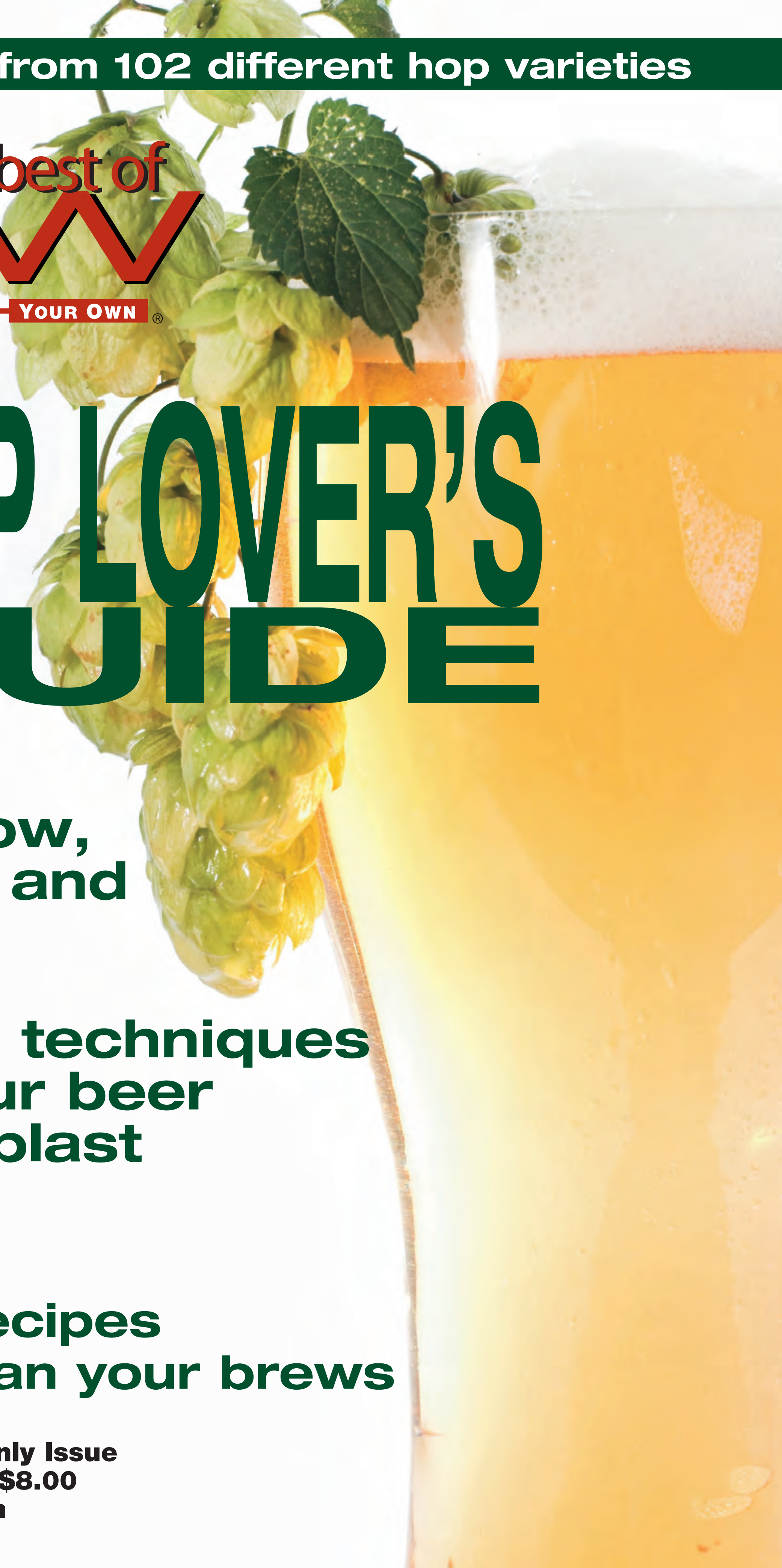
HOP LOVER'S GUIDE



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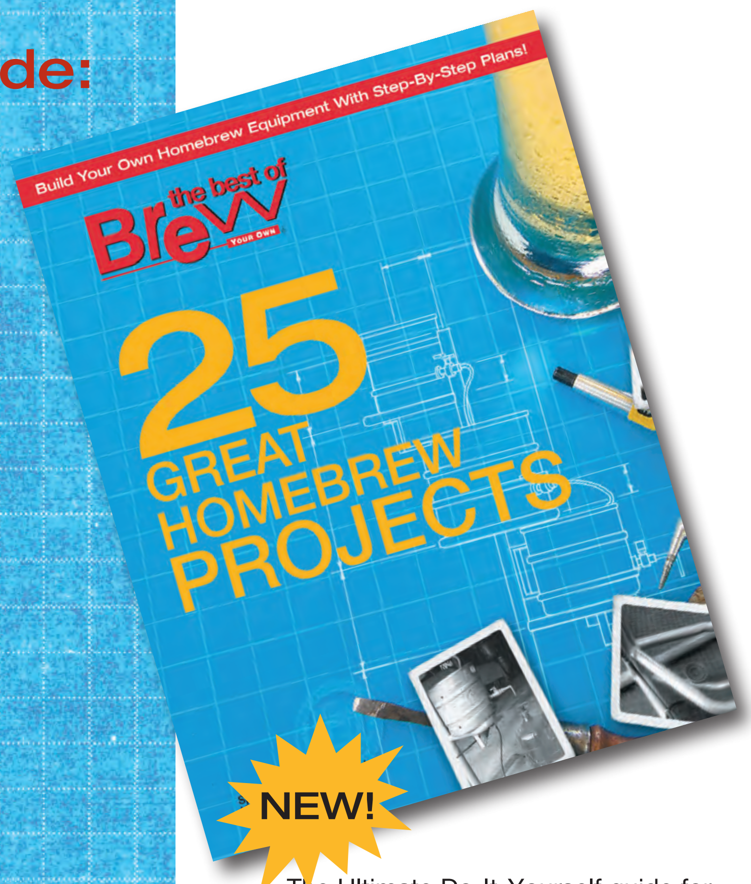

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editor's note

Welcome to *Brew Your Own's* Hop Lover's Guide. Like the vast majority of homebrewers, we love hops. From the mildest Saaz to the wildest "C" hop, we can't get enough of our green friends.

In recent years, homebrewers have been favoring hoppier and hoppier beers. In 1998, BYO published an article called "Pucker up! Way Hoppy Beers." Most of the beers in that collection had an estimated IBU rating of 30 to 60. Around that time — or not too many years earlier — the hoppiest beer you could likely find in your beer aisle was Sierra Nevada's Celebration at 62 IBUs (according to their website).

In 2003, we published an article called "10 Hoppy Clones" and only a couple of the clone recipes were under 60 IBUs. By then, hoppy brews such as AleSmith's IPA, Bear Republic's Hop Rod Rye, Dogfish Head's 90-minute IPA, Russian River's Pliny the Elder, Stone's Ruination, Three Floyd's Dreadnaught and Rogue's I^2PA were commonplace. Russian River Brewing has labeled this accumulation in hop tolerance a Lupulin Threshold Shift, and while mass market brewers worry about inducing "bitter beer face" if they release a beer over 17 IBUs, many homebrewers ask "Where's the hops?" when presented with any beer under 70 IBUs.

If you are a hop-loving homebrewer, this special issue is for you. In it, you will learn what hops are, how to store them, the many ways hops can be used and infused into beer at every stage of brewing (even serving!), how to bring out the best hop character in your creations and even how to grow and dry your own hops. For stovetop extract brewers, we even outline the ways to get around the limitations of a smaller boil volume. And, of course, we throw in some recipes and some do-it-yourself projects. Finally, we have a series of hop charts to help with hop substitutions or finding the hop with the right alpha acid level or cohumulone level for your brew.

Happy hopping!

Chris Colby, Editor

The hop plant (Humulus lupulus) produces the hop cones that are used in brewing. The cones form from the hop flowers and hold the lupulin glands that produce the resins and oils used in brewing. Hop resins can be divided into soft resins, hard resins and uncharacterized resins. The soft resins include the alpha acids. In brewing, the three most important alpha acids are humulone, cohumulone and adhumulone. These compounds, upon boiling, provide most of the bitterness found in beer. Beers brewed with hops high in cohumulone are considered by some to have a "harsher" hop character. The soft resins also include the beta acids that, when oxidized, can also contribute to bitterness. Hop aroma comes from hop oils, which may comprise up to 2% of the weight of the hop. Different classes of compounds, including hydrocarbons, oxygen-containing compounds and sulfur-containing compounds all contribute to hop aroma. Among the hydrocarbons, myrcene, humulene, carophyllene and farnescene are the major components. The noble hops contain high amounts of humulene.

Brewers use the cones of the

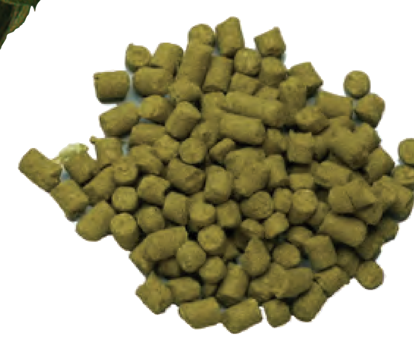
HOP basics

by **Steve Parkes**

Historically speaking, hops are a fairly recent innovation in the brewing world. Although evidence exists of their cultivation as early as 200 AD in Babylon, and 700 AD in Germany, they were not widely used in brewing until the 11th Century in Bavaria. They didn't gain wide acceptance until the 15th or 16th Century in the rest of Europe. In England they were not highly thought of initially, and their use was banned by King Henry VIII. This was only a short time before brewers began emigrating to the United States, so American brewers have been using hops for about as long as their European counterparts.

It is impossible to think of a beer today that does not include hops. In fact, it is a legal requirement in the UK that beer includes hops in the formulation. The Bavarian purity law, the Rheinheitsgebot, written in 1516, also legislates the use of hops for German brewers.

Hops provide a bitter flavor, a nice flavor and a pleasant aroma to beer. They enhance the foam on beer and the way the foam clings to the side of the glass. They also provide protection against beer spoilage from certain microorganisms. Over the centuries of hop use, microorganisms have evolved that are resistant to hops, but most of these are found only in breweries. This was once an important factor in the evolution of the beer style known as India pale ale (IPA). This beer was designed to survive a long sea voyage and hence was heavily hopped. As brewers' understanding of microbiology and sanitary brewing practices have grown, hopping levels and alcohol content have dramatically decreased in this famous beer style.



Hop cones used for brewing are the dried seed cases of the hop plant H*umulus lupulus*. The hop plant is a vining plant that can grow as tall as 30 feet (9 m) high. The vines of the hop plant are called bines, because they grab their support surfaces with a multitude of tiny hairs, not the grasping tendrils of a true vine. The hop plant produces flowers that are small, green and spiky, somewhat resembling a bur. From these flowers the hop cone (or strobile) is formed. Hop cones consist of a central strig or stalk, and between 20 and 50 "petals," called bracts. At the base of these bracts, the resin (known as lupulin) is produced as a sticky yellow powder.

> The hops used for bittering and flavoring beer are the female cone of the hop vine (Humulus lupulus).

The hop plant is a perennial with separate male and female plants. All commercial hops, used for flavoring beers of all sorts, grow on the female plants and will contain seeds if male plants are allowed to produce pollen near them. To prevent seeds from developing in the hops, most countries do not permit male plants to be grown anywhere.

In England, male hops are permitted (except in Hampshire) and most English hops contain seeds. The plants grow up strings or trellis wires during the summer and the hops are harvested and dried in September. In England, the USA, Canada and Australia, hops are packed into the final package on the farm where they were grown. In European countries, the individual farmer's hops are blended, re-dried and packed into bales in large lots or processed directly from the farmer's lots.

There is a great deal of variation between hops from the different countries, as well as different growing regions within a country and even from farm

hop plant (*Humulus lupulus*) for bittering their beers

to farm. Typically a hop cone consists of the following components: 10% water, 15% total resins, 0.5% essential oil, 4% tannins, 2% monosaccharides, 2% pectins, 0.1% amino acid, 3% lipids and wax, 15% proteins, 8% ash and 40.4% residual carbohydrate (cellulose, lignin).

Brewers are largely interested in the total resins and the essential oils, which represent the brewing value of the hop. Both are contained in the yellow lupulin dust that is found around the base of each bract on the hop cone. This material is essentially the only portion of the hop a brewer need be concerned with. The rest of the hop's plant matter may perform an important role in the brewery as a separation aid. The green material acts as a filter screen which aids in clarifying the wort after it has been boiled. The other components, particularly proteins and polyphenols, are soluble in boiling wort, although it should be remembered that greater quantities of protein and polyphenols are derived from malt.

The total resins are further sub-divided into hard resins, soft resins and uncharacterized soft resins. Soft resins consist of alpha- and beta-acids and it is those compounds that the brewer is most interested in.

Alpha-Acids

Alpha-acids comprise more than 50% of the soft resins and are largely thought of as the primary source of bitterness in beer. Not directly, though, as they are insoluble in wort and must first be isomerized by heat to become soluble. It requires around 45 minutes of boiling to isomerize and solubilize 30% of the potential alpha-acids from the hops. This amount drops dramatically as the boiling time diminishes. The isomerization reaction results in a change in the chemical structure of the alpha-acid molecule.

Alpha-acids belong to a class of compounds known as humulones. They consist of a complex hexagonal molecule with several side chains, including ketone and alcohol groups. Examples of humulones include humulone, cohumulone, adhumulone, posthumulone and prehumulone. Each different humulone differs in the make-up of the side chain. For instance, humulone has a side chain of isovalerate attached, while cohumulone has isobutyrate as its side chain. These side chains can become detached during extended storage under poor conditions and result in the cheesy flavors sometimes associated with old hops. It has become accepted dogma among brewers to think of each of these humulones as having different bittering characteristics. There are some that swear that the bitterness associated with cohumulone is "harsher" than that from humulone. Other studies have shown no difference in sensory impact when each of the different humulones are compared. Nevertheless, the humulone to cohumulone ratio is now quoted in hop analyses and new varieties are being bred with low cohumulone levels in mind. Historically, the most highly prized hop varieties — including noble hops such as Hallertau, Tettnang and Saaz — also happen to be those that have low cohumulone levels.

The alpha-acid levels in hops begin to tail off immediately after harvesting, and continue to decline in storage. The number quoted to you on a packet of hops was the alpha-acid content when the hops were tested immediately after harvest. Despite the best intentions of the retailer, the hops have been subjected to conditions that cause their alpha-acid levels to be lower. High temperature and exposure to air will speed up the losses of alpha-acids. In hop varieties with poor storage characteristics, up to 50% of the total harvest alpha-acids may be lost in six months when hops are stored at 70 °F (21 °C). A good hop will still lose 20% of its total acids under the same storage conditions. Hops should be stored in a fridge, or preferably a freezer, and air must be excluded from the package. This will more than half the deterioration rate of your hops. Since you have no way of knowing what the hops experienced before you bought them — remember, the inside of a UPS truck can get up to 140 °F (9 °C) in the summer in Arizona — it is always better to buy your hops from a reputable hop supplier.

Additional benefits of alpha-acids are seen from their role in foam formation and head retention. They cross link chemically with certain specific proteins in an extremely complex manner to support foam. If you sip the thick foam on a pint of nitrogen-poured Guinness, you will notice a distinctly more bitter taste than that found in the beer beneath.

Beta-Acids

These compounds are not actually bitter, but will turn bitter when they oxidize during storage. The alpha to beta ratio is considered important in gauging how a hop will provide bitterness as the hops age. The bittering potential from alpha-acids declines with time but the bittering potential from oxidized beta-acids increases. In a hop with a 2:1 ratio of alpha to beta acids, the bittering potential may remain fairly constant. The oxidation reaction will take place to an even greater extent during kettle boiling. Beta-acids consist of lupulone, colupulone, adlupulone and other substances and, like alpha-acids, differ in the structure of the side chains. Again there is a difference of opinion in the brewing world as to the character of bitterness derived from beta-acids compared to that of alpha-acids. In Germany, oxidized beta-acid bitterness is preferred while in Japan it is considered too harsh.

Uncategorized Soft Resins

Dr. David Ryder gave a talk at the National Craft Brewers Conference in Milwaukee on April 28th, 2000, entitled "Hopping to Perfection." Ryder is Vice President of Brewing, Research and Quality Assurance at Miller Brewing Company. In his lecture, Dr. Ryder introduced the idea that perhaps uncategorized soft resins may have some brewing value. In his talk, Ryder announced that Miller researchers have discovered that this fraction contains a portion of hop aroma compounds chemically bound to sugars. The upshot of the research suggested that maybe these compounds find their way into beer where yeast may transform them into beer flavor compounds. However, until the research is published in a journal and is evaluated by brewing scientists, the uncategorized compounds will remain just that, uncategorized.

Oils

The total oils, formed in the lupulin glands, represent the general aroma characteristics of the hop. It varies in concentration depending on hop variety and from season to season. It may be as low as 0.5% or as high as 2%. The oils are soluble in boiling wort but are extremely volatile and are largely lost during the wort-boiling phase of brewing. A full boil of an hour to an hour and a half, needed to volatalize most of the unfavorable aroma characteristics from the malt and precipitate enough of the denatured protein and polyphenols, results in the complete loss of any of the aroma components from the hops. Brewers get around this issue by adding a portion of the hop charge to the boiling wort 5–10 minutes from the end of the boil. Alternatively, brewers add hops immediately after boiling, but before chilling, to attempt to extract the aromas and avoid the losses due to volatilization. The action of yeast fermenting sugar and causing vast amounts of CO_2 to rise through the wort has the effect of carrying hop aroma away with it. While this may produce a wonderful hop aroma in your fermentation area, it will cause a decrease of hop aroma in the beer. Remember that intense hop aromas are not always pleasant, so losing some may be a good idea. Hop aroma may also be added to the finished beer by a process known as dry hopping, in which whole hops are added to the beer in a maturation vessel. Oils dissolve slowly into the beer, probably into the alcohol fraction, while there is no increase in bitterness in the beer.

There may be up to 300 different compounds in hop oil and much of the chemistry associated with their role in beer flavor is yet to be unraveled. Three classes of compounds exist within the hop oil fraction: hydrocarbons, oxygenated compounds and sulfur containing compounds. The majority of the compounds in fresh hops are hydrocarbons (75%) and oxygenated compounds account for most of the balance. Sulfur compounds represent only around one percent of the hop oils, but are potent flavor compounds with low taste thresholds.

Hydrocarbons

Principally, hydrocarbons consist of a class of essential oils known chemically as terpenes. These include monoterpenes such as myrcene, diterpenes such as dimyrcene, and sesquiterpenes such as farnascene, humulene, caryophyllene, selenine and limonene. Each of these essential oils can be isolated and their individual aroma contributions identified. Some are floral, others spicy, some are simply described as “hoppy.”

Myrcene, humulene, caryophyllene, and farnescene are the four major components of hop oil, accounting for up to 80% of the total essential oils. They are, however, extremely volatile and are only found in large quantities in beer that has been dry hopped. The amount of these constituents, and particularly the ratios between them, can be used as clear varietal indicators.

Myrcene particularly is a major oil and is characterized as having an unpleasant, aggressively hoppy aroma, with a harsh grassy character. It is very volatile and hence not found in beer in large quantities unless the beer has been heavily dry hopped. Humulene is the hop aroma that is perhaps the most prized. So hops with a lot of this compound are well thought of, largely because it oxidizes readily and it’s oxidized form is pleasantly hoppy. Saaz contains as much as 45% humulene. Some hop merchants quote the humulene to caryophyllene ratio as an indicator of hop aroma quality.

Oxygen-Containing Compounds

This class of compound grows with time as hops are stored and their components oxidize. Poor storage of hops will result in hops that may contain up to 50% of these compounds. Since they may represent powerful flavoring agents that find their way into beer through late kettle additions of hops, some brewers deliberately age their hops to enhance these qualities. Oxygen-containing compounds consist of oxidized terpenes, higher alcohols, aldehydes, ketones and esters. Linalool and geraniol are higher alcohols and provide a floral character to beers, while geranyl acetate is an ester and provides a fruity character.

Sulfur-containing Compounds

Sulfur-containing compounds are found in trace amounts, but may be potent flavoring agents. Hops in the field are treated with sulfur to control mildew, and in Europe some sulfur may have been added to the warm air in the hop kiln. This causes several highly volatile compounds, including dimethyl sulfide (DMS), to be produced and are responsible for cooked vegetable, onion and garlic flavors. Late kettle additions may slightly increase the levels of these compounds.

Tannins or Polyphenols

Hops also contribute additional polyphenolic compounds to wort, and these compounds are known to contribute significantly to beer haze. Luckily, boiling will cause them to combine with proteins and precipitate out of solution, avoiding additional haze problems with the finished beer. However, beers that are dry hopped often exhibit hazes that are difficult to remove.

Noble Hops

Certain hops are prized for their special characteristics. In Europe these varieties are known as noble hops. The origins of this term are unknown but it is likely that through their long history of use they became prized because beer made from them was favored by drinkers. There are only four true noble hops: Hallertau Mittelfrüh, Tettnang Tettnanger, Czech Saaz, and Spalt Spalter.

Some consider the English varieties Fuggle and East Kent Golding to be noble. They are characterized through analysis as having an alpha to beta ratio of 1:1, low alpha-acid levels (2–5%) with a low cohumulone content, low myrcene in the hop oil, high humulene in the oil, a ratio of humulene to caryophyllene above three, and poor storability resulting in them being more prone to oxidation. In reality this means that they have a relatively consistent bittering potential as they age due to beta-acid oxidation. Their flavor improves as they age during periods of poor storage.

While it would appear that researchers have managed to unravel the exact nature of hop aroma, the sheer number of compounds present, the levels at which they are present, the degree to which they become modified during aging and storage, and the multitude of ways they can be used by brewers, make truly accurate use difficult. Likewise, control of the actual bittering potential of hops is difficult to predict. This is why some of the larger brewers use extracts, emulsions or oils added directly to finished beer as a way of controlling the character of a beer’s bitterness, hop aroma and flavor. This is also why brewers are justified in insisting they are “artists.”

Steve Parkes was Brew Your Own’s *“Homebrew Science” columnist and is Owner and Lead Instructor at the American Brewers Guild.*

recipes

AleSmith IPA clone (AleSmith Brewing Co.)

(5 gallons/19 L, all-grain)
OG = 1.073 FG = 1.014
IBU = 93 SRM = 9 ABV = 7.6%

Ingredients

14.66 lbs. (6.6 kg) Gambrinus 2-row pale malt
2.0 oz. (57 g) crystal malt (15 °L)
2.0 oz. (57 g) Carapils® malt (6 °L)
2.0 oz. (57 g) Munich malt (10 °L)
2.0 oz. (57 g) wheat malt
1.0 oz. (28 kg) honey malt
7.0 AAU Columbus hops (FWH) (0.5 oz./14 g of 14% alpha acids)
7.0 AAU Simcoe hops (FWH) (0.53 oz./15 g of 13% alpha acids)
3.25 AAU Columbus hops (60 mins) (0.23 oz./6.5 g of 14% alpha acids)
1.33 AAU Amarillo hops (30 mins) (0.17 oz./4.8 g of 8.0% alpha acids)
2.25 AAU Simcoe hops (15 mins) (0.17 oz./4.8 g of 13% alpha acids)
2.66 AAU Columbus hops (10 mins) (0.19 oz./5.4 g of 14% alpha acids)
2 AAU Cascade hops (5 mins) (0.4 oz./11 g of 5.0% alpha acids)
5 AAU Cascades hops (1 mins) (1.0 oz./28 g of 5.0% alpha acids)
0.5 oz. (14 g) Columbus hops (dry hop)
0.5 oz. (14 g) Amarillo hops (dry hop)
0.5 oz. (14 g) Cascade hops (dry hop)
0.25 oz. (7.1 g) Simcoe hops (dry hop)
0.25 oz. (7.1 g) Chinook hops (dry hop)
1 tsp. Irish moss (15 mins)
White Labs WLP001 (California Ale)
0.75 cups corn sugar (for priming)

Step by Step

Mash at 152 °F (67 °C) for 60 minutes. Boil for 90 minutes, following hop addition schedule. ("FWH" means first wort hops — hops added to the wort before the boil starts.) Whirlpool wort and let sit for 15 minutes before you begin cooling. The fermentation temperature is 68.5 °F (20.3 °C).

Extract with grains version:

Replace pale malt with 7.25 lbs. (3.3 kg) light dried malt extract and 1.0 lb. (0.45 kg) 2-row pale malt. Steep crushed pale malt plus specialty malts in 64 oz. (1.9 L) of water at 152 °F (67 °C) for 45 minutes. To finish, follow remaining all-grain instructions.

Flying Dog Gonzo Porter clone

(5 gallons/19 L, all-grain)
OG = 1.088 FG = 1.025
IBU = 75 SRM = 83 ABV = 8.2%

Ingredients

15 lbs. (6.8 kg) 2-row pale malt
2.5 lbs. (1.1 kg) crystal malt (120 °L)
1.0 lb. (0.45 kg) black malt
0.5 lb. (0.23 kg) chocolate malt
5.5 AAU Warrior hops (90 mins) (0.34 oz./9.7 g of 16% alpha acids)
9.4 AAU Northern Brewer hops (60 mins) (1.0 oz./30 g of 9% alpha acids)
9.4 AAU Northern Brewer hops (30 mins) (1.0 oz./30 g of 9% alpha acids)
3.0 oz. (85 g) Cascade hops (0 mins)
4.0 oz. (114 g) Cascade hops (dry hops)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast (3 qt./~3 L yeast starter)
0.75 cups corn sugar (for priming)

Step by Step

Mash at 152 °F (67 °C). Lauter slowly to allow maximum sugar collection. Two hour boil. Ferment at 70 °F (21 °C).

Flying Dog Gonzo Porter clone

(5 gallons/19 L, countertop partial mash)
OG = 1.088 FG = 1.025
IBU = 75 SRM = 84 ABV = 8.1%

Ingredients

3.0 lbs. (1.4 kg) Briess Light dried malt extract
6.75 lbs. (3.1 kg) Alexander's Pale liquid malt extract (late addition)
2.5 lbs. (1.1 kg) crystal malt (120 °L)
1.0 lb. (0.45 kg) black malt
0.5 lb. (0.23 kg) chocolate malt
5.5 AAU Warrior hops (90 mins) (0.34 oz./9.7 g of 16% alpha acids)
9.4 AAU Northern Brewer hops (60 mins) (1.0 oz./30 g of 9% alpha acids)
9.4 AAU Northern Brewer hops (30 mins) (1.0 oz./30 g of 9% alpha acids)
3.0 oz. (85 g) Cascade hops (0 mins)
4.0 oz. (114 g) Cascade hops (dry hops)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast (3 qt./~3 L yeast starter)
0.75 cups corn sugar (for priming)

Step by Step

Heat 5.5 quarts (5.2 L) of water to 166 °F (74 °C). Let grains mash, starting at 155 °F (68 °C), for 30 minutes. Heat 2.0 gallons (7.6 L) of water to a boil in your brewpot and 2.5 qts. (2.4 L) of water to 180 °F (82 °C) in a large kitchen pot. Run off "grain tea" to brewpot. Add the 2.5 qts. (2.4 L) of 180 °F (82 °C) water to the grains and let sit for 5 minutes. Run off remaining "grain tea" to brewpot. Add dried malt extract and bring to a boil, adding hops at times indicated in the ingredient list. With 15 minutes left in boil, stir in the liquid malt extract. Cool wort and transfer to fermenter. Add water to make 5.0 gallons (19 L), aerate well and pitch yeast. Follow fermentation instructions in all-grain recipe.

Hop Rod Rye clone (Bear Republic Brewing Co., California)

(5 gallons/19 L, all-grain)
OG = 1.072 FG = 1.017
IBU = 84 SRM = 17 ABV = 7.2%

Ingredients

8.75 lbs. (4.0 kg) 2-row pale malt
2.5 lbs. (1.1 kg) rye malt
1.25 lbs. (0.57 kg) flaked rye
1.15 lbs. (0.52 kg) Munich malt
0.625 lbs. (0.28 kg) wheat malt
0.625 lbs. (0.28 kg) Carapils® malt
1.75 oz. (49 g) black malt
10.4 AAU Tomahawk hops (60 mins) (0.74 oz./21 g of 14% alpha acids)
4.73 AAU Centennial hops (30 mins)

(0.43 oz./12 g of 11% alpha acids)
24.3 AAU Tomahawk hops (0 mins)
(1.7 oz./49 g of 14% alpha acids)
0.75 oz. (21 g) Amarillo hops (dry hop)
1.0 oz. (28 g) Centennial hops
(dry hop)
1 tsp Irish moss (15 mins)
Wyeast 1272 (American Ale II) or
White Labs WLP051
(California V) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash in at 145 °F (63 °C) then ramp temperature to 152 °F (67 °C) for conversion. Mash out to 170 °F (77 °C). Boil for 90 minutes, adding hops at the times indicated in the ingredient list. Whirlpool the wort and let it sit for 15 minutes prior to cooling. Ferment at 68 °F (20 °C).

Extract with grains version:

Replace the 2-row pale malt with 4.25 lbs. (1.9 kg) dried malt extract and 1.0 lb. (0.45 kg) 2-row pale malt. Steep crushed grains in 2.25 gallons (8.5 L) of water at 152 °F (67 °C) for 45 minutes.

Mirror Pond Pale Ale clone (Deschutes Brewery Inc., Oregon)

(5 gallons/19 L, extract with grains)

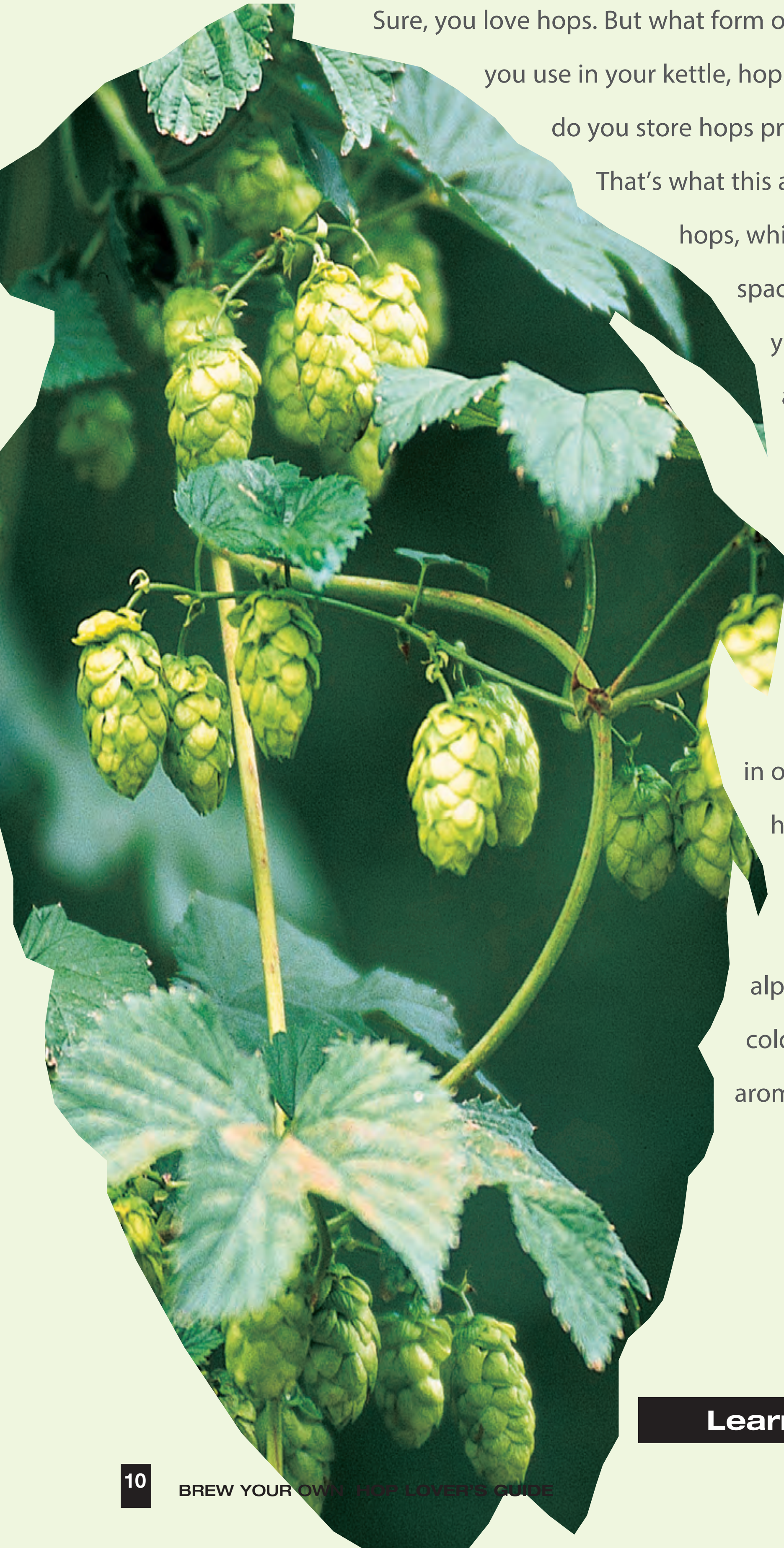
OG = 1.052 FG = 1.013
IBU = 40 SRM = 10 ABV = 5.0%

Ingredients

2.5 lbs. (1.1 kg) light dried
malt extract
3.3 lbs. (1.5 kg) Coopers
Light liquid malt extract
(late addition)
1.0 lb. (0.45 kg) Munich malt (10 °L)
14 oz. (0.39 kg) Great Western two-row
pale malt
4.0 oz. (112 g) crystal malt (60 °L)
8.25 AAU Centennial hops (60 mins)
(0.69 oz./19 g of 12% alpha acid)
3.75 AAU Cascade hops (15 mins)
(0.75 oz./21 g of 5% alpha acid)
3.75 AAU Cascade hops (5 mins)
(0.75 oz./21 g of 5% alpha acid)
1 tsp. Irish moss (15 mins)
White Labs WLP001 (California Ale) or
Wyeast 1056 (American Ale) yeast
(1.75 qts./~1.75 L yeast starter)
0.75 cup corn sugar
(for priming)

Step by Step

Steep crushed malts in 3.3 qts. (3.1 L) of water at 150 °F (66 °C) for 30 minutes. Rinse grains with 1.5 qts. (~1.5 L) of water at 170 °F (77 °C). Add water to make 3 gallons (11 L), stir in dried malt extract and bring to a boil. Boil for 60 minutes, adding hops and Irish moss at times indicated. Cool wort and transfer wort to fermenter. Top up to 5 gallons (19 L) with cool water. Aerate wort and pitch yeast. Ferment at 68 °F (20 °C).



Sure, you love hops. But what form of hops — whole, plug or pellet — should you use in your kettle, hopback or secondary fermenter? And how do you store hops properly so they remain fresh and usable? That's what this article is all about. We'll examine whole hops, which are lightly-processed, but take a lot of space to store. If you use a hopback, though, you'll need whole hops for it. Hop pellets are a condensed form of hop that also give higher utilization in the kettle. Hop plugs can be thought of as a hybrid of these two forms.

Storing your hops properly means keeping them cold and away from oxygen. The hops you buy should come in oxygen-barrier bags. Once you get them home, you should store them in a freezer — a non-frost-free freezer if you plan to store them for awhile. Hops will lose alpha acids over time, even when stored cold, but they will maintain their flavor and aroma properties for a few years.

Learn the types of hops, how to

buying & storing HOPS

by **BILL PIERCE** & **CHRIS COLBY**

There are many different varieties of hops available to the homebrewer. In addition, hops come in a few different forms. Different forms of hops vary with regards to their storage potential and performance in the brewhouse.

Whole Hops

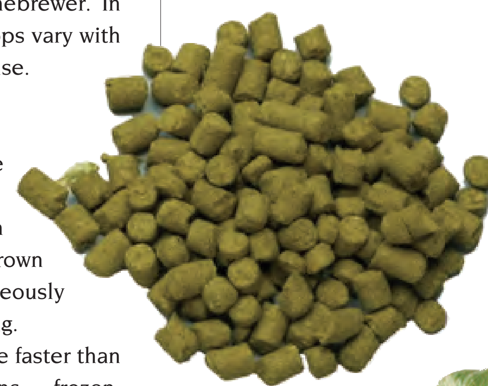
Whole hops are simply hop cones that have been picked and dried in large kilns called oasts. Some European hops may also have been sulfured, meaning sulfur sticks were burned in the kiln to give the hops a uniform green appearance. German hops are almost always sulfured. In contrast, no hops grown in the United States are. Whole hops, or cone hops, are sometimes erroneously called leaf hops, although the leaves of the hop plant are not used in brewing.

In storage, the lupulin glands of whole hops are exposed and will oxidize faster than pellet or plug hops when exposed to oxygen. Under optimal storage conditions — frozen, inside an oxygen-barrier bag — the difference is minimal.

Many homebrewers grow their own hops, and hence have whole hops to brew with. However, measuring the alpha acid level in them requires laboratory analysis and equipment beyond that found in a typical homebrewery. However, hop producers, larger breweries and some independent laboratories routinely measure the alpha acid level of hops. For a fee, it is possible to send samples to these labs for precise analysis.

When boiled, whole hops float on top of the wort and it is easy to siphon clear wort out from underneath them after the boil. When brewing with a kettle with a spigot at the bottom, a screen at the bottom of the kettle may be employed to keep the hops from exiting the kettle. Whole hops may be used in a hopjack (or a Randall) as the cones will form a filter bed for the wort or beer. In the same situation, pellets would dissolve into a "sludge," blocking the flow of the liquid.

Whole hops are only lightly processed (just picked and dried) and this appeals to some brewers. Many prefer to use whole hops when dry hopping — even if they use pellet hops in the kettle — as they feel their aroma qualities are better.



Hops come in several different forms. The most popular three forms for homebrewers are pellets (top), whole hops (middle) and plugs (bottom).

Hop Plugs

Hop plugs are made from whole hops, cut into small pieces and pressed into half-ounce (14 g) disks. As with T-90 hop pellets (discussed below), they contain all the material of the whole hops. Unlike hop pellets, the material in hop plugs will float once the plug breaks apart in the kettle.

One advantage of plug hops is that their weight is consistent and this can make it easy to make hop additions to your kettle during the boil. As long as you round off your hop additions to the nearest half-ounce (14 g), you can simply count out the number of plugs you need.

Pellet Hops

Pellet hops are whole hops that have been finely milled and extruded through a die. Pellets are widely used by homebrewers and commercial brewers because they are much more compact than whole hops and have better storage characteristics when storage conditions are not optimal. Pellet hops also show about 10% better hop utilization than whole hops.

The friction from pressing the hop material through the die causes it to heat up. In

evaluate them and how to properly store them at home.

the past, this heat led to the degradation of some volatile hop components. These days, pellet dies are cooled by liquid nitrogen and the flow rate through the die and temperature of the extruded product are monitored to keep these losses to a minimum.

In the kettle, pellets dissolve and the material from them sinks to the bottom of the vessel. (They also sink when used as dry hops.) As such, whirlpooling your wort — stirring it in a circular motion, then letting the debris settle in the middle of the kettle — is advised before racking the wort to your fermenter.

The kind of pellets homebrewers are familiar with are T-90 pellets. These pellets contain everything that whole hops contain — both lupulin gland material and vegetative matter. As such, the alpha acid rating of these pellet hops will be the same as (or close to) the alpha acid rating of the whole hops they were made from.

T-45 pellets are hop pellets made such that about half of the vegetative matter is removed, thus roughly doubling the alpha acid percentage of the pellet. Brewers wishing to brew highly bitter beer, but minimize the amount of vegetative matter in their kettle should consider T-45 pellets. Unfortunately, they are not commonly available to homebrewers.

Evaluating

When buying hops, you should search out those that look green, not brown. In addition, hops should smell fresh, not cheesy. A standard way of evaluating hop aroma is to take whole hops in your hands, rub them together briskly three or four times, then quickly put your nose right down in the sample and smell it. Rubbing ruptures the lupulin glands and releases aroma.

At your homebrew shop, hops should be stored frozen and packaged in oxygen barrier bags. Hop resins are somewhat unstable and prone to oxidation, and the alpha acid level of hops decreases over time. This loss is decreased at lower temperatures, and when hops are shielded from exposure to oxygen. The storage stability also varies with the variety of hops. Some varieties will lose more than 50 percent of alpha acids if stored for a year at room temperature; the loss is less than 15 percent if stored at 0 °F (-18 °C). Of course, you will not be able to smell the aroma of frozen and properly bagged hops until you open the package.

Storing at Home

Hops should be stored in your freezer at home until it is time to use them. If you are going to use the hops within a few months, an ordinary frost-free freezer — like that found in almost all home refrigerators — is fine. (For short term storage, up to a couple weeks, your refigerator is fine.)

For long-term storage, hops should be placed in a non frost-free freezer which does not go through freeze-thaw cycles. If you are storing your hops for 6 months or longer, they would be better off permanently frozen. In this state, they can last for years. The alpha acids will still degrade over time, but the hops will still smell good and be suitable for brewing.

If you don't have a frost-free freezer, you can package the hops to minimize the effects of the freeze-thaw cycles. Take a small cooler or large ziplock bag and place a layer of crushed ice in it. Pack your hops — inside their oxygen barrier bags — on top of the ice and then cover them with more crushed ice. A buffer of ice between the hops and the environment of the freezer will keep the hops at a more steady temperature. After awhile in storage, you may need a hammer to crack through the ice to get to your hops.

Some homebrewers buy their hops in bulk late in the year after the harvest comes in. (If you plan to do this, be sure you confirm which year your hops come from.) Big packages of hops should be broken down into smaller packages once opened. Regular plastic ziplock bags are oxygen permeable. If you're stuck with this as your only option, double bag your hops to minimize exposure to oxygen.

Food sealers, such as Seal-A-Meal or Food Saver, are great for repackaging bulk hops into smaller portions. These devices remove most of the air (and hence the oxygen) from the portion, then seal the bag. The bags themselves can be stored in a large canning jar.

If you plan to store hops for any length of time, be sure to label the bag with the variety, the alpha acid rating and when you purchased it.

Bill Pierce was the Advanced Homebrew columnist for Brew Your Own.

recipes

Sierra Nevada Celebration Ale clone

(Sierra Nevada, California)
(5 gallons/19 L, all-grain)

OG = 1.064 FG = 1.014
IBU = 60 SRM = 12 ABV = 6.4%

Ingredients

11.5 lbs. (5.2 kg) 2-row pale malt
1.0 lb. (0.45 kg) crystal (35 °L)
0.5 lb. (0.23) Carapils® malt
11 AAU Chinook hops (60 mins)
(1.0 oz./28 g of 11% alpha acids)
8.5 AAU Cascade hops (30 mins)
(1.7 oz./48 g of 5.0% alpha acids)
0.66 oz. (19 g) Cascade whole hops
(dry hop)
0.66 oz. (19 g) Centennial whole hops
(dry hop)
1 tsp. Irish moss (15 mins)
Wyeast 1056 (American Ale) or
White Labs WLP001
(California Ale) yeast
(1.5 qt./1.5 L yeast starter)
0.75 cups corn sugar (for priming)

Step by Step

Mash at 156 °F (69 °C) for 60 minutes. Boil wort for 90 minutes, adding hops as indicated in the recipe. Ferment at 66 °F (19 °C). Dry hop in secondary for 5 days at 60 °F (16 °C).

Extract with grains option:

Replace 2-row malt with 3.0 lbs. (1.4 kg) light dried malt extract, 3.3 lbs. (1.5 kg) light liquid malt extract and 1.5 lb. (0.68 kg) 2-row malt. Steep crushed grains in 120 fl. oz. (3.5 L) of water at 156 °F (69 °C) for 45 minutes. Combine "grain tea" and water to make 4.0 gallons (11 L) in brewpot. Add dried malt extract and boil wort for 90 minutes, adding hops as indicated in the recipe. Do not let wort volume dip below 3.0 gallons (11 L) during boil. Add liquid malt extract at end of boil. Let sit (with the brewpot cover on) for 15 minutes, then cool wort. Transfer to fermenter and top up to 5 gallons (19 L). Aerate wort and pitch yeast. Ferment at 66 °F (19 °C). Dry hop in secondary for 5 days at 60 °F (16 °C).

Two Hearted Ale clone

(Bell's Brewery, Michigan)

(5 gallons/19 L, all-grain)

OG = 1.058 FG = 1.012
IBU = 56 SRM = 8 ABV = 5.9%

Ingredients

9 lb. 5 oz. (4.2 kg) 2-row pale malt
2.0 lbs. (0.91 kg) Vienna malt
0.5 lbs. (0.23 kg) crystal (10 °L)
0.33 lbs. (0.15 kg) Carapils® malt (6 °L)
5.5 AAU Centennial hops (60 mins) (0.5 oz./14 g of 11% alpha acids)
5.5 AAU Centennial hops (45 mins) (0.5 oz./14 g of 11% alpha acids)
5.5 AAU Centennial hops (30 mins) (0.5 oz./14 g of 11% alpha acids)
5.5 AAU Centennial hops (15 mins) (0.5 oz./14 g of 11% alpha acids)
0.33 oz. (9.4 g) Centennial hops (0 min)
0.33 oz. (9.4 g) Centennial hops (dry hop)
0.5 tsp. Irish moss (15 mins)
Wyeast 1272 (American Ale II), White Labs WLP051 (California V) or yeast cultured from a bottle of this beer
0.75 cups corn sugar (for priming)

Step by Step

Mash at 152 °F (67 °C) for 1 hour. Boil wort for 75 minutes, adding Centennial hops at the times indicated in the recipe. Ferment at 70 °C (21 °C). Dry hop for three days in secondary.

Extract with grains option:

Replace 2-row malt with 2.0 lbs. (0.91 kg) light dried malt extract, 3.3 lbs. (1.5 kg) light liquid malt extract and 1 lb. (0.45 kg) 2-row malt. Steep crushed grains in 1.2 gallons (4.6 L) of water at 152 °F (67 °C) for 45 minutes. Begin 60-minute boil with 4.0 gallons (15 L) and do not let volume dip below 3.0 gallons (11 L) during boil. Add dried malt extract at beginning of boil, hops at times indicated and liquid malt extract at end of boil. Ferment at 70 °C (21 °C). Dry hop for three days in secondary.

Racer 5 clone

(Bear Republic Brewing Co., California)

(5 gallons/19 L, all-grain)

OG = 1.071 FG = 1.015
IBU = 60 SRM = 10 ABV = 7.2%

Ingredients

11.25 lbs. (5.1 kg) 2-row pale malt
1 lb. 11 oz. (0.76 kg) wheat malt
10 oz. (0.28 kg) crystal malt (15 °L)
6.7 oz. (0.19 kg) dextrose (corn sugar)
3.4 oz. (95 g) Carapils® malt
6.1 AAU Chinook hops (90 mins) (0.51 oz./14 g of 12% alpha acids)
8.7 AAU Cascades hops (60 mins) (1.74 oz./49 g of 5.0% alpha acids)
0.3 oz. (8.5 g) Centennial hops (dry hop)
0.3 oz. (8.5 g) Amarillo hops (dry hop)
0.2 oz. (5.7 g) Cascade hops (dry hop)
0.2 oz. (5.7g) Tomahawk hops (dry hop)
Wyeast 1272 (American Ale II) or White Labs WLP051 (California V) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash in at 145 °F (63 °C) then ramp temperature to 152 °F (67 °C) for conversion. Mash out to 170 °F (77 °C). Boil for 90 minutes, adding hops at the times indicated in the ingredient list. Ferment at 68 °F (20 °C).

Extract with grains version:

Replace pale malt with 3.0 lbs. (1.4 kg) light dried malt extract, 4.0 lbs. (1.8 kg) light liquid malt extract and 5.3 oz. (0.15 kg) 2-row malt. Steep crushed grains in 1 gallon (3.8 L) of water at 152 °F (67 °C) for 45 minutes. Combine "grain tea," water and dried malt extract in brewpot to make 4 gallons (15 L) of wort. Boil for 90 minutes, keeping boil volume over 3.0 gallons (11 L) by topping up with boiling water, if needed. Add hops at times indicated and liquid malt extract at end of boil. Ferment beer at 68 °F (20 °C).

Hop Jack Pale Ale clone

(Widmer Brothers Brewing Co., Oregon)

(5 gallons/19 L, extract with grains)

OG = 1.056 FG = 1.014
IBU = 40 SRM = 19 ABV = 5.4%

Ingredients

1 lb. 2 oz. (0.51 kg) Coopers Light dried malt extract
3.3 lbs. (1.5 kg) Muntons light liquid malt extract (late addition)
0.5 lb. (0.23 kg) Vienna malt
1.0 lb. (0.45 kg) Munich malt
1.5 lb. (0.68 kg) crystal malt (40 °L)
0.25 lb. (0.11 kg) dextrin malt
1.9 AAU Willamette hops (60 mins) (0.38 oz./11 g of 5% alpha acid)
5.6 AAU Cascade hops (60 mins) (1.1 oz./31 g of 5% alpha acid)
7.1 AAU Cascade hops (10 mins) (1.4 oz./39 g of 5% alpha acid)
3.8 AAU Centennial hops (2 mins) (0.31 oz./9 g of 12% alpha acid)
3.7 AAU Cascade hops (2 mins) (0.74 oz./21 g of 5% alpha acid)
1 tsp. Irish moss (15 mins)
White Labs WLP001 (California Ale) or Wyeast 1056 (American Ale) yeast (1.75 qts./1.75 L yeast starter)
0.75 cup of corn sugar (for priming)

Step by Step

Steep crushed malts in 2.0 gallons (7.6 L) of water at 150 °F (66 °C) for 45 minutes. Rinse grains with 1.0 gallon (3.8 L) of water at 170 °F (77 °C). Add water to make 3 gallons (11 L), stir in dried malt extract and bring to a boil.

Add Willamette and Cascade (bittering) hops and boil for 60 minutes. Add the liquid malt extract and Irish moss with 15 minutes left in the boil. Add flavor hops for the last 10 minutes of the boil. Add aroma hops (Centennial and Cascade) for the last 2 minutes of the boil. When done boiling, cool wort and transfer to a sanitary fermenter. Top up to 5.0 gallons (19 L) with cool water. Aerate wort well and pitch yeast. Ferment at 68 °F (20 °C) for 10 to 14 days. Bottle your beer, age for two weeks and enjoy!

How you add hops to your beer affects the hop character of the finished beer. Traditionally, bittering hops were added to the boiling wort and boiled for 60 to 90 minutes. If additional hop flavor and aroma was required, some hops were added late in the boil. However, hops can be added to the wort before it boils (as in first wort hopping), to the kettle or other vessel after the boil (as in whirlpool hopping) or at any time throughout the boil (as in continuous hopping).

Hops can also be added after the boil. Traditionally, hops added to a cask were called dry hops, but you can also add hops in kräusen beer or a hop tea, or at bottling.

Different hops have different characteristics. The level of alpha acids and essential oils in your beer is altered by boilovers, blowoffs, hops clinging to the side of your kettle and oxidation, so your brewing techniques also affect hop character.

Learn how and when to add hops to

hopping METHODS

by **Chris Colby**

Homebrewers love beer recipes, and we've included plenty in this Hop Lover's Guide. However, a recipe is not the same thing as a finished beer — you need to brew it. And, the equipment and techniques you use affect the character of your brew. To give one hop-related example, how you chill your wort affects your hop profile. If you use an immersion chiller, the wort is chilled in bulk. However, if you employ a counterflow chiller, hot wort remains in the kettle as smaller volumes of wort are drawn off and quickly cooled as they flow through the chiller. As such, the heat profile the hops experience differs between the two methods. If you are used to brewing beers with lots of hops added late in the boil, switching cooling methods will alter your hop flavor and aroma.

Likewise, your water chemistry, how you handle the hopping during the boil, how you conduct the fermentation and how well you protect the beer from oxidation all influence the hop presentation. For example, did you know that the air inside the little spaces between the bracts of the hop cones can contribute to oxidation if you dry hop? It can. To minimize this threat, you can add a small amount of dry ice (frozen CO_2) to your keg before you rack the beer into it. Add the dry hops to the keg and let them sit there as the dry ice sublimes. Put a square of aluminum foil over the top of the keg to hold the gas in, but don't seal the keg. The evolving CO_2 gas will displace much of the oxygen entrained in the hops. Once the dry ice is gone, promptly rack the beer into the keg, seal and purge the headspace with a couple bursts of CO_2 from your tank and your beer is being dry hopped. (Note: don't rack beer into the keg while solid CO_2 remains, this will cause explosive foaming.)

That's a small example, but in the next few chapters, we'll review the major hopping techniques and how they influence hop character. How long you heat your hops affects whether they contribute mostly bitterness, flavor or aroma to your beer. Likewise, knowing the factors that decrease hop bitterness during beer production can also influence when you decide to add your hops — and hops can be added at many points in the brewing stream besides the boil.

Brewing a quality hoppy beer is not excessively difficult. But to really make a great pale ale, IPA or double IPA — or even a nice, hoppy robust porter — you need to know the various influences on hop profile beyond hop varieties and how much of them you add. This section covering hopping methods is divided into three chapters, wort boiling and hop character (page 16–18), fermenting and conditioning (page 19–21), and hop character (page 22–23).

The method and timing of adding hops influences the hop profile of your beer.

your beer and how your brewhouse choices affect hop character.

WORT BOILING & HOP CHARACTER

by **Chris Colby**

The bitterness in beer is developed by boiling the hops in wort. Likewise, boiling hops adds hop flavor and aroma. The bitterness balances the sweetness of the beer and the flavor and aroma of hops add a special "spice" to it. The amount of bitterness in beer depends primarily on how much hops are added to the kettle, the alpha acid rating of the hops and how long they are boiled. The hop flavor and aroma of a beer can be altered by adding hops at different times during the boil. Hop flavor and aroma can also be added to beer outside of the boil, for example, when a hop jack is used or the beer is dry hopped.

There are many hopping methods and these affect hop character.

Since the boil is where most of the "action" happens with regards to hopping, we'll start by reviewing what happens in the boil.

What Happens During the Boil?

A lot happens during the boil, even though brewers don't do much during this period except for adding hops (and perhaps a fining agent) at specified times.

Wort Expansion: Wort expands when heated. A 5-gallon (19-L) brewer is unlikely to notice this, but larger-volume homebrewers may notice the volume shrinkage upon cooling. At 68 °F (20 °C), ale fermentation temperature, wort occupies about 4% less volume than it did at boiling (around 215 °F/102 °C for most worts). For a 5-gallon (19-L) batch, the volume shrinkage is approximately equal to two (12 oz./355 mL) beers.

Evaporation of Water: When wort boils, water evaporates from it. One consequence is that, the wort volume will shrink during the boil. (This shrinking more than counteracts the expansion due to heating, which stops once boiling starts and the temperature is no longer rising.)

An easy way to determine the vigor of your boil is to measure the evaporation rate. To calculate this, measure your wort volume at the beginning of the boil and again one hour later. Your evaporation rate, given in percent per hour, is calculated as:

$$\text{Evap. Rate (per hour)} = 1-(V_{60}/V_0) \times 100$$

where V_{60} is your wort volume after boiling for 60 minutes and V_0 is the volume of the wort before the boil (i.e. when it's been boiled for 0 minutes).

For example, let's say you had 6 gallons (23 L) at the beginning of the boil (time 0) and 5 gallons (19 L) one hour later (time 60). Your evaporation rate would be 1-(5/6) X 100 = 16.67, an evaporation rate of 16.67%. For most homebrews, a 10% evaporation rate per hour provides a sufficiently vigorous boil. Less than this and your hop extraction and break formation suffers. An evaporation rate over 20% can result in excessive wort darkening.

Another consequence of evaporation is that the concentration of sugars will increase in the wort. You can estimate how the gravity of your wort will change by using the formula $C_1V_1 = C_2V_2$. In the equation, C_1 is the concentration of wort at the beginning of the boil and V_1 is the volume at the beginning of the boil and C_2 is the unknown concentration of wort at the end of boil, when the wort will have a volume of V_2.

Let's say that you have 6 gallons (23 L) of wort at a specific gravity of 1.040 and plan to boil it down to 5 gallons (19 L). Substituting the numbers into the equation, we get 6(40) = 5(X), where X is our unknown specific gravity. (Notice that you only use the decimal portion of specific gravity — i.e. 1.040 becomes 40.) Solving for X, we get 6(40)/5 = 240/5 = 48. So our expected specific gravity would be 1.048.

Wort Color: Wort darkens for two reasons. Primarily, the wort gets darker because it is getting more concentrated and secondarily because chemical reactions are forming colored molecules from colorless precursors. The carmelization of sugars is one example of this type of reaction. Maillard reactions are another. Carmelization occurs when (colorless) sugars react with other sugars and form color-bearing polymers. Maillard reactions occur between sugars and amino acids.

If you want to differentiate between the effect of wort concentration and direct color development in your wort, try this experiment. Take a sample of wort immediately after the hot break then take a second sample at the end of your boil. You can compare the two to see the extent of wort darkening. To estimate how much of the darkening was due to color-developing reactions, dilute your final wort back to the concentration it was when you took the first sample. Comparing the early and late worts, corrected for loss of water, should show you how much wort color comes from Maillard reactions and sugar carmelization.

Don't take this test too seriously, though. Other things that affect color are going on as well, including the effect of the precipitated break material. However, this is a good, quick check for extract brewers whose beers are too red. You can check if the color is developing during the boil or if your extract was simply carrying too much color to begin with.

Evaporation of DMS: Other volatile chemicals, including DMS, are also evaporated during the boil. DMS is a molecule that leads to a cooked corn smell in the beer. Precursors to DMS are found in lightly kilned malts. A good, rolling boil — followed by fast wort cooling — will minimize DMS concentration in the finished beer.

Convection Currents: Wort is not heated evenly. When temperature differences within a volume of liquid exist, convection currents result. In commercial kettles, the shape of the kettle — and the presence and placing of internal heating elements — are designed to induce currents in the kettle. Convection currents help mix the wort and help with break formation. Homebrewers don't need to worry about convection currents. Stirring the wort a few times during the boil should ensure adequate mixing.

Cessation of Biological Activity: Boiling will kill bacteria and yeasts. Some bacteria and fungi can form spores and survive a boil, but there are no common wort or beer spoilers that do this. Boiling will also inactive the enzymes you utilized in the mash.

Kettle Additions: The boil is also a time for kettle additions such as Irish moss, which helps clear break material, and yeast nutrients.

Wort pH: In the boil, calcium ions in the water and phosphates derived from the grain react and drop out of solution. This results in a drop in pH. The wort should drop from a pH of 5.4–5.6 to a pH around 5.0–5.2. If your wort pH is too high, the resulting beer may taste dull and lifeless. Adding a small amount of calcium — about ¼ tsp. gypsum or calcium chloride per 5 gallons (19 L) — can help the pH get to the right point.

Isomerization of Alpha Acids: Wort is a complex mix of water and biochemical molecules, including carbohydrates, proteins, lipids and other molecules. When you heat this mixture, many chemical reactions occur. I've already mentioned two important reactions — those that form Maillard products and those that form break material.

The chemical reactions involving hops and their bittering compounds are what we are interested in here. In the boil, alpha acids in hops are converted via heat to iso-alpha acids. Alpha acids are insoluble in wort and are not bitter. Iso-alpha acids, however, are both soluble and bitter. The amount of alpha acids converted to iso-alpha acids depends primarily on how long the wort is boiled and the specific gravity of the wort. The conversion of alpha acids to iso-alpha acids is relatively slow and never reaches completion. In the first few minutes of the boil, only a small percentage of the total alpha acids in the hops is converted to iso-alpha acids. After an hour, only 25–30% of the alpha acids are converted and boiling beyond an hour brings diminishing returns in terms of how much iso-alpha acid is converted over time. Most brewers boil their bittering hops for an hour, or sometimes as long as 90 minutes.

The "thickness" of the wort also affects the rate of conversion of alpha acids to iso-alpha acids. In higher gravity worts, fewer alpha acids are converted compared to in lower gravity worts. Most homebrew recipe calculators take this into account when calculating the estimated IBUs from a recipe. This is especially a concern in methods of extract brewing that involve boiling a concentrated wort.

"Traditional" Hopping

Hop growers often divide hop varieties into two functional categories: bittering hops and aroma hops. Bittering hops are varieties that have high levels of alpha acids, over 8% or so and up to 18% in some of the newest high-alpha types. Like all hops, they also contain oils and other compounds that result in hop aroma and flavor, but bittering hops are primarily used as a source of alpha acids. Aroma hops have lower alpha levels, some as low as only a few percent, but have a mixture of oils that are prized for their aroma properties. Some varieties are called dual purpose hops because they can be used either as bittering hops or as aroma hops.

Most brewers add bittering hops at or near the beginning of the boil. The hops are then boiled for 60–90 minutes, until the rate of alpha acid isomerization slows (in other words, when boiling the hops longer would result in only small increases in bitterness). Sixty to ninety minutes is frequently also the amount of time the wort is boiled to achieve the right amount of evaporation and hit the correct OG for a beer. During the first few minutes of this boiling time, most of the volatile oils in the hops are blown off.

If more hop flavor and aroma is desired than would be delivered by the single dose of bittering hops, aroma hops are added late in the boil. Usually, hops may be added with 10 to 20 minutes left in the boil if more flavor is desired. Hops added in the last 10 minutes of the boil —and especially those added during the last few minutes or right at knockout, when the heat is shut off — contribute hops aroma, from the volatile oils they contain. Adding hops late in the boil, and thus boiling them for only a short period of time, ensures that the hop oils are not all evaporated away.

Brewers should note that although hop varieties may be described bittering or aroma hops and kettle additons may be referred to as bittering, flavor or aroma additions, all hops contribute to bitterness, flavor and aroma to some degree. A beer brewed with a single addition of bittering hops will still retain a small amount of hop flavor and aroma. Likewise, an addition of hops late in the boil will contribute a small amount of bitterness along with the flavor and aroma contribution.

"Traditional" hopping — with bittering hops added early, then flavor and aroma hops added near the end — is widely practiced because it gives the biggest "bang for your buck" and results in the fewest problems in the brewhouse. If you pick a nice, high-alpha variety to use for your bittering hops and then throw in some aroma hops at the end, you'll need fewer hops overall to reach your target bitterness. This saves money in terms of how much you pay for the hops and, for commercial brewers, how much wort is lost due to being absorbed into the hops. Also, with less hop "gunk" in your kettle, getting the wort from the kettle to your fermenter can be easier. And finally, alpha acids and the essential oils that convey flavor and aroma aren't the only compounds in hops. As with most plant material, they also contain tannins. Methods of hopping that involve using more hops to obtain less bitterness run the risk of being overly grassy or — in extreme circumstances — excessively tannic or vegetal.

Multiple Addition or Continuous Hopping

Some beers, especially IPAs and other hoppy brews, are made with numerous hop additions, many in the middle of the boil. The Dogfish Head 60-, 90- and 120- Minute IPAs carry this approach to the extreme and add hops continually throughout the boil. Proponents of adding hops throughout the boil claim that this method gives a hop character you can't achieve with a "bookend" approach of adding hops early and late.

Critics of the practice say it is a waste of hops as "middle hops" contribute little flavor or aroma, but aren't boiled long enough to extract much bitterness either. They also claim that, because you are using more hops to achieve the same level of bitterness and aroma, beers brewed with middle additions could be more likely to show a grassy or vegetal character due to the increased amount of plant material added to the kettle. Homebrewers interested in brewing hoppy beers will most likely try both approaches and decide for themselves which is more suited to their tastes.

Hop Bursting

Some homebrewers have experimented with adding all of their hops at or near the end of the boil — a practice that is sometimes referred to as hop bursting. Typically, to overcome the decrease in hop utilization, a larger amount of hops is added than would be usual. The short boil time results in a beer with an enormous "burst" of hop flavor and aroma.

Whirlpool Hopping

In many commercial breweries, hot wort is pumped to a settling tank after the boil. The wort enters the tank at an angle to the side of the vessel, causing the wort to rotate. For this reason, this vessel is called the whirlpool. In the whirlpool, solid matter suspended in the wort collects in the center of the rotation and falls to the bottom of the tank as the spinning slows. This leaves a little cone of debris in the middle of the tank. The hot wort — now with less debris suspended in it — is then pumped through the chiller. In some craft breweries, hops are added at this stage. In some cases, enough hops are added that a significant percentage of the IBUs of the beer are obtained in the whirlpool. Since most homebrewers do not employ a separate whirlpool tank, this method is not used much in homebrewing. Some homebrew recipes, such as the ACME IPA recipe on page 26, use this method by having the homebrewer stir stir his wort in a circular manner after knockout.

Hopback

A hopback (or hopjack) is a device that strains spent, boiled hops out of wort. That's where the name comes from, in fact: It's something that's supposed to hold the hops back. At the same time, a hopback also helps filter undesirable coagulated protein ("hot break") from the boil.

Most brewers would argue that a hopback is more than just a filter device: The term also has come to imply that the gizmo uses an addition of fresh, unboiled hops as a filter medium and as a way of imparting additional hop character to the wort. A commercial hopback is usually designed like a mash tun and has an inlet, where the wort (still containing kettle hops and coagulated proteins) enters. It features some kind of screen or false bottom, where the fresh hops are added, and an outlet.

First Wort Hopping

In first-wort hopping, some of the bittering hops are added to the kettle along with the very first runoff from the mash. This differs from the usual homebrew practice of adding hops after the wort has begun boiling (and perhaps after the first signs of a hot break are visible). In a blind taste test cited in "Principles of Brewing Science" by George Fix (Brewer's Publications, 1999), beer drinkers showed a preference for Pilsners brewed using first-wort hopping over Pilsners brewed the traditional way. Specifically, the subjects in this test — originally published in a German magazine called *Brauwelt* — felt that first-wort hopped beers have a more rounded bitterness and a more elegant hop nose. Other studies have not supported these findings, but some brewers remain enthusiastic about this method of hopping. Clearly, more experimental work is needed.

The procedure for first-wort hopping is simple. Take a portion of your bittering hops (the hops you would normally add early in the boil) and add them to the first wort that is run off from the mash.

Typically between ¼ to ½ of the bittering hops are used for first-wort hopping, although some brewers have used more. Using less than ¼ will probably not make much of a difference in your finished beer. You may want to decrease the amount of hops slightly, since they will be boiled longer. Consult a hop utilization chart to see if the added boiling time will make a difference.

Practical Considerations

Once you have formulated the size and timing of your hop charges, the actual boiling of the hops is fairly easy, but there are a few practical considerations. In order for alpha acids to be isomerized efficiently, the wort must be hot and in motion. The churning action of the boil helps extract bitterness from the hops as well as the heat. Anything you do to decrease the amount of motion of the hops decreases your hop utilization. One way this may happen in a homebrewery is when homebrewers use a hop bag. A nylon or muslin bag works well to hold the hops and makes it easier to remove them from the kettle after the boil, where they won't interfere with racking the wort to the fermenter. However, the bags also constrain the flow of wort past the hops required. If you do bag your hops, make sure to leave at least three times the volume in the bag as the hops occupy. (In other words, don't cinch the sack tight around the hops, give them room to expand and room for hot wort to flow by them.

Hops that cling to the side of the kettle will also decrease your hop utilization. Take your brewing spoon or paddle and knock these back into the kettle. Avoid boilovers, as any hops carried out of the kettle by the boilover will no longer contribute any bitterness.

Hops can be added anytime around the boil, from slightly before (as in first wort hopping) to just after (as in whirlpool hopping and when using a hop jack). As we'll see in the next chapter, hops can also be added later "downstream" — in the fermenter, in the serving vessel or even as the beer is being poured.

FERMENTING & CONDITIONING

by **Chris Colby & Don Million**

Hops play a number of roles in the brewing process. Depending on when they are added, they contribute bitterness, flavor, aroma or something of all three. The bitterness comes from alpha acids contained in hops, while flavor and aroma come mostly from volatile oils. The term volatile refers to the fact that the oils boil out of the wort relatively quickly — most within 15–20 minutes. As we saw in the previous chapter, this is why brewers normally add flavor and aroma hops closer to the end of the boil. However, what happens to the wort and fermenting beer after the boil also affects the hop character of beers. And, of course, hops can be added to the fermenting or conditioning beer at a variety of different points after the boil.

Fermenting

Once the hopped wort is cooled, it contains all the iso-alpha acids it will ever have (barring the addition of a hop extract). In addition, the wort will contain plenty of hop oils, especially if late hops were used. The concentration of these compounds, however, will decrease during fermentation.

While the beer is fermenting, yeast will take in some bitter compounds and the action of the fermentation will blow off some of the oils. Pitching too much yeast can actually reduce the amount of bitterness in a beer and fermenting at higher-than-recommended temperatures can reduce the potential hop aroma.

During fermentation, a thick layer of kräusen forms on top of the beer. Some of this kräusen is brown and very bitter. The Germans call it braun-hefe and skim it, believing that they get a smoother bitterness. Skimming, or using a blowoff tube to get rid of some of your braun-hefe will reduce the level of bitterness in your beer. If you are brewing a delicately hopped lager, this might be a good thing. Anheuser-Busch has special false ceilings on their fermenters for the braun-hefe to stick to.

If you are brewing a monster IPA, you will want to let the kräusen rise and then fall back into your beer. Most commercial brewers using unitanks do not let any kräusen blow off. With the exception of hop residue stuck to the sides of the tank, this keeps all the bitter compounds in contact with the beer.

Adding Hops During Conditioning

There are several ways to add hops to your beer after it has begun fermenting. Dry hopping is a common practice, which began in England. Kräusening is a common practice in German lager brewing. Traditionally, this was done for reasons other than enhancing the hop profile of a beer, but heavily hopped kräusen beers can add a dash of hop flavor and aroma.

Two newer practices homebrewers are experimenting with are adding a hop aroma tea and hopping the priming sugar of bottle conditioned beers.

What Is Dry Hopping?

The term dry hopping originated centuries ago with British brewers and was used to refer to adding hops to the cask shortly before it was shipped off to the customer. In fact, ½-ounce hop plugs were specifically developed by British hop producers to be a convenient way to add whole hops to a keg or cask. Nowadays, dry hopping refers to any hop addition after the wort has been cooled. These additions can be done in the fermenter or by adding hops directly to a keg. I have even heard of one homebrewer attempting to add one or two hop petals to each bottle of a bottle-conditioned batch! (It didn't work though.)

Pros and Cons

Due to the fact that no volatile oils are boiled off, the benefit to dry hopping is that the brewer can get as much flavor and aroma possible into the final beer. This can give your beer a floral hop essence and an intense flavor that is desirable in hoppy beer styles like pale ales and IPAs. Some commercial beers that are dry-hopped include Sierra Nevada's Celebration Ale, Young's Special Ale, Anchor Liberty and Sam Adams Pale Ale.

What dry hopping does not add to the beer is bitterness. Boiling is necessary to convert the alpha acids in the hops to iso-alpha acids to create bitterness. To maintain your desired bitterness, you still need to add the bittering hops to the boil.

The lack of boiling, however, is also a potential drawback of dry hopping. That is, since they are not boiled, the hops are not sanitized. This seems to worry a lot of brewers, especially those who haven't tried dry hopping before. The truth is that hops do not provide a supportive environment for most types of bacteria. On top of that, if the hops are added to the primary fermenter after the start of fermentation, any bacteria on them will have a difficult time competing with the vigorously active yeast in the wort. If the hops are added to the secondary fermenter then the alcohol content and the low pH of the beer will suppress bacterial growth. Keeping this in mind, it's safe to say that bacterial contaminations caused by dry hopping are extremely rare and not worth worrying about.

The only other drawback to dry hopping is that some beer drinkers just don't like the effect. They think it makes the beer taste "grassy" or "oily." This method definitely gives a different kind of flavor and aroma than the traditional method of adding hops to the boil, but if you like any of the commercially dry-hopped beers mentioned, you will probably like it in your homebrew as well.

Which Hops to Use?

The first step in dry hopping is to select the hop variety to use. You normally want to use a hop variety that is considered a "flavor" or "aroma" hop. It is common for these hops to have relatively low alpha acid ratings, often around 6% or less. Some hop varieties commonly used for dry hopping include Cascade, Crystal, Willamette, East Kent Golding, Fuggle, Saaz, Hallertau and Tettnanger.

Of course, one of the beauties of homebrewing is that you do not have to follow anyone's suggestions; you can try whatever you want. This being said, some homebrewers dry-hop with high alpha acid varieties like Centennial and Chinook. Personal preferences vary, and you should experiment to see what you like. In general, if you like the results of using a particular hop variety in the last 5–10 minutes of the boil, then you will probably like the results of dry hopping with the same variety.

When to Dry Hop

Once you've decided what hops you're going to use, you need to decide when to add them. Your choices are in the primary fermenter, in the secondary fermenter or in the keg.

Dry hopping in the primary fermenter will work, and is favored by some brewers, but conventional wisdom teaches that the primary might not be optimal. The problem lies in the bubbling of the CO_2 and the agitation of the wort during primary fermentation. This bubbling and agitation takes some of the hop aroma out of the beer just like boiling would. This, of course, may defeat the purpose of dry hopping, although some of the hop essence will subsist. If you choose to dry-hop in the primary fermenter, you may want to add more hops than you would for dry hopping in the secondary or keg.

The secondary fermenter is generally considered the best place for dry hopping for a couple of reasons. First, the beer has already mostly fermented so, as mentioned above, the alcohol and low pH helps to ward off any bacteria on the un-sanitized hops. Second, the vigorous CO_2 activity of the primary is finished, so the aroma of the hops won't be scrubbed out of the beer.

There is, however, one potential difficulty with dry hopping in the secondary. Many homebrewers use glass carboys with narrow necks as their secondary fermenters. Getting the hops into, and then back out of the opening can be frustrating. This is especially true if you like to keep the hops in a bag, making it easy to separate them from the beer. My recommendation is to use a bucket with a large opening rather than a carboy, or forget about putting the hops in a bag and just dump them in. You can then separate the hops from the beer when racking to your bottling bucket or keg.

The final option for dry hopping is in the keg. Here, it is advisable to use a muslin or cheesecloth bag to contain the hops. Otherwise you run the risk of sucking hops into the system, clogging it up or getting hops into your glass. One concern with dry hopping in the keg is the extended duration that the hops are in contact with the beer.

Some brewers feel that if the hops are in the beer for more than a few weeks, the beer develops a "grassy" flavor. Personally, I've never experienced it, despite leaving hops in my kegs for as long as six weeks.

Pellets, Plugs or Loose?

Okay, you've decided on the variety of hops to use and when to add them. The next question is, what form of hops to use? The choices are the same as the hops that you add to the kettle: pellets, plugs, or loose. The pros and cons are a bit different though.

As I said before, plugs were originally designed specifically for dry hopping and they work quite well for that purpose. They're easy to measure (since each plug is a ½-ounce), easy to put into a bag if you choose, and are easy to fit through the neck of a carboy — even more easy if you cut them in half. Loose hops have to be weighed, but are also easy to stuff through a carboy neck — not so easy if put in a bag though. Pellet hops also have to be weighed, but are probably the easiest type of hops to pour through a carboy neck. They are also easy to put into a bag, but only a very fine bag will contain the powder when they dissolve.

On the other hand, pellets can cause a sudden eruption of foam that will have you scrambling for a towel and wondering what sort of alien being has taken over your beer. This is because as the pellets break apart (almost immediately) they provide thousands of nucleation sites for the CO_2 in the beer to attach itself and come out of solution. Be careful and go slowly when adding pellet hops to any nearly full container.

Pellet hops will sink when well soaked. Plug and loose hops usually float. Either way it's not too hard to rack the beer away from any form of hops if you are careful. Since pellet hops are more highly processed than plugs or loose hops, there is some concern that volatile oils are lost. When using pellets for dry hopping, you may want to add a little more than usual.

How Much?

This brings us to the question of quantity. A "normal" measurement for dry hopping is between 1–2 oz. (28–56 g) of hops for a 5-gallon (19-L) batch. But the real answer to the question of how much is simply, "as much as you want." If you want just a hint of hop aroma you might go as low as a 0.5 oz. (14 g). If you want a beer that will knock you over with a pungent hop flavor and aroma, you might decide to go nuts and throw in 4.0 oz. (112 grams). I've heard of brewers using even more than this, but even a serious hophead like myself will tell you that more than four ounces of dry hops may be pushing it.

You should also take into account the variety of hop. If you're using a hop with a high essential oil content, you probably don't want to use as much as you might if you were using something less oily.

My advice for your first experiments with dry hopping would be to pick a traditional aroma hop and use no more than 1.0 oz. (28 g). This will give you a good idea of what dry hopping does for a beer. From there you are only limited by your own sense of adventure in deciding what hops to try and how much to use.

To Bag or Not to Bag?

The final question in dry hopping is whether or not to put your hops in a bag. Bagging your hops can make them easier to retrieve when either you (or your beer) decide it's time. On the other hand, hops tend to expand when wet, so a bag that you were able to stuff through the neck of a carboy dry may be difficult or impossible to get out when fully saturated.

Another issue with bagging is that it tends to reduce the hops exposure to the beer. To account for this, you may want to use 10–15% more when bagging. Also, while the hops are naturally resistant to bacteria, the bag is not. Because of this, you should always boil the bag to sanitize it before putting hops in it.

If you're a fan of hop flavor and aroma, you really have to try dry hopping your homebrew. I'm enough of a hophead that, unless it is completely inappropriate for the style, I am dry hopping nearly all of my beers these days and enjoying every one of them.

Kräusen Hopping

Kräusening is a traditional German practice of adding fermenting beer to a lager beer that has just finished fermenting (or almost so). The kräusen beer aids in the conditioning of the beer, specifically by reducing the amount of diacetyl in the lager. Although not traditional, you can add a measure of highly-hopped fermenting wort to any beer as a way to enhance its hop profile.

Kräusen hopping is similar to dry hopping in that the hops are added to the beer while it is conditioning. The hop character obtained from kräusen hopping is different from dry hopping though. Because the hops have been boiled when the kräusen beer is made, kräusen hopping imparts some bitterness to the beer as well as some flavor compounds that need to be boiled out of the hops. Conversely, some aroma compounds may be lost during the boil.

Kräusen hopping also has the potential to dilute the beer. If the kräusen beer is less hoppy than the base beer, you can actually lose bitterness. (You will also need to plan for the effect the color and strength of the kräusen beer will have on the base beer.)

To employ kräusen hopping, make a batch of beer with a volume approximately one-tenth of the volume of your base beer. For a 5-gallon (19-L) batch of beer, a 2 qt. (~2 L) batch of beer is the right size. Make the wort similar in strength, color and bitterness to the base beer, but add an amount of late hops that would be more appropriate to 5 gallons (19 L) of wort than 2 qts. (2 L). An ounce or two (28–56 g) of hops, added sometime in the last 15 minutes of the boil, gives an amount of hop character suitable for a pale ale. Use more for IPAs or double IPAs. Keep in mind that hops absorb wort and take up space when cooled; to yield 2 qts. (~2 L) of kräusen beer, you may need to produce 2.25–2.5 qts. (~2.2.5–2.5 L) to account for the hop debris left behind.

Cool the wort and pitch your yeast to the kräusen beer. Once the kräusen beer begins fermenting, add it to the base beer. This should be timed such that kräusen beer is added to the base beer right after it finishes fermenting.

You can use your usual brewing software to compile a recipe using kräusen hopping. Just plan for 5.5 gallons (20 L) of beer — 5 gallons (19 L) of base beer plus the 2 qts. (~2 L) of kräusen beer — and enter the recipe as if it were a single batch of beer. (Alernatively, you can plan for 5 gallons/19 L and only make 4.5 gallons (18 L) of base beer.) Then, when you're brewing, reserve all or most of the late addition hops to the kräusen beer.

Keep in mind, though, that kräusen hopping adds more hop character per unit of hops than traditional late kettle additions. This may be because yeast density and fermentation intensity are much lower in conditioning beer than in the primary fermentation.

Hop Aroma Tea

Another way to add hop character is to make an aroma tea and add it to secondary. This is quicker than making kräusen beer, although the effect is slightly different.

To make an aroma tea, boil a small amount of very low gravity wort. For 5 gallons of beer, 2 qts. (~2 L) of wort at a specific gravity of 1.005–1.015 will work fine. Add some hops to a French press coffee maker and add the boiling wort. Let the hops steep for awhile in the French press, then press off the hop tea. This should be cooled immediately and added to some conditioning beer.

The hot wort will extract flavor and aroma from the hops. You will get more hop flavor from using an aroma tea than from dry hopping. Compared to kräusen hopping, you will get less bitterness (none, in fact) but more aroma because the hops were not boiled.

Adding an aroma tea adds a ton of hop flavor and aroma. Use roughly one-third the amount of hops you would add as late hops or dry hops in a 5-gallon (19-L) batch when making the tea. (Just half an ounce (14 g) of hops in an aroma tea gives a nice kicker to a regular pale ale.) You may wish to consider adding part of the tea and tasting the beer before adding all of the tea.

The small amount of fermentable sugars in the tea will cause a slight secondary fermentation. Let this go to completion and then let the beer sit on the yeast for a day or two before racking to your keg or bottling bucket.

Bottle Hopping

Many homebrews are bottle conditioned, and this is another place that hops can be added to the beer. To do this, add some hops when you boil your priming solution. You can use either sugar or malt extract for the fermentables in the priming mix. You can bag the hops to remove them from the boil when you are done.

As with the methods mentioned above, the amount you add should be a reasonable amount for 5 gallons (19 L) of beer. As with the hop aroma tea, a half ounce (14 g), added to your priming sugar, will give a nice boost to a pale ale.

Hopping at Dispense

You might think that the conditioning tank (or bottle) is the last point to add hops to beer. Not so. With a organoleptic hop transducer (also knon as a Randall), you can pour beer through a filter of hops when you serve it. Developed by Dogfish Head, the Randall sits between the keg and your glass. Beer is pushed through a bed of hops, picking up some aroma and small amount of flavor. (The only downside is that it tends to dispense foamy beer.)

HOP CHARACTER

by **Chris Colby**

To brew a hoppy beer, you need to understand that there are many things that affect hop character. The first, and most obvious, is the amount of hops you add and the characteristics of these hops. The amount of hops to add will usually be specified by your recipe, or you may calculate the amount you want using brewing software, the alpha acid rating of the hops and an idea of how many IBUs you want your beer to have. More hops, higher-alpha hops and a greater percentage of your hops added early in the boil will contribute to more hop bitterness in your beer.

Keep in mind, though, that hops are not just alpha acid delivery vehicles. Each hop variety has a character all its own and this varies from year to year and field to field. Getting to know the characteristics of different hop varieties can only be done by drinking beer. You can read all the descriptions of hops you want, but until you taste, say, Amarillo hops, you won't really know what it's like. Fortunately, lots of brewpubs and craft brewers list the hops they use, so many times you can get an idea of what a variety tastes like before brewing with it.

Another important hop characteristic is its oil content. Although usually not specified on homebrew hop packets, as alpha acids are, the amount of oil in your hops will have a big impact on the hop aroma of your beer. Get used to smelling your hops as you put them in the kettle and — for hoppy beers in which hop aroma is important — be prepared to adjust the amount of late addition hops if you detect more or less hop aroma than usual. (If you can get your hands on the hop evaluation sheet that went with the hops before it got broken down into homebrew-salable sizes, the oil content would be given. It's usually in the range of 0.7 to 1.2%.) There are many different hop oils and their differing abundance in different hop varieties give each its own character. Two oils that are abundant in most hops and have been studied are humulene and myrcene. Humulene is present in high quantities in noble hops and is seen as a sign of a good aroma variety when it is abundant. Myrcene, in contrast, has an aggressive, sometimes grassy, aroma that brewers of lightly hopped lagers avoid. In a more highly-hopped ale, high levels are not necessarily a bad thing.

Cohumulone

The percentage of cohumulone, usually given as a percentage of the alpha acids as a whole, is also a valuable indicator of hop character. Cohumulone — along with humulone and adhumulone — is one of the three main alpha acids found in hops. Cohumulone has a more aggressive character than the other two common alpha acids. Some label this character "harsh." For beers with a smoother hop bitterness, choose hops with a low level of cohumulone (under 25%). Very hoppy beers may benefit from a little "bite" from the cohumulone and many of the favorite hops used in American IPAs and double IPA have a high cohumulone percentage. Cascade, for example, can have up to 40% of its alpha acids as cohumuone. (Cascade also has a relatively high percentage of myrcene in its oil fraction.)

Cohumulone is also the most soluble of the three common alpha acids. In other words, when you first throw your hops in the kettle, cohumulone enters the wort a bit faster than the other two. This is another thing to consider when adding a substantial portion of your hops late in the boil. If you want a bit of an aggressive edge to your hop character, you don't need to worry. However, if you are adding a lot of late hops but want a smooth hop flavor, choose low-cohumulone hops.

Adding hops to the boil adds alpha acids and hop oils to the wort, but it also adds one potentially undesirable element — extraneous plant material. Using too many low-alpha or late addition hops to achieve your bittering goal can give beer a vegetal or grassy edge. Of course, you have to add a lot of hops for this to appear (or accidentally carry some hop material over from the kettle to your fermenter).

Water Chemistry

Your water chemistry also plays a role in how hop character is perceived. Two ions that play a big role are carbonate and sulfate ions. Carbonate ions may be in your water if there is limestone near your aquifer. Or, it may come from the addition of calcium carbonate ($CaCO_3$ or chalk) or sodium bicarbonate ($NaHCO_3$ or baking soda). In the mash, carbonate ions raise the pH and this increases alpha acid solubility in the boil. Unfortunately, beers brewed with higher levels of carbonates show a harsh, gritty type of bitterness that nobody finds pleasant. (Likewise, an overly high mash pH (above 5.6) has other negative consequences.)

In pale, hoppy beers, keep the level of carbonate ions below 50 ppm (and your level of calcium ions should be 100 ppm or more). In darker beers, the level of carbonates can be higher, to counteract the acids found in darkly-roasted malts.

Sulfate ions, found naturally in your water or from the addition of calcium sulfate ($CaSO_4•2H_2O$ or gypsum), enhance hop bitterness. For hoppy beers, add gypsum until your water has over 150 ppm of sulfate. In excess (over 250 ppm), sulfate gives water a bitter or astringent taste and can have a laxative effect. In brewing, there's really no reason ever to exceed 200 ppm. It's a little like adding salt to your food — a little enhances the flavor, too much wrecks the food.

Competing Flavors and Body

The non-hop ingredients in your beer recipe affect the perception of hop character in your beer. In beer, hop bitterness, flavor and aroma exist alongside other beer characters such as malt, flavors from specialty grains, body and "yeasty" aromas (for example, esters and the phenolic "spice" from Belgian beer strains). While you need some malt character and body to balance the hops, too much can mute their expression. Avoid an excess of crystal malts or any specialty malt that adds body to beer or contributes to a higher finishing gravity. If your beer finishes too high, the hop character will seem less crisp. Vinnie Cilurzo of Russian River advocates using a maximum of 5% crystal malt in IPAs and less (3.5–4%) in double IPAs. Couple the restrained usage of crystal malt with an attenuative yeast strain to achieve a reasonably dry beer. Most "ordinary" pale ales finish in the vicinity of SG 1.008–1.012 (2–3 °Plato) and it's good to shoot for this range in all hoppy beers, even bigger brews such as IPAs or double IPAs. To achieve this, you may even want to substitute cane or corn sugar for a small percentage of the malt (10% at most). These sugars are 100% fermentable and can add strength without increasing the body of a beer (as they do in Belgian tripels).

Accentuate Aroma

Aroma and flavor are strongly linked. If you want to accentuate the hop character of a beer, always add enough late addition hops to the kettle or dry hops to the fermenter to get a nice hop aroma. Obviously, some beers are balanced more to a strong hop bitterness with little aroma while others are not very bitter, but show a lot of hop flavor and aroma.

Keep in mind that the oil content in hops varies, just as alpha acid levels do. Be prepared to make adjustments in the amount of late hops you add to the boil based on how they smell.

Avoid Oxidation

A lot of the discussion in these methods chapters revolved around adding hop character to brews. But, you also need to be aware of things that remove hop character from beer, or alter the hop character for the worse.

Oxidation affects hop character in a variety of ways. Oxidation alters the configuration of alpha acids, which leads to a cheesy aroma and flavor. This is most often noticed in old, poorly-stored hops, but can happen in beer, too. Iso-alpha acid levels in beer decrease over time, but the oxidation of beta acids actually adds bitterness. The character of this bitterness, however, differs from that conferred by alpha acids and some beer drinkers find it objectionable.

So You Want to Brew a Hoppy Beer?

OK, let's pull together everything in this issue — from this chapter and elsewhere — into a compact guide to brewing a hoppy beer. If you're lucky enough to live somewhere, such as the Pacific Northwest, where fresh hops are easily obtainable and the water is perfectly suited for hoppy beers, you'll likely have no problems. For other homebrewers, you may have to work just a bit.

Begin with your recipe formulation and either select or write a recipe with a lot of hops and a low amount of specialty malts that contribute to the body or viscosity of the beer. If you are a new brewer, compare your prospective recipe with others of the same type to see if the amounts of hops are adequate (and keep "hop inflation" in mind — homebrew recipes have drifted towards hoppier and hoppier beers in the last 10 years or so). Pick a yeast strain with a moderate to high level of attenuation.

Use hops that are fresh, green and don't smell cheesy. Your homebrew shop should have their hops frozen and, hopefully, packaged in oxygen-barrier bags. Likewise, you should keep your hops frozen until brewday.

Prepare your brewing liquor by keeping the level of carbonates down — the easiest way to dilute it is with distilled water, if needed. Then, if needed, add gypsum so the level of sulfates is adequate to enhance the hoppiness. All-grain brewers should mash in the low to middle range of saccharification temperatures. Along with your malt selection, you should aim to finish no higher than SG 1.012.

Boil your wort vigorously. If you are an extract brewer, perform a full-wort boil, or at least boil as much volume as you can manage. If you are boiling less than the full volume, withhold some of the malt extract and add it for the last 15 minutes of the boil.

Avoid boiling the wort over (and carrying hop material out of the kettle). Knock down any hop material clinging to the side of the kettle above the liquid line. Smell your late addition hops and adjust the amount needed if they smell more or less aromatic than usual.

Pitch an adequate (but not excessive) amount of yeast and hold your fermentation in the low to middle end of the yeast's recommended range. You want to balance the need to get a good fermentation to achieve an appropriate level of dryness with the desire to minimize the loss of bitterness to yeast and the loss of volatile oils to being blown off by the fermentation. Do not use a blow-off tube and do not skim the braun-hefe from the kräusen.

Let the beer clear, then add your dry hops, kräusen beer or aroma tea. Carbonate and serve your beer (perhaps through a "Randall").

Finally, taste your beer critically. You may want to try your homebrew side by side with similar commercial beers. If you're a new brewer, perhaps seek out a more experienced homebrewer who's judgement you trust. Compare your tasting notes with your recipe and brewing practices and tweak it, if necessary, to bring the actual beer closer to the beer you envisioned. Then, brew the beer again, applying these tweaks. Repeat until you are in hop heaven.

With some knowledge, skill and practice, your hoppy beers will be excellent.

recipes

Sierra Nevada Pale Ale clone (Sierra Nevada Brewing Co., California)

(5 gallons/19 L, all-grain)
OG = 1.052 FG = 1.011
IBU = 37 SRM = 10 ABV = 5.3%

The Sierra Nevada website has tons of information about their flagship brew, including the new information that they now use Magnum hops. Use only fresh hops that have been stored correctly (frozen, preferably in an airtight container) for the best hop flavor and aroma.

Ingredients

10.25 lbs. (4.6 kg) 2-row pale malt
10 oz. (0.28 kg) crystal malt (60 °L)
2.5 AAU Magnum hops (60 mins)
(0.18 oz./5.1 g of 12% alpha acids)
4.8 AAU Perle hops (60 mins)
(0.7 oz./19 g of 7% alpha acids)
5 AAU Cascade hops (15 mins)
(1.0 oz./28 g of 5% alpha acids)
0.75 oz. (21 g) Cascade hops (0 mins)
0.75 oz. (21 g) whole Cascade hops
(dry hop)
1 tsp Irish moss
Wyeast 1056 (American Ale) or
White Labs WLP001
(California Ale) yeast
(1.5 qt./~1.5 L yeast starter)
⅞ cup corn sugar (for priming)

Step by Step

Heat 3.42 gallons (13 L) of water to 161 °F (72 °C), stir in crushed grains and mash at 154 °F (68 °C). Mash for 60 minutes then stir in boiled water to raise grain bed temperature to 168 °F (76 °C). Hold for 5 minutes. Recirculate until wort is clear (about 20 minutes), then begin running wort off to kettle. Sparge with water hot enough to maintain grain bed temperature at 170 °F (77 °C). Collect 6.5 gallons (25 L) of wort and boil for 90 minutes, adding hops at times indicated in the ingredient list. Add Irish moss with 15 minutes left in boil. Cool wort and transfer to fermenter. Aerate wort and pitch sediment from yeast starter. Ferment at 68 °F (20 °C). Rack to secondary when fermentation is complete and add dry hops. Bottle when beer falls clear.

Sierra Nevada Pale Ale clone (Sierra Nevada Brewing Co., California)

(5 gallons/19 L, extract with grains)
OG = 1.052 FG = 1.011
IBU = 37 SRM = 11 ABV = 5.3%

Ingredients

1.8 lbs. (0.82 kg) Briess Light dried
malt extract
4.0 lbs. (1.8 kg) Briess Light
liquid malt extract (late addition)
1 lb. 6 oz. (0.62 kg) 2-row pale malt
10 oz. (0.28 kg) crystal malt (60 °L)
2.5 AAU Magnum hops (60 mins)
(0.18 oz./5.1 g of 12% alpha acids)
4.8 AAU Perle hops (60 mins)
(0.7 oz./19 g of 7% alpha acids)
5 AAU Cascade hops (15 mins)
(1.0 oz./28 g of 5% alpha acids)
0.75 oz. (21 g) Cascade hops (0 mins)
0.75 oz. (21 g) whole Cascade hops
(dry hop)
1 tsp Irish moss
Wyeast 1056 (American Ale) or
White Labs WLP001 (California
Ale) yeast (1.5 qt./~1.5 L yeast
starter)
⅞ cup corn sugar
(for priming)

Step by Step

In a large soup pot, heat 3.0 quarts (2.8 L) of water to 161 °F (72 °C). Add crushed grains to grain bag. Submerge bag and let grains steep around 154 °F (68 °C) for 45 minutes. While grains steep, begin heating 2.4 gallons (9.1 L) of water in your brewpot. When steep is over, remove 0.83 qts. (0.78 L) of water from brewpot and add to the "grain tea" in steeping pot. Place colander over brewpot and place steeping bag in it. Pour grain tea (with water added) through grain bag. This will strain out any solid bits of grain and rinse some sugar from the grains. Heat liquid in brewpot to a boil, then stir in dried malt extract, add first charge of hops and begin the 60 minutes boil. With 15 minutes left in boil, add hops and Irish moss, then turn off heat and stir in liquid malt extract. Stir well to dissolve extract, then resume heating. (Keep the boil clock running while you stir.) At the end of the boil, add last charge of hops, cool wort and transfer to fermenter. Add water to make 5 gallons (19 L). Aerate wort and pitch yeast. Ferment at 68 °F (20 °C). Rack to secondary when fermentation is complete and add dry hops. Bottle when beer falls clear.

Pliny the Elder clone (Russian River Brewing Co.)

(5 gallons/19 L, all-grain)
OG = 1.074 FG = 1.014
IBU = 100+ SRM = 8 ABV = 8-8.5%

Ingredients

12.2 lbs. (5.5 kg) 2-row malt
0.28 lbs. (0.13 kg) crystal malt (45 °L)
0.86 lbs. (0.39 kg) Carapils® malt
1.0 lb. (0.45 kg) dextrose
(corn sugar)
19.5 AAU Chinook whole hops
(mash hops)
(1.5 oz./43 g of 13% alpha acids)
42.9 AAU Warrior hops (90 mins)
(2.75 oz./78 g of
15.6% alpha acids)
6.1 AAU Chinook hops (90 mins)
(0.5 oz./14 g of 12.2% alpha acids)
12 AAU Simcoe hops (45 mins)
(1.0 oz./28 g of 12% alpha acids)
14.3 AAU Columbus hops (30 mins)
(1.0 oz./28 g of 14.3% alpha acids)
20.5 AAU Centennial hops (0 min)
(2.25 oz./64 g of 9.1% alpha acids)
12 AAU Simcoe hops (0 min)
(1.0 oz./28 g of 12% alpha acids)
3.25 oz. Columbus hop (dry hop)
1.75 oz. Centennial hops (dry hop)
1.75 oz. Simcoe hops (dry hop)
1 tsp. Irish moss (15 mins)
White Labs WLP001
(California Ale) yeast
0.75 cups corn sugar
(for priming)

Step by Step

Mash at 150–152 °F (66–67 °C). Boil 90 minutes, adding hops at the time indicated in recipe. Ferment at 68 °F (20 °C). Dry hop two weeks.

Extract with grains version:
Replace 2-row malt with 6.15 lbs. (2.8 kg) dried malt extract and 1.0 lb. (0.45 kg) 2-row malt. Steep crushed grains in 1 gallon (3.8 L) of water at 151 °F (66 °C) for 45 minutes. See remaining instructions above for boil and fermentation info.

Ruination IPA clone (Stone Brewing Company)

(5 gallons/19 L, extract with grains)
OG = 1.075 FG = 1.010
IBU = 100+ SRM = 6 ABV = 7.7%

Ingredients
6.6 lbs. (3.0 kg) Northwestern Gold liquid malt extract syrup
2.0 lbs. (0.91 kg) Northwestern Gold dried malt extract
1.0 lb. (0.45 kg) Briess 2-row malt
1.0 lb. (0.45 kg) Briess crystal malt (15 °L)
1 tsp. Irish moss (15 minutes)
36.0 AAU Magnum hops (60 mins) (2.25 oz./64 g of 16.0% alpha acids)
15.7 AAU Centennial hops (0 mins, steep for 5 mins) (1.5 oz./43 g of 10.5% alpha acid)
21.0 AAU Centennial hops (2.0 oz./56 g of 10.5% alpha acid)
White Labs WLP001 (California Ale) or Wyeast 1056 (American Ale) yeast
0.75 cup of corn sugar (for priming)

Step by Step
Steep the two crushed grains in 3.0 gallons (11 L) of water at 149 °F (65 °C) for 30 minutes. Remove grains from wort, add Magnum hops, malt syrup and bring to a boil. Add Irish moss and boil for 60 minutes. Add the first addition of Centennial hops at the end of the boil, and let steep for 5 minutes. Add wort to 2.0 gallons (7.6 L) cool water in a sanitary fermenter, and top off with cool water to 5.5 gallons (21 L). Cool the wort to 75 °F (24 °C), aerate the beer and pitch yeast. Allow the beer to cool over the next few hours to 68 °F (20 °C) and hold at this temperature until the yeast has finished fermentation. Add last addition of Centennial hops for dry hopping. Dry hop for 3 to 5 days, then bottle your beer.

All-grain version:
Use 14.6 lbs. (6.6 kg) 2-row malt and 1.0 lbs. (0.45 kg) of crystal malt (15 °L) in your grain bill. Mash your grains at 149 °F (65 °C) for 60 minutes. Collect enough wort to boil for 90 minutes and have a 5.5-gallon (21-L) yield.

Dreadnaught clone (Three Floyd's Brewing Co.)

(5 gallons/19 L, all-grain)
OG = 1.084 FG = 1.021
IBU = 100 SRM = 11 ABV = 8.1%

Ingredients
16.25 lbs. (7.4 kg) American 2-row pale malt
1.25 lbs. (0.57 kg) melanoidin malt (27 °L)
8.0 AAU Warrior hops (60 mins) (0.53 oz./15 g of 15% alpha acids)
8.0 AAU Simcoe hops (60 mins) (0.62 oz./17 g of 13% alpha acids)
8.0 AAU Centennial hops (45 mins) (0.72 oz./20 g of 11% alpha acids)
8.0 AAU Centennial hops (30 mins) (0.72 oz./20 g of 11% alpha acids)
8.0 AAU Cascades hops (15 mins) (1.6 oz./45 g of 5.0% alpha acids)
1.5 oz. Cascade whole hops (dry hops)
1 tsp. Irish moss (15 mins)
Wyeast 1968 (London ESB) or White Labs WLP002 (English Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step
Mash at 159 °F (71 °C) for 60 minutes. Boil the wort 90 minutes, adding hops at the times indicated in the ingredient list. Ferment at 68 °F (20 °C).

Extract with grains version:
Replace pale malt with 8.0 lbs. (3.6 kg) dried malt extract and 1.33 lbs. (0.6 kg) 2-row pale malt. Steep crushed grains in 3.2 quarts (~3 L) of water at 159 °F (71 °C) for 45 minutes.

Bottleworks IPA clone (Dick's Brewing Company)

(5 gallons/19 L, extract with grains)
OG = 1.080 FG = 1.018
IBU = 100+ SRM = 11 ABV = 8.0%

Ingredients
11.75 lbs. (5.3 kg) Briess light unhopped malt extract syrup
8.0 oz. (224 g) crystal malt (120 °L)
1.0 oz. (28 g) chocolate malt
1 tsp Irish moss (60 min.)
33.7 AAU Columbus hops (60 min) (2.25 oz./63 g of 15% alpha acid)
15.0 AAU Columbus hops (20 min) (1.0 oz./28 g of 15.0% alpha acid)
15.0 AAU Columbus hops (5 min.) (1.0 oz./28 g of 15% alpha acid)
White Labs WLP001 (California Ale) or Wyeast 1056 (American Ale) yeast
0.75 cup corn sugar (for priming)

Step by Step
Steep the crushed malts in 3 gallons (11 L) of water at 155 °F (68 °C) for 30 minutes. Remove grains from wort, add the malt syrup and bring to a boil.

Add the Columbus bittering hops and Irish moss, then boil for 60 minutes. Add the second addition of Columbus hops for the last 20 minutes of the boil. Add the remaining Columbus hops at the end of the boil and let them steep for five minutes. Now add the wort to 2 gallons (7.6 L) of cool water in a sanitary fermenter, and top off with cool water to 5.5 gallons (~21 L). Cool the wort to 75 °F (24 °C), aerate the beer heavily and pitch your yeast. Allow the beer to cool over the next few hours to 68 °F (20 °C), and hold at this temperature until the beer has finished fermenting. Dick's conditions this beer for approximately a total of six weeks, then bottle or keg your beer and enjoy! (Note: To get the full amount of bitterness in an extract IPA, you will need to do a full-wort boil.)

All-grain version:
This is a single step infusion mash. Replace the malt syrup with 16 lbs. (7.3 kg) of 2-row pale malt. Mash the three grains together at 155 °F (68 °C) for 60 minutes. Collect approximately 7 gallons wort (27 L) to boil for 90 minutes. The remainder of the recipe is the same as the extract recipe.

Old Ruffian clone (Great Divide Brewing Co.)

(5 gallons/19 L, all-grain)
OG = 1.105 FG = 1.026
IBU = 90 SRM = 16 ABV = 10.2%

Ingredients

20.75 lbs. (9.4 kg) American 2-row pale malt
0.50 lb. (0.23 kg) crystal malt (75 °L)
0.50 lb (0.23 kg) Victory malt
0.25 lbs. (0.11 kg) flaked wheat
36 AAU Chinook hops (60 mins) (3.0 oz./85 g of 12% alpha acids)
16 AAU Amarillo hops (30 mins) (2.0 oz./57 g of 8% alpha acids)
24 AAU Amarillo hops (5 mins) (3.0 oz./85 g of 8% alpha acids)
White Labs WLP051 (California V) or Wyeast 1272 (American II) yeast (5 quarts/~5 L yeast starter)

Step by Step

This is a very big beer. See below for four options for generating your wort. In all cases, use a single infusion mash (or steep) at 154 °F (68 °C), held for 45-60 minutes. Add hops with 60 minutes, 30 minutes and 5 minutes left in the boil, as indicated in the ingredient list. Pitch the yeast from your yeast starter, aerate very well and hold fermentation temperature at 66 °F (19 °C). Keg the beer when fermentation is complete and beer has fallen clear.

Long boil option:

Mash grains listed in ingredient list with 28 quarts (26 L) of mash liquor. Collect wort until the specific gravity of the final runnings falls below 1.010. (This may be up to 12 gallons (45 L), depending on a number of variables.) Keep your sparge water heated such that your grain bed temperature creeps up to 168 °F (76 °C) near the end of wort collection. Boil wort to reduce volume to 6.0 gallons (23 L). Add first dose of hops and boil them for an hour, aiming for 5.0 gallons (19 L) of post-boil wort.

First wort option:

Add enough pale malt to your mash tun so that you can run off 6.0 gallons (23 L) of first wort without adding sparge water. For this you will need between 26.75 lbs. to 32.5 lbs. (12–15 kg) of pale malt (in addition to the specialty malts and flaked wheat), depending on how much water your grains normally absorb. You will need roughly 9.0–10 gallons (34–38 L) of mash liquor (and 12–14 gallons (45–53 L) of mash tun space to hold it all). Your 6.0 gallons (23 L) of pre-boil wort should have a specific gravity of 1.085–1.090. Boil for one hour to reduce wort to a volume of 5.0 gallons (19 L). [Note: You can (and should) sparge the grain bed to collect wort for a second beer.]

Full mash plus extract option:

Reduce the amount of pale malt to 10.75 lbs. (4.9 kg). Mash all grains in 15 qts. (14 L) of mash liquor. Collect 6.0 gallons (23 L) of wort and stir in 5.25 lbs. (2.4 kg) of light dried malt extract to raise pre-boil wort gravity to 1.085–1.090. Boil for one hour to reduce volume to 5.0 gallons (19 L).

Extract option:

Reduce amount of pale malt to 0.75 lbs. (0.34 kg) and steep, along with specialty grains, at 154 °F (68 °C)for 45 minutes. Add 10.6 lbs. (4.8 kg) light dried malt extract at beginning of boil. You must do a full-wort boil to get the proper level of bitterness.

Imperial IPA (I^2PA) clone (Rogue Ales, Oregon)

(5 gallons/19 L, all-grain)
OG = 1.080 FG = 1.020
IBU = 62 SRM = 7 ABV = 7.8%

Ingredients

16.25 lbs. (7.4 kg) British pale malt
13.5 AAU Newport hops (60 min) (1.0 oz./28 g of 13.5% alpha acids)
5.0 AAU Cascade hops (30 min) (1.0 oz./28 g of 5.0% alpha acids)
7.0 AAU Sterling hops (15 min) (1.0 oz./28 g of 7.0% alpha acids)
1.0 oz. (28 g) Amarillo hops (dry hops)
1 pkg Whirfloc (20 min)
White Labs WLP0051 (California V) yeast
4.0 oz. (110 g) corn sugar (for priming)

Step by Step

Mash at 154 °F (68 °C). Boil for 90 minutes, adding hops at the time indicated in the recipe. Ferment at 68 °F (20 °C).

Extract with grains version:

Replace pale malt with 11.0 lbs. (5.0 kg) English light malt extract and 2.0 lbs. (0.91 kg) 2-row pale malt. Steep crushed pale malt in 80 fl. oz. (2.4 L) of water at 154 °F (68 °C) for 45 minutes.

Lagunitas IPA clone (Lagunitas Brewing, California)

(5 gallons/19 L, all-grain)
OG = 1.059 FG = 1.015
IBU = 67 SRM = 9 ABV = 5.7%

Ingredients

11.33 lbs. (5.1 kg) 2-row pale malt
0.4 lbs. (0.18 kg) dextrine malt
0.3 lbs. (0.14 kg) crystal malt (60 °L)
0.2 lbs. (91 g) light Munich malt (4 °L)
8.25 AAU Horizon hops (60 mins) (0.75 oz./21 g of 11% alpha acids)
4.5 AAU Cascades hops (30 mins) (0.90 oz./26 g of 5.0% alpha acids)
1.25 AAU Willamette hops (30 mins) (0.25 oz./7.1 g of 5.0% alpha acids)
15.75 AAU Cascade hops (0 min) (3.15 oz./89 g of 5.0% alpha acids)
1 tsp. Irish moss (15 mins)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash at 154 °F (68 °C). Boil for 90 minutes, adding hops as indicated in the ingredient list. After the boil, let the wort sit for 15 minutes before cooling. Ferment at 70 °F (21 °C).

Extract with grains version:

Replace pale malt with 5 lbs. 9 oz. (2.5 kg) of light dried malt extract and 1.0 lb. (0.45 kg) 2-row pale malt. Steep crushed pale malt and other malts in 76 oz. (2.2 L) of water at 154 °F (68 °C) for 45 minutes.

Acme IPA clone (North Coast Brewing, California)

(5 gallons/19 L, all-grain)
OG = 1.062 FG = 1.011
IBU = 56 SRM = 7 ABV = 6.6%

Ingredients

11.33 lbs. (5.1 kg) Great Western

2-row pale malt
1.0 lb. (0.45 kg) Vienna malt
0.33 lbs. (0.15 kg) Munich malt
0.33 lbs. (0.15 kg) Carapils® malt
3.3 AAU Clusters hops (60 mins)
(0.47 oz./13 g of 7.0% alpha acids)
3.3 AAU Clusters hops (30 mins)
(0.47 oz./13 g of 7.0% alpha acids)
14 AAU Northern Brewer (0 mins)
(1.6 oz./44 g of 9.0% alpha acids)
1 tsp. Irish moss (15 mins)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast
0.75 cups corn sugar (for priming)

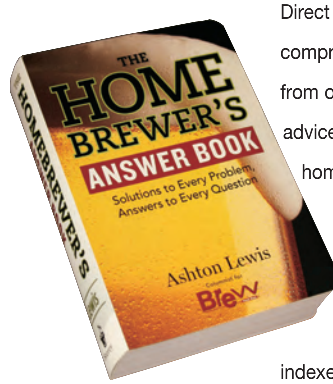
Step by Step
Mash at 154 °F (68 °F) for 60 mins. Recirculate for 20 minutes, then collect 7 gallons (26 L) of wort. Boil for 90 minutes, adding Clusters hop charges with 60 minutes and 30 minutes left in boil. At 15 minutes left in the boil, add the Irish moss. At knockout, add the Northern Brewer hops, whirlpool the wort and let it sit for 30 minutes (covered) before you begin cooling. After 30 minutes, chill wort, aerate and pitch yeast. Ferment at 68 °F (20 °C).

Extract with grains version:
Replace 2-row malt with 5.5 lbs. (2.5 kg) of light dried malt extract and 1.0 lb. (0.45 kg) 2-row malt. Steep crushed 2-row, Vienna, Munich and Carapils® malts in 3 quarts (~3 L) of water at 154 °F (68 °C) for 45 minutes. Follow all-grain instrcutions for boiling and fermentation.

Elissa IPA clone (Saint Arnold Brewing Co., Texas)

(5 gallons/19 L, all-grain)
OG = 1.061 FG = 1.010
IBU = 60 SRM = 10 ABV = 6.6%

Ingredients
12.0 lbs. (5.4 kg) Maris Otter
2-row pale malt
0.71 lbs. (0.32 kg) Crisp crystal
malt (45 °L)
13.5 AAU Cascade hops (60 mins)
(2.7 oz./34 g of 5.0% alpha acids)
6.0 AAU Cascade hops (15 mins)
(1.2 oz./34 g of 5.0% alpha acids)
6.0 AAU Cascade hops (4 mins)
(1.2 oz./34 g of 5.0% alpha acids)



0.8 oz. (23 g) Cascade whole hops (dry hop)
1 tsp. Irish moss (15 mins)
Wyeast 1028 (London Ale) or White Labs WLP013 (London Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash at 156–158 °F (69–70 °C). Boil 90 minutes. Ferment at 72 °F (22 °C).

Extract with grains version:

Replace pale malt with 5.9 lbs. (2.7 kg) light dried malt extract and 1.0 lb. (0.45 kg) 2-row pale malt. Steep crushed malts in 70 fl. oz. (2.1 L) of water at 156-158 °F (69-70 °C) for 45 minutes.

Terrapin Rye Pale Ale clone (Terrapin Beer Co., Georgia)

(5 gallons / 19 L, extract with grains)

OG = 1.054 FG = 1.013
IBU = 45 ABV = 5.2%

Ingredients

3.3 lbs. (1.5 kg) Briess Light liquid malt extract
2.33 lbs. (1.1 kg) Briess Light dried malt extract
1.0 lb. (0.45 kg) rye malt
1.0 lb. (0.45 kg) Munich malt (10 °L)
0.5 lb. (0.23 kg) Victory malt (30 °L)
6 oz. (170 g) Gambrinus honey malt
14 AAU Magnum hops (60 mins) (1.0 oz./28 g of 14% alpha acid)
3.75 AAU Fuggle hops (30 mins) (0.75 oz./21 g of 5% alpha acid)
2.38 AAU East Kent Golding hops (20 mins) (0.5 oz./14 g of 4.75% alpha acid)
2.38 AAU East Kent Golding hops (10 mins) (0.5 oz./14 g of 4.75% alpha acid)
6.8 AAU Cascade hops (3 mins) (1.0 oz./28 g of 6.8% alpha acid)
16.4 AAU Amarillo leaf hops (dry hop) (2.0 oz./56 g of 8.2% alpha acid)
1 tsp. Irish moss
White Labs WLP051 (California Ale V) or Wyeast 1332 (Northwest Ale) yeast
0.75 cup of corn sugar (for priming)

Step by Step

Steep crushed grains in 1.0 gallon (3.8 L) of water at 155 °F (68 °C) for 30 minutes. Remove grains. Add 2.0 gallons (7.6 L) of water, malt extracts and bring these 3.0 gallons (11 L) of wort to a boil. Add Magnum, Irish moss and boil for 60 min. Add Fuggle for final 30 min. Add first East Kent Goldings for last 20 min. Add second East Kent Goldings for last 10 min. Add Cascade for last 3 mins.

When you are done boiling, add the wort to 2.0 gallons (7.6 L) of cool water in a sanitary fermenter and top off with cool water to 5.5 gallons (21 L). Cool to 80 °F (27 °C), aerate and pitch your yeast. Allow beer to cool over the next few hours to 68–70 °F (20–21 °C), and hold at this temp until the yeast has fermented completely. Add the Amarillo hops when the beer is done fermenting. Remove the dry hops after about 4 days. Bottle your beer, age for two to three weeks and enjoy!

Extract with grains version:

Replace the malt extracts with 9.0 lbs. (4.1 kg) 2-row pale malt. Mash at 155 °F (68 °C) for 60 minutes. Boil for 90 minutes. Ferment at 68–70 °F (20–21 °C).

HopBack Amber Ale clone (Tröegs Brewing Co., Pennsylvania)

(5 gallons/19 L, extract with grains)

OG=1.063 FG=1.017
IBU = 55 SRM= 10 ABV = 6.0%

Ingredients

7.75 lbs. (3.5 kg) Briess Pilsen Light liquid malt extract
2.5 lbs. (1.1 kg) Munich malt (20 °L)
0.25 lbs. (113 g) crystal malt (20 °L)
1.0 oz. (28 g) chocolate malt
15.25 AAU Nugget hops (60 mins) (1.25 oz./35 g of 13 % alpha acid)
5.7 AAU Nugget hops (in hopback) (0.5 oz./14 g of 13% alpha acid)
2.8 AAU Liberty hops (in hopback) (0.25 oz./7 g of 4% alpha acid)
2.8 AAU Simcoe hops (in hopback) (0.25 oz./7 g of 12% alpha acid)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast
0.75 cup corn sugar (for priming)

Step by Step

Steep the 3 crushed malts in 3.0 gallons (11 L) of water at 152 °F (67 °C) for 30 minutes. Remove grains from wort, add the malt syrup and bring to a boil. Add the Nugget bittering hops and boil for 60 minutes. For the hopback, run the hot wort through an in-line hopback type filter where you have the remaining three hops in a straining bag, with the outlet going into 2.0 gallons (7.6 L) of cool water in a sanitary fermenter and top off with cool water to 5.5 gallons (21 L). Cool the wort to 75 °F (24 °C), aerate the beer and pitch your yeast. Allow the beer to cool over the next few hours to 68 °F (20 °C), and hold at this temperature until the beer has finished fermenting, then bottle and enjoy!

All-grain version:

This is a single step infusion mash. Replace the malt syrup with 10.3 lbs. (4.7kg) of Briess Pilsner malt. The rest of the grains used are the same as the extract recipe. Mash the four grains together at 152 °F (67 °C) for 60 minutes. Collect approximately 7 gallons (26 L) of wort to boil for 90 minutes and have a 5.5-gallon (21-L) yield.

Toki's Brutal Pale Ale (Brew Your Own magazine)

(5 gallons/19 L, all-grain)
OG = 1.050 FG = 1.010
IBU = up to 50 (depending on hop selection)
SRM = 9 ABV = 5.1%

This recipe is not a homebrew clone. It was developed to test some new hopping methods and to brew a hoppy beer with relatively few hops. To brew this recipe, you will need one unusual piece of equipment, a 1-liter (8 cup) French press, used for making coffee. If you don't already have one, you can find one cheap (~$20 US) at any almost any store that sells housewares.

Ingredients

7.0 lbs. (3.2 kg) 2-row pale malt (US) or German Pilsner malt
1.0 lb. (0.45 kg) Munich malt (10 °L)
0.50 lbs. (0.23 kg) crystal malt (30 °L)
1.0 lb. (0.45 kg) cane sugar
0.25 lbs. (0.11 kg) Briess Light dried malt

extract (secondary)
¼ tsp. yeast nutrients (15 mins)
1 tsp. Irish moss (15 mins)
1 oz. (28 g) Columbus, Tomahawk, Zeus, Simcoe, Chinook or Nugget hops (75 mins)
(second choices: Magnum, Summit, Newport, Horizon or Sun)
1 oz. (28 g) Glacier, Mt. Hood, Palisades, Santiam, Sterling, Strisselspalt or Vanguard hops (secondary)
(second choice: your favorite hop among the choices you have)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) or Safale US-05 yeast
(~1.25 qt./1.25 L yeast starter)
1 cup corn sugar (for priming)

Step by Step

Mash at 150 °F (66 °C) for 60 minutes in 3 gallons (11 L) of brewing liquor. Mash out to 168 °F (76 °C). Recirculate until wort clears substantially. Run off wort to kettle, sparging with water hot enough to keep the top of the grain bed at 168 °F (76 °C). Collect about 6.0 gallons (23 L) of wort, and bring to a boil. (Shoot for 4.25 gallons (16 L) at end of 90-minute boil.) Once wort boils, add the bittering hops to the French press and ladle in boiling wort until full. Let sit for 15 minutes, then press off hops. Pour hoppy liquid from French press into a clean container, cover and set aside. Scrape wet hops from French press to kettle. Boil these hops for 75 minutes. With 15 minutes left in the boil, add cane sugar, Irish moss and yeast nutrients to kettle. At end of boil, add hoppy liquid and let steep for 15 minutes before cooling. Cool wort and transfer to fermenter. You should have approximately 4.25 gallons (16 L) at this point. Aerate and pitch yeast. Let ferment at 65–68 °F (18–20 °C). Once fermentation has stopped, add malt extract to one gallon (3.8 L) of water and bring to a boil. Add hops to French press. Boil wort for 15 minutes, turn off heat, then ladle 1 qt. (1 L) of hot wort into French press. After 15 minutes, pour off hoppy liquid into a sanitized bowl and cover. Add wet hops to remaining wort and boil for 30 minutes. Aim to reduce wort volume to 2 qts. (2 L). If wort volume dips below this, add boiling water to top up. Combine reserved hoppy liquid and boiled wort and cool this combined wort. With minimal splashing, transfer cooled, hoppy wort to secondary fermenter. Do not transfer hop debris to fermenter. Rack primary batch onto this "hop shot" to make 5 gallons (19 L) of beer (give or take, depending on racking losses and other factors). Condition at 60–65 °F (16–18 °C) until renewed fermentation settles down and beer clears. Rack to keg or bottle.

Partial mash option:

Reduce amount of Pilsner malt to 2.5 lbs. (3.2 kg) and add 3.3 lbs (1.5 kg) of Munton's Light liquid malt extract.

Mash grains at 150 °F (66 °F). Boil wort, starting with a pre-boil volume of 3.5 gallons (13 L) for 90 minutes. After cooling, top up to 4.5 gallons (17 L). Let ferment at 65–68 °F (18–20 °C). Follow the all-grain instructions for how to handle the hopping of this beer.

Brewing with malt extracts is a popular form of homebrewing. However, using the simplest extract mehods can yield a beer with a limited amount of hop bitterness. In this article, the various methods of extract brewing are discussed with regards to their effect on hop bitterness. The two major factors impacting this are how much dilution water is used and how "thick" the wort is when boiled. Switching to a full-wort boil eliminates both of these problems, but is not feasible for all extract brewers. Stovetop brewers can employ the Texas Two-Step or use the extract late method to achieve a higher level of hop utilization compared to using the "standard" method of extract wort production. Three example recipes are also given.

Learn the tips and techniques for

hopping help for EXTRACT BREWERS

by **CHRIS COLBY**

All forms of homebrewing — whether all-grain, partial mash or extract — share many similarities. However, each has its own set of challenges as well. One of the biggest complaints of beginning extract brewers is that their beers do not turn out hoppy enough. Many homebrewers became interested in homebrewing after tasting hoppy pale ales or IPAs. However, their attempts to replicate these hoppy beers on their stovetop often end in disappointment. Stovetop extract and partial mash brewers can, however, make bitter beers if they understand a few facts about hops and bitterness.

Limits to Bitterness

Alpha acids are compounds in hops that, upon boiling, lend bitterness to beer. When you buy hops, their strength (measured in the percentage of alpha acids) should be given on the package. In the boil, alpha acids are extracted from the hops and the heat of the boil alters their chemical conformation (isomerizes them). These isomerized alpha acids are primarily what adds bitterness to beer, although similar compounds called beta acids also play a role.

The amount of bitterness in extract beer is primarily limited by two factors. The first is the inherent solubility limit of bittering compounds in wort — in short, there is only so much bitterness you can boil out of hops.

Estimates of maximum hop bitterness range from 100–120 International Bittering Units (IBUs). Above this level, adding more hops in the boil does not result in more bitter beer. However, more bitterness could theoretically be obtained by adding hop extracts.

The solubility of isomerized alpha acids also varies with wort density — the denser the wort, the less alpha acids will dissolve into it. For example, if you boiled 2.5 gallons (9.5 L) of wort at a specific gravity (SG) of 1.048 and 2.5 gallons (9.5 L) of wort at SG 1.096, and added the same amount of hops to both brewpots, the weaker wort would yield a more bitter beer. Given that most stovetop brewers boil a concentrated wort, wort density frequently limits the amount of bitterness in their beers.

The second variable influencing bitterness in extract beers is the dilution factor. When stovetop brewers are done boiling their wort, they dilute it with water in their fermenter. The water dilutes not only the sugars in the wort (lowering the specific gravity to its target), but the alpha acids as well. So, if you want to brew 5.0 gallons (19 L) of beer with 30 IBUs and your post-

Brewing a hoppy beer using malt extract can be challenging, unless the right techniques are used.

brewing hoppy extract beer and you'll always be bitter.

boil volume is 2.5 gallons (9.5 L), your boiled wort will need to measure 60 IBUs.

When you combine boiling a high gravity wort with a sizeable dilution — as commonly instructed in many homebrew recipes — you are severely limiting the amount of bitterness in your beer. There are, however, a number of ways to compensate for, or eliminate, these problems.

The Best Solution

The best solution to increasing the amount of hop bitterness in a stovetop beer is to boil a larger volume of wort. With regards to hopping, there are two benefits to doing this:

First, with a larger volume, you add less dilution water — and consequently experience less dilution of the bittering compounds. (The best case scenario would be to boil your full wort, eliminating the need for any dilution water.)

Secondly, boiling the extract in more water results in a "weaker" wort. With a lower-density wort, you extract more bitterness from your hops. Other factors, such as boil vigor and if the hops are bagged or not also influence hop bitterness, but not to the degree that wort volume does.

If your limitation to boiling a larger volume is brewpot size, there are a couple options to consider. As you boil, the volume of your wort decreases as water evaporates. If you are already dealing with a small amount of wort, you should consider topping up with boiling water as you boil. Keep a smaller pot of boiling water next to your brewpot and add water to the wort to replace any water lost to evaporation every 10 minutes or so.

Two better options are to boil your wort in more than one pot, thus boiling a larger volume, or make your wort in stages — for example by splitting your wort preparation into two separate boils. If you boil in multiple pots, spread the hops amongst the pots evenly, taking into consideration the size of the pots.

One method of splitting the boil into two pots is the Texas Two-Step, as described in the October 2003 issue of BYO. In this method, you boil half of your wort — made with half of your grains, extract and hops — on the first brewday and pitch your yeast to 2.5 gallons (9.5 L) of chilled wort. Sixteen to twenty four hours later, you boil the second half of your wort, with the second half of your hops, chill it and add it to the fermenting wort. The primary advantage is that you boil all of your wort and thus can get as much bitterness into your beer as any all-grain brewer could. Minor advantages include not having to make a yeast starter, the ability to make very light colored beers and not needing a wort chiller for wort chilling. (It's fairly easy to chill 2.5 gallons/9.5 L of wort in your sink.) The big disadvantage is that you need to schedule time two days in a row for brewing. However, if you normally make yeast starters for your beer, the "extra" time required to do the Two-Step is actually fairly small.

Boiling a larger volume of wort has other benefits as well, most notably limiting the amount of wort darkening that occurs during the boil. The only drawbacks to boiling a larger wort volume are that you need to cool more wort. You may also have trouble maintaining a good rolling boil.

To cool up to 2.5 gallons (9.5 L) of wort in a sink just put the lid on your brewpot after the boil and place the pot in a sink of cold water. Change the water several times, then add ice when the side of the pot feels neither hot nor cold (i.e. when it's around body temperature). A bathtub can be a convenient water bath for holding multiple pots.

If you're boiling 3.0 gallons (11 L) or more, you'll probably want to invest in a copper immersion chiller (about $35 U.S. at most homebrew shops.)

If you buy a larger brewpot, but your stove can't bring the full volume to a rolling boil, experiment with the placement of the lid on the pot. Although you don't want to boil wort in a closed pot, leaving the lid mostly on can help your boil vigor and still provide an outlet for steam. If you still can't bring the full volume to a rolling boil, reduce the wort volume to the point that a sustainable rolling boil is possible.

Better Late than Early

If your stove can't bring the full volume of wort to a rolling boil, you still have options to help with your bittering. One practice — introduced by Steve Bader in the October 2002 issue of BYO — is adding some of your malt extract late in the boil. The basic idea is to boil your wort, made up of the "grain tea" from your steeping grains (or wort from partial mashing) and half or less of your malt extract, for the full boil time. For the last 15 minutes of the boil, the remaining malt extract can be stirred in. Alternately, the "late extract" can be added at the very end of the boil, then left to steep for 15 minutes before you begin to chill your wort.

Brewery-grade malt extract has already been boiled, so you only need to heat it enough to sanitize it. Adding half (or more) of your extract late in the boil means that you are boiling your hops at a lower gravity. (If you're making 5 gallons (19 L) of beer, adding half of the total fermentables at the beginning of the boil, and yielding 2.5 gallons (9.5 L) at the end of the boil, you are boiling your hops at the wort density they would encounter with a full wort boil. Many BYO recipes are formulated this way.) Another benefit of this procedure is your wort will not darken as much during the boil, allowing you to brew lighter-colored brews than "regular" extract beers.

Estimating Bitterness

Of course, it's been known for a long time that boiling a larger volume of wort leads to better hop utilization — but how big is the effect? To get some idea, see the table on page 33. The table shows the maximum level of bitterness (in IBUs) you can achieve in an extract wort, given your wort volume at the end of the boil.

Estimates for maximum IBUs in both extract late beers and "standard method" beers are given. For the extract late beers, it is assumed that you boil your wort (whatever its volume) with a boil gravity of less than SG 1.050, then add the remainder of your malt extract at the end of the boil. At that boiling gravity, the wort could contain up to 100 IBUs. The maximum IBUs achievable for 5.0 gallons (19 L) would then depend only on how much you diluted the wort.

For example, let's say you boiled 3.0 gallons (11 L) of wort down to 2.5 gallons (9.5 L). If the boil gravity was 1.050 or less, and you added enough hops, you should end up with 2.5 gallons (9.5 L) of wort at 100 IBUs. After dilution, you would have 5.0 gallons (19 L) of wort at 50 IBUs. The values in the standard method col-

PREDICTED MAXIMUM IBUs (for 12 °Plato/OG 1.048 beer)

post-boil volume [gallons (L)]		max IBUs extract late method [boil SG < 1.050]	max IBUs standard method [boil SG in parenthesis]	
1	(3.8)	20	5	(1.240)
1.5	(5.7)	30	17	(1.160)
2	(7.6)	40	30	(1.120)
2.5	(9.5)	50	42	(1.096)
3	(11)	60	53	(1.080)
3.5	(13)	70	66	(1.069)
4	(15)	80	77	(1.060)
4.5	(17)	90	89	(1.053)
5(*)	(19)	100	100	(1.048)

(*) full-wort boil or Texas two-step method

Note: These are calculated estimates, not experimental measurements. Values given are for a 5-gallon (19-L) batch of beer hopped to saturation.

umn are calculated in a similar manner, but also figuring in that the boil gravity will be higher at smaller wort volumes. It's important to note that the values in the table are estimates based on the calculations I just described; they make sense — and mesh with my brewing experience — but they have not been experimentally verified. Also, note that the table applies to moderate-gravity beers (around OG 1.048); for bigger beers, the values would be lower as the higher gravities would result in lower hop utilization.

Style Follows Size

So what do the numbers mean? Essentially, they mean that the volume of wort you boil determines the styles of beer you can brew successfully. For example, if you are following the "standard" extract instructions of boiling all your malt extract in 1.5 gallons (5.7 L) of water, then diluting to 5 gallons (19 L) after the boil, you can only get about 17 IBUs of bitterness in your beer. With this limitation, your choice of possible beer styles isn't very wide. Two good candidates for this method are British mild ales or Scottish 60-shilling ales. Both of these styles are lightly hopped (target IBUs less than 20), low gravity (original gravity less than 1.040) ales and are dark enough (SRM values of 20–30 are fine) that moderate amounts of wort caramelization won't detract from the beer's appearance.

By increasing the amount of wort you boil to 2.5 gallons (9.5 L) and switching to the extract late method, you can brew beers with up to 50 IBUs. This will allow you to brew almost any classic beer style, including most pale ales, porters and stouts. To brew the newer, hoppier styles of American ales — such as American pale ales, ambers, IPAs and double IPAs — you will need to boil at least 3.0 gallons (11 L) of wort. See the recipes on pages 34–35 for examples of hoppy extract beers.

Other Considerations

There are a few other ways to boost the amount of hop bitterness, or the perception of bitterness, in a beer.

Extract brewers should add their hops loose in kettle. Hop bags are convenient, but they limit the degree of hop utilization.

Adding some gypsum in the boil — up to 2 tsp. per 5.0 gallons (19 L) in soft or distilled water — accentuates hop bitterness. If your water already contains some sulfates, add proportionally less. (See your local water report to find this out.)

Likewise, adding hop aroma by dry hopping increases the perception of hop bitterness slightly. You can use up to 2.0 oz. (57 g) of dry hops per 5.0 gallons (19 L).

Finally, hop bitterness is more pronounced in drier beers, so always add enough yeast to properly attenuate your beer — yet another reason for making a yeast starter. Likewise avoid adding large amounts of specialty malts, especially crystal malt, that contribute a bigger body to beer. And, be aware that some malt extracts are more fermentable than others and avoid extracts that cause your beer to finish at a high final gravity (FG).

In the end, the amount of hop bitterness needs to be confirmed by your taste buds. If the numbers say your beer is fine, but your tongue says it still isn't hoppy enough, add more.

Chris Colby is Editor of Brew Your Own *and a confirmed hoppy beer brewer and hoppy beer lover.*

recipes

Groom Lake IPA

(5 gallons/19 L, extract with grains)

OG = 1.056 FG = 1.014
IBU = 51 SRM = 8 ABV = 5.4%

Here's an American IPA especially formulated by top BYO scientists for stovetop extract brewers, not reverse engineered from an all-grain recipe. Follow the instructions as closely as possible —especially with regards to boil volume — for the best results.

Ingredients

1.5 lbs. (0.68 kg) US 2-row pale malt
0.5 lb. (0.23 kg) crystal malt (30 °L)
2 lb. 2 oz. (0.96 kg) light dried malt extract
4 lb. 2 oz. (1.9 kg) light liquid malt extract (late addition)
6 AAU Magnum hops (60 mins) (0.43 oz./12 g of 14% alpha acids)
3.5 AAU Simcoe hops (60 mins) (0.27 oz./7.6 g of 13% alpha acids)
10 AAU Centennial hops (15 mins) (1.0 oz./28 g of 10% alpha acids)
1.0 oz. (28 g) Cascade hops (5 mins)
1.5 oz. (43 g) Cascade hops (dry hops)
1 tsp. Irish moss (15 mins)
Wyeast 1056 (American Ale), White Labs WLP001 (California Ale) or Safale US-05 (formerly US-56 dried) yeast (1.5 qt./~1.5 L yeast starter)
1.0 cup corn sugar (for priming)

Step by Step

Place crushed grains in a steeping bag. In a large kitchen pot, heat 3.0 qts. (2.8 L) of water to 163 °F (73 °C). Submerge grain bag in this water and let steep at 152 °F (67 °C) for 45 minutes. (If the temperature drops below 148 °F/ 64 °C, heat to 152 °F (67 °C) again.) While grains are steeping, heat 1.5 qts. (~1.5 L) of water to 170 °F (77 °C) in a soup pan. Also, begin heating 2.0 gallons (7.6 L) of water to a boil in your brewpot. When steeping is done, place a colander over your brewpot and lift the grain bag into it. Pour the "grain tea" through the bag (which will strain out the grain bits), then rinse the bag with the 1.5 qts. (~1.5 L) of 170 °F (77 °C) water.

Heat the (roughly) 3.0 gallons (11 L) of wort in your brewpot to a boil, then stir in dried malt extract. (It will foam a bit, so don't pour all the extract in at once.) Bring the wort back to a boil, add the 60-minute hops and boil for 60 minutes, adding late hops at times indicated. Stir in liquid malt extract and add Irish moss with 15 minutes left in boil.

During the boil, scrape any hops clinging to the side of the brewpot back into the wort. Also, do not let the wort volume drop below 2.5 gallons (9.5 L). Keep a small pot of boiling water handy to top up boil, if needed.

After the boil, put a lid on your brewpot and cool the wort (either in a cold-water bath in your sink or with a wort chiller). Cool until the side of the brewpot no longer feels warm, then let it sit for about an hour (with the lid on) to let the hop debris settle. With a racking cane, transfer the wort above the hop "sludge" to your fermenter. Pour the remaining wort/sludge slowly through a sanitized strainer. Top wort up to 5 gallons (19 L) with cool water, aerate wort and pitch the yeast from your starter. Ferment at 68 °F (20 °F). When fermentation slows to a halt, rack to secondary. Add the dry hops a few days later, then bottle or keg after beer has been in contact with dry hops for 3–4 days.

Groom Lake IPA

(5 gallons/19 L, countertop partial mash)

OG = 1.056 FG = 1.012
IBU = 51 SRM = 8 ABV = 5.7%

This version of Groom Lake IPA is more highly-attenuated than the extract with grains version and shows a little more malt aroma. Follow the instructions closely and the light color, high attenuation, alluring aroma and firm bitterness of this beer will render it unidentifiable as a stovetop beer.

Ingredients

3.5 lbs. (1.6 kg) US 2-row pale malt
0.5 lbs. (0.23 kg) crystal malt (30 °L)
1 lb. 12 oz. (0.79 kg) light dried malt extract
3 lb. 4 oz. (1.5 kg) light liquid malt extract (late addition)
6 AAU Magnum hops (60 mins) (0.43 oz./12 g of 14% alpha acids)
3.5 AAU Simcoe hops (60 mins) (0.27 oz./7.6 g of 13% alpha acids)
7.5 AAU Centennial hops (15 mins) (0.75 oz./14 g of 10% alpha acids)
0.75 oz. (21 g) Cascade hops (5 mins)
1.5 oz. (43 g) Cascade hops (dry hops)
1 tsp. Irish moss (15 mins)
Wyeast 1056 (American Ale), White Labs WLP001 (California Ale) or Safale US-05 (formerly US-56 dried) yeast (1.5 qt./~1.5 L yeast starter)
1.0 cup corn sugar (for priming)

Step by Step

Put crushed grains in a large nylon steeping bag. Heat 5.5 qts. (5.2 L) of water to 163 °F (73 °C) and pour into your 2.0-gallon (7.6-L) cooler. Slowly submerge grain bag, then open the bag and use a large brewing spoon to ensure that grain mixes completely with the water. Let mash rest, starting at 152 °F (67 °C) for 45 minutes. While mash is resting, heat 0.75 gallons (2.8 L) of water to 152 °F (67 °C) in your brewpot and stir in dried malt extract. Hold the dissolved malt extract at 152 °F (67 °C). Also heat 5.5 qts. (5.2 L) of water to 180 °F (82 °C) in a large kitchen pot.

Recirculate your partial mash wort by drawing off a pint or two of wort from the cooler and returning it to the top of the mash. Repeat until wort is clear or 3 quarts (~3 L) have been recirculated. Next, run off entire first wort and add to the hot wort in your kettle. Continue holding wort in brewpot around 152 °F (67 °C) while you prepare to draw off the second wort.

Add 180 °F (82 °C) water to cooler until liquid level is the same as during the first mash. Let rest for 5 minutes, then recirculate and run off wort as before. Bring wort to a boil, add bittering hops and boil for 60 minutes. Add other hops at times indicated in ingredient list. Stir in liquid malt extract and add Irish moss with 15 minutes left in boil.

During the boil, scrape any hops clinging to the side of the brewpot back into the wort. Also, do not let wort volume drop below 3.0 gallons (11 L). Keep a small pot of boiling water next to your brewpot to top up the boil.

After the boil, put a lid on your brewpot and cool the wort (either in a cold-water bath in your sink or with a wort chiller). Cool until the side of the brewpot no longer feels warm, then let it sit for about an hour (with the lid on) to let the hop debris settle. With a racking cane, transfer the wort above the hop "sludge" to your fermenter. Pour the remaining wort/sludge slowly through a sanitized strainer. Top wort up to 5 gallons (19 L) with cool water, aerate wort and pitch the yeast from your starter. Ferment at 68 °F (20 °F). When fermentation slows to a halt, rack to secondary. Add the dry hops a few days later, then bottle or keg after beer has been in contact with dry hops for 3–4 days.

Bierce's Bitter (IPA)

(5 gallons/19 L, extract with grains)

OG = 1.072 FG = 1.018
IBU = 68 SRM = 13 ABV = 7.0%

Ingredients

Step One
3.0 lbs (1.4 kg) dried malt extract
1.5 lbs. (0.68 kg) Munich malt (10 °L)
0.50 lbs. (0.23 kg) crystal malt (40 °L)
0.25 lbs. (0.11 kg) crystal malt (60 °L)
8 AAU Magnum hops (60 mins) (0.5 oz./14 g of 16% alpha acids)
6 AAU Centennial hops (15 mins) (0.5 oz./14 g of 12% alpha acids)
0.5 oz. (14 g) Cascade hops (0 mins)
1 tsp. Irish moss (15 mins)
Wyeast 1272 (American II) or White Labs WLP051 (American V) yeast
Step Two
4.0 lbs (1.8 kg) dried malt extract
8 AAU Simcoe hops (60 mins) (0.66 oz./19 g of 13% alpha acids)
4 AAU Ahtanum hops (15 mins) (0.66 oz./19 g of 6% alpha acids)
0.5 oz. (15 g) Amarillo hops (0 mins)
1 tsp Irish moss (15 mins)
1.0 oz. (28 g) Cascade hops (dry hops)
1.0 oz. (28 g) Amarillo hops (dry hops)
⅞ cup corn sugar (for priming)

Step by Step

Step One: Place crushed grains in a nylon steeping bag. In a large kitchen pot, heat 3.0 qts. (2.8 L) of water to 167 °F (75 °C). Submerge grain bag in water and steep at 156 °F (69 °C) for 45 minutes. While grains are steeping, heat 1.5 qts. (~1.5 L) of water to 170 °F (77 °C) in a sauce pan. Also, begin heating 2.0 gallons (7.6 L) of water in your brewpot. When steeping is done, place a colander over your brewpot and lift the grain bag into it. Pour the "grain tea" through the bag , then rinse the bag with the 1.5 qts. (~1.5 L) of 170 °F (77 °C) water. Heat the (roughly) 3 gallons (11 L) of wort in your brewpot to a boil, then stir in dried malt extract. Bring the wort back to a boil, adding hops and Irish moss at times indicated. Total boil time is 60 minutes. After the boil, put a lid on your brewpot and cool the wort to 68 °F (20 °C). Transfer the post-boil wort — which should be around 2.5 gallons (9.5 L) — to your fermenter, aerate the wort and pitch your yeast.

Step Two: (16–24 hours after Step One): Bring 3 gallons (11 L) of water to a boil, add dried malt extract and return to a boil. Add hops and Irish moss at times indicated. Cool wort to 68 °F (20 °F) and rack cooled wort into fermenting beer from Step One. Add water to make 5 gallons (19 L), if needed. Ferment IPA at 68 °F (20 °F). Add dry hops to secondary. Bottle or keg.

Some folks brew to make great beer. Others brew to save money. Still others brew as an excuse to build awesome brewing projects, and we've got three hop-related projects for the homebrewer who spends as much time at Home Depot as at his local homebrew shop.

A hopjack, or hopback, is a vessel that sits between the kettle and a counterflow chiller. Hot wort enters the vessel and is strained through a bed of hop cones. These filter the beer, and also infuse it with hop aroma. Our hopjack borrows from the idea of a French press for a slightly different twist on an old theme.

For you home hop growers, we also feature an oast — a hop drying device. Freshly harvested hops should be quickly dried to prevent mold from growing on the cones. Our oast supports the hops on a screen as a powerful fan moves air past them.

Finally, we present a continuous wort hopper gadget to recreate the unique hopping schedule created by Sam Calagione of Dogfish Head. This device will add hop pellets slowly throughout an entire boil. We even include two Dogfish Head IPA clone recipes that feature continuous hopping to put your new project to use.

Three do-it-yourself projects describing

build
YOUR OWN HOP PROJECTS

Sure, you love to brew, but you also love to build. You know that beer tastes better when you brew it yourself. — and it tastes even better brewed on a system you built with your own hand. In every issue of BYO, we publish a DIY project for the handy homebrewer in our Projects department. Here, we've selected three useful hop-oriented projects for the Hop Lover's Guide.

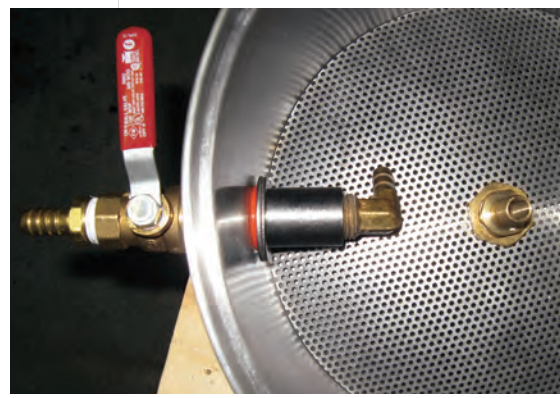
The first project is a hopback. A hopback is essentially a strainer. Hot, post-boil wort flows through it and hot break and hop debris are filtered from the beer through a bed of whole hops. Of course, using hops as the filter medium also infuses the hot wort with hop oils, imparting a blast of hop aroma to your beer. A typical hopback (also called a hopjack) is designed similarly to a lauter tun. The vessel is fitted with a false bottom and a drain below the false bottom. Hops are layered on top of the false bottom. After the boil, hot wort is directed to the hop back on the way to the counterflow chiller. It flows through the hops, past the false bottom and out the drain, taking with it clear wort with an extra dose of hop oils.

Our design deviates from this basic idea, taking a cue from a French press coffee maker. In our hopback, hot wort flows into the vessel, but is first directed below the false bottom, where the hops are placed. Wort then bubbles up through the bed of hops and is drained off from a point above the false bottom.

The second project is a hop dryer, or oast, for the homebrewer who also grows his own hops. When hops are ready to harvest, the bracts on the cones change from green and spongy to yellow and paper-like. However, they still retain a lot of moisture. Recently, a few breweries have experimented with brewing beer from green hops at harvest time, but almost all hops are dried prior to being used.

In our project, the hop dryer is an unheated box that dries the hops by keeping air flowing past them. As long as the relative humidity is low — and remember that air conditioning also removes moisture from the air — the hops will gently dry within a day or so. If you do feel the "need for speed," you can place a space heater near the air intake on the hop dryer, but this certainly isn't required.

Our third project slowly adds hop pellets throughout the entire duration of a boil. Sam Calagione started this "continuous hopping" schedule with his popular Dogfish Head 60, 90 and 120 minute IPAs. With our project you will be able to trickle in pellets slowly recreating this hopping method. Have fun with this experimental hopping schedule and see if the continuous additions make a difference with your beers. We include two Dogfish Head recipes to put your gadget to use.



Homestyle Hopback

Build An Oast

Continuous Wort Hopper

how to build a hopback, an oast and a continuous wort hopper.

Homestyle Hopback

Build your own French press hybrid

Story and photos by **Forrest Whitesides**

The concept of a hopback — a device containing hops through which you pump your still-hot wort before it is chilled — is certainly nothing new. It's a technique both pros and homebrewers have been using for years. In professional brewing applications, a hopback (also sometimes called a hopjack or simply a hop separator) has traditionally been used to remove cone hops from the wort post-boil. The process of loading the hopback with fresh hops — as a means to add flavor and aroma to the wort as it is pumped to the chiller — was a subsequent innovation in commercial settings. But homebrewers can use the basic concepts behind a hopback to add a new dimension of hop kick to their beers.

While the designs for hopbacks are as varied as the brewers who use them, this article outlines the procedure for building a hopback that somewhat resembles the operation of a French press coffee maker. It offers superior filtering and maximum wort-to-hops contact surface area. For this hopback (and most other hopbacks I've seen) to work properly, you should use whole hops instead of pellets. Hop pellets break down into particles too fine to be strained out and thus are not suitable for hopback use.

2 You will need a false bottom that fits in your cooking pot. Try bringing the false bottom along when finding your pot to ensure a good fit.

Design and Parts List

A lot of hopbacks are made from a CPVC or metal cylinder and often use a pump to push the wort through. The wort goes into one end of the cylinder, which is loaded with fresh leaf hops, and flows through the other end into a counterflow chiller. Instead of that, we're going to gravity-flow (or optionally pump) hot wort into a small pot with hops held under a false bottom and then let the beer flow up through the hops and out of a ball valve into a counterflow or plate chiller. Our design here works in a very different way mechanically from many other hopbacks, but yields the same result: a big, fat post-boil addition of fresh hops to add more depth to the hop aroma and flavor of your beer.

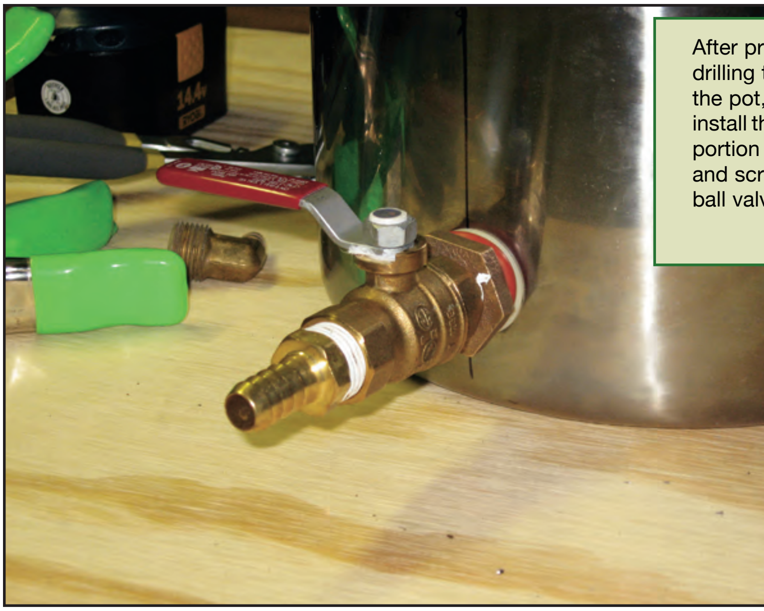
Our hopback is built from three main critical components: a 8-quart (or larger, depending on your needs) common cooking pot, (Figure 1) a false bottom (Figure 2), and a ball valve with bulkhead fitting (Figure 3). You'll also need a ½-inch male NPT-threaded hose barb and some high-temp tubing.

The most important thing in selecting a pot is to make sure the diameter is very close to the diameter of the false bottom you're going to use. I chose a Northern Brewer 9-inch diameter false bottom commonly used in lautering, but you can also go with a 10-inch (23 cm) or 12-inch (30.5 cm) false bottom. Whatever you choose, make sure that it fits the pot you intend to use and that it is safe for use with near-boil-

1 To build this hopback project, you will need a large, common cooking pot that can hold at least eight quarts.

PARTS LIST

- 8-quart (or larger) cooking pot
- false bottom that fits into the pot
- ball valve with bulkhead fitting
- ½-inch male NPT-threaded hose barb
- high-temperature tubing



After properly drilling the hole in the pot, you can install the bulkhead portion of the valve and screw on the ball valve.

ing liquid. (Hint: I took my false bottom into a department store and tested the fit in several pots before making a purchase. You might get a few funny looks, but it'll save you a big headache down the road.) Either stainless steel or aluminum pots are fine for this, but I recommend stainless. There are many inexpensive and widely available stainless pots in this smaller size.

I recommend a ½-inch ball valve to allow for an outflow that will be close to matching the inflow from the kettle. I used a spare weldless kettle conversion kit from Zymico from another project, but you don't necessarily need something that fancy.

Drilling the Pot

This is probably the trickiest part of the project, and the one step you want to get right the first time. There are no do-overs when drilling a hole. For an in-depth look at proper drilling techniques for both stainless steel and aluminum, see page 55 of the March-April 2007 issue of BYO. I recommend using a step-drill bit for drilling, especially for stainless steel. With aluminum, you can get the job done with a spade/paddle bit.

Drill a ⅞-inch hole approximately 1.5 inches (4 cm) up from the bottom of your pot. What is critical here is to put the hole high enough so that when the ball valve and bulkhead are installed there is enough clearance for the false bottom to be easily inserted and removed. I highly recommend doing a few test placements of the bulkhead — before you drill — to make sure it's high enough (you'll need an extra set of hands to help you do this). The horizontal placement of the hole is up to you, but I personally prefer to have it about 90 degrees from the handles.

Installing the Valve and False Bottom

Install the bulkhead portion of the valve and then screw on the ball valve itself (Figure 3). Do not over-tighten, as you could possibly damage the gaskets.

The false bottom comes with a 90-degree barbed elbow fitted in the center of the screen. Unscrew the top nut holding in the elbow and remove the fitting. In its place, screw in a ½-inch male NPT-threaded hose barb and replace the top nut to secure it (Figure 4).

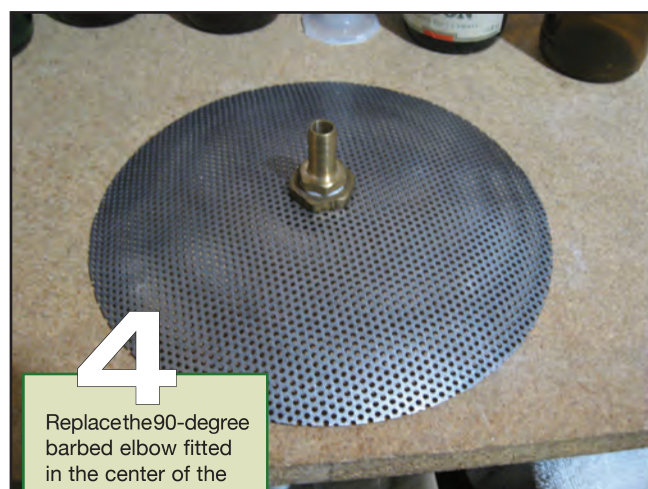
Now simply slide the false bottom in under the bulkhead fitting and you're done (Figure 5). If you used a Zymico weldless bulkhead (or made your own with similar parts), you can use the barbed elbow that you removed from the false bottom as a pickup tube to minimize the wort lost to the dead space in the hopback. Just screw it into the bulkhead and push the barb down against the false bottom (Figure 6).

Using the Hopback

The operation of this hopback is fairly straightforward:

- Put some hops in the bottom of the hopback
- Slide in the false bottom (above the hops)
- connect the hopback's hose barb to your kettle's ball valve via high-temp tubing
- open the outlet valve on the hopback, and then
- open the valve on your kettle.

The hopback's outlet valve, of course, will be connected to the "wort in" side of your counterflow chiller, also with high-temperature tubing.



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Replace the 90-degree barbed elbow fitted in the center of the screen with a ½-inch male NPT-threaded hose barb.

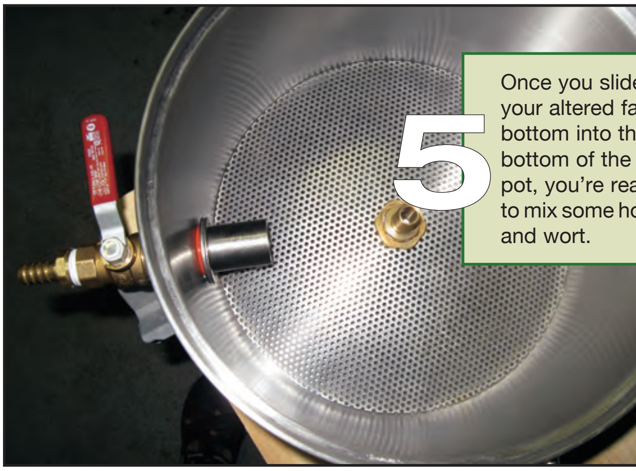
Some Things to Consider

If you intend to use the barbed elbow as a dip tube, be aware that it will somewhat restrict the outlet flow of your wort. In this case, your kettle valve should only be opened between half and two-thirds of maximum flow to make sure the hopback valve can keep up with the inflow of wort.

Also, because of the nature of the design, if you intend to use a pump with this hopback, be sure you can restrict the flow rate enough to avoid an overflow of the hopback reservoir (the pot).

Another consideration is that since the flow into your chiller will likely be at a lower rate than you are used to, you should adjust your cooling water flow rate accordingly.

With the hopback pictured ((9-in./23 cm) false bottom in a 8-quart/7.6 L pot), I find that 1–3 ounces (28–85 g) of whole hops

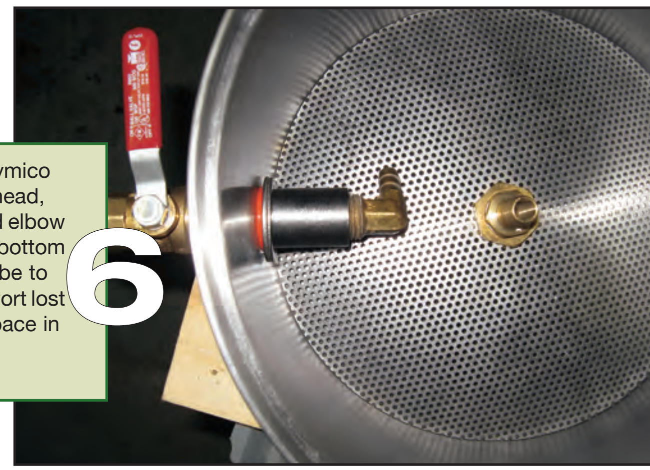


5 Once you slide your altered false bottom into the bottom of the pot, you're ready to mix some hops and wort.

works best. More than three ounces (28 g) is a tight fit once the hops are fully hydrated, but it can be done. If you're going to try to cram a whole lot of hops in there, I recommend not breaking up the hops after taking them out of their vacuum-packed bags. Using too much, however, may cause the false bottom to lift up and allow hops to get pulled into the valve and into your chiller (possibly causing a frustrating clog).

Using a larger false bottom will more easily accommodate larger quantities of hops. Stepping up the size of the false bottom and pot may be a good option if you plan to brew 10-gallon (38-L) batches. The point of a hopback is to add hop aroma (and some hop flavor) to your beer, but not so much for bitterness. Therefore, you may want to select more aromatic hop varieties for your hopback. But as always, feel free to disregard "conventional wisdom" and experiment to your taste buds content.

Forrest Whitesides writes the "Projects" column in every issue of Brew Your Own *and has admitted to using a salad spinner to retrieve wort from post-boil hop cones.*



6 If you use a Zymico weldless bulkhead, use the barbed elbow from the false bottom as a pickup tube to minimize the wort lost to the dead space in the hopback.

Build An Oast

How to make your own hop dryer

Story and photos by **Forrest Whitesides**

1 If you plan on growing your own hops this year, consider building an oast to dry your harvest.

Historically, hops were dried in two- and three-story round brick buildings called oasts, which made their first appearance in England in the 16th Century. You can recreate this same basic convection-driven drying effect at home on a scale to match your own homebrew-sized hop harvest.

Concept Overview

What we're building is a dehydrator that uses active convection (driven by a small fan) as the main means of dehydration. The hops are suspended on a drying rack and the fan pulls a constant flow of air over the hops, which carries the moisture away.

The following build guide is just one of many ways to put together your own oast. The size, shape, look, and general construction of the oast can be almost anything you want to match your needs (or whatever you can manage to bang together, as in my case). What is critical to the design is that there is an adequate flow of air across the hops. Everything else is negotiable.

Tools and Materials

A miter box and back saw, hand saw, keyhole saw and sanding block, along with a power drill and a staple gun will suffice for this project. If you have power tool equivalents to these hand tools, use them at your discretion.

I built my oast primarily from ½" medium-density fiberboard because it is an easy material to cut, it takes glue very well, and it is economical. I used inexpensive 1 ½" by ¾" pine stock to make the drying rack frame and the interior rack supports. (Note: These are great materials for prototyping and proof-of-concept builds, but if I had to do it over I would've gone with a thicker, higher-grade plywood for the box and some hardwood stock for the rack). I used vinyl-coated fiberglass screen to finish the drying rack but you could also use stainless steel screen.

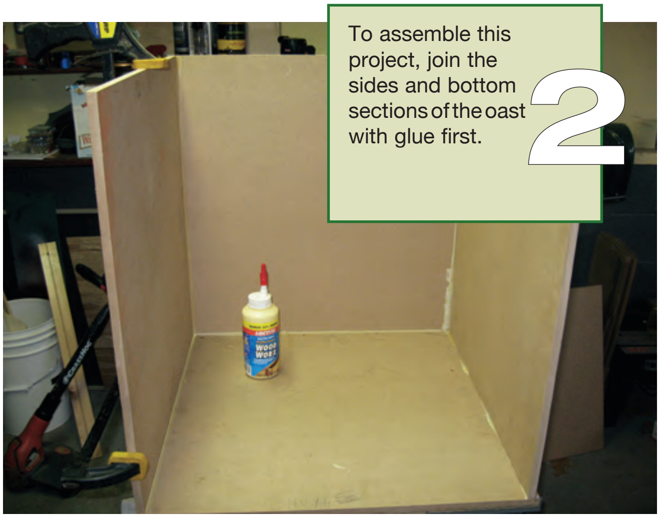
I used two small utility hinges to create a "front door" for the oast. And to keep the door closed, I used a sash lock commonly used to latch windows. You can also add a knob- or bar-style drawer pull to complete the door paradigm. I used a medium-duty staple gun to attach the screen to the drying rack. Look for a gun that uses T50-sized staples. I don't recommend using staples smaller or thinner than the T50.

Electronic Components

To generate the convection current, I used a 65-mm (2.5") 12 Volt DC fan. This is the type commonly found inside computers to help keep the processor cool. They move a lot of air (about 25 cubic feet per minute) and have a low current draw (about 0.125 amps). A fan like this will "turn over" the entire interior air volume of the oast two or three times per minute. You can scavenge one from an old PC or you can buy one new from big-box consumer electronics stores or Radio Shack. But you don't need to use a 2.5" fan specifically. The most common size you're likely to find at a store or in a computer is 80 mm (3.125"), which will also work.

Traditional oast designs require a heat source, although from what I've read about DIY dehydrating, heat is not a necessary component. This design does not use heat, however, a very simple and relatively safe way to go about it would be to position a typical electric space heater a few feet away from the air vents that are drilled into the bottom of the oast. The fan on top would pull the warm air through the bottom holes and out the top.

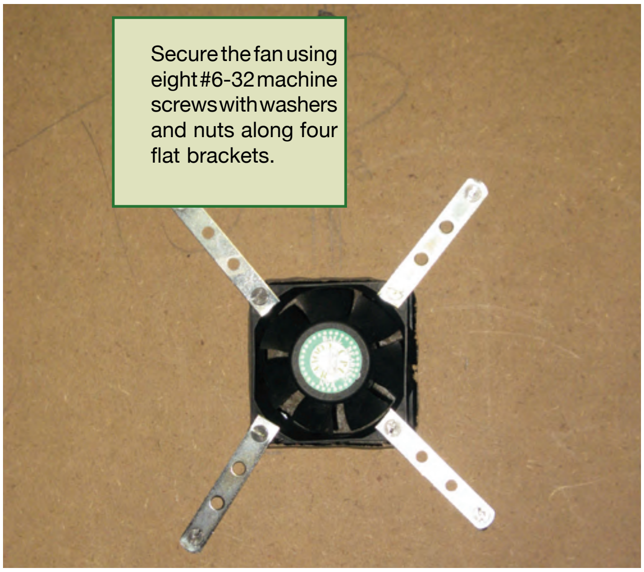
I also added two simple controls to the fan: an on/off power switch and a variable fan-speed control. The power switch I used is a simple "pushbutton" SPST (single-pole, single-throw) switch.



2 To assemble this project, join the sides and bottom sections of the oast with glue first.

Any style of SPST switch will work, whether it's a toggle, pushbutton, slide, rocker, etc. Avoid "momentary" type switches, which will only allow current to the fan while you hold the button down.

The speed control is a 500-ohm linear potentiometer, which, along with the SPST switches mentioned above, is available at most Radio Shack stores. If you can't find a 500-ohm potentiom-



Secure the fan using eight #6-32 machine screws with washers and nuts along four flat brackets.

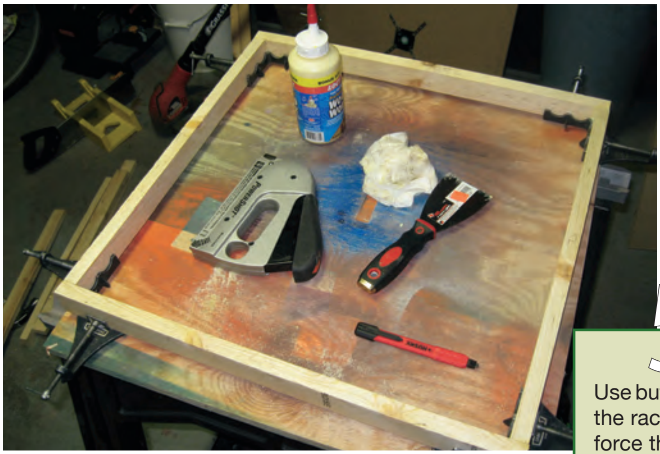
eter, you can use higher values, such as 1k-ohms or 2.5k-ohms. Higher values than this will work, but as you go higher, the useful range of the potentiometer decreases and the touch sensitivity of the control increases until it is almost like an on/off switch.

To fasten the fan to the top of the oast, I used #6-32 machine screws (along with the corresponding washers and nuts) and four flat pre-drilled brackets.

Additionally, you'll need a DC power supply to run the fan. Just about any DC supply will work, from 5 volts up to 12 volts. You probably have a few of them laying around your house left over from electronic gadgets you no longer use or own. What you're looking for is the typical black, square adapter that plugs into a wall socket and has a round adapter plug with a metal or plastic/metal tip. Just cut off the plug end and strip back the plastic insulation about half an inch to expose the wires. Use a voltmeter to verify wire polarity (i.e.: which wire is ground). Check your fan for current requirements, which will be specified on the fan case. Be sure that your power supply can deliver the specified current (usually between 0.1 and 0.2 amps).

Dimensions and Structural Design

Because it was easier for me to visualize in my head, I built my oast as a cube (my wife affectionately calls it the "big box 'o hops"). Each side is roughly 24" (61 cm) because the fiberboard I bought came in 48" x 24" sheets, so going with that size saved me a few cuts at the beginning. You can build yours in any size or shape that fits your brewing space. So long as the air is flowing inside, the shape of your oast is irrelevant. Following is a general guide you can follow to build your own DIY hop dryer. There are many ways to get the job done, and this is just one of them. Feel free to deviate from the process below at your discretion.



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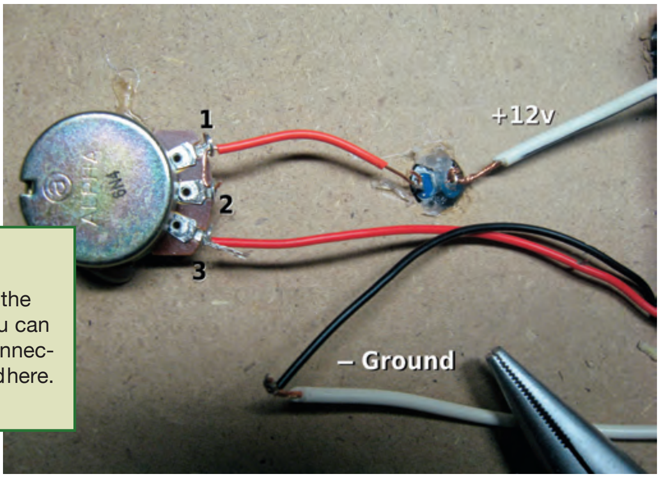
Use butt joints to join the rack, then reinforce the joints with staples.

General Build Guide

Assuming you want to go with a box-like shape, you'll need to cut six sections of fiberboard or plywood. The dimensions of each section will vary based on your design and also based on how you intend to join the sections together. For simplicity, I chose to use common butt joints, but I reinforced each joint with dowels for added strength. You could opt for any style of joinery that you're comfortable with (miter joints or rabbet joints would work exceptionally well here, as would butt joints reinforced with biscuits).



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Once you have the fan in place, you can solder all the connections, as pictured here.

I opted to join the sides and rear sections with the bottom section first, and left attaching the top and front for the last part of the build (Figure 2). Before gluing, drill a few ½" holes near the bottom of the left, right, and rear sections of the box. These holes serve as intake vents from which the fan can pull air up through the oast. Also drill a ¼" hole at the top of the back section for the power supply wires.

Now apply glue to the sections, fit and clamp them, and wait for the glue to dry. With most wood glue, the joints will set up enough to remove the clamps after about 30 to 45 minutes, but I would advise that you take your time and let the glue fully cure (which takes about 24 hours) before taking the clamps off. Better safe than sorry.

With the bottom and sides clamped and drying, now is a good time to mount and wire the fan and electronic controls to the top section of the soon-to-be oast. Lay the fan flat on the board where you want to mount it (I recommend close to the center for more even airflow) and trace the outline with a pencil or pen.

For my oast, I decided to mount my fan flush with the board, but you can also mount it directly on top of the board. This is much easier than

Once the joints are together, you can staple the screen along the edges.

6

flush mounting, and the overall performance is practically identical.

For flush mounting, cut around the fan outline you traced on the board. You can use a rotary tool (Dremel, RotoZip, etc), jigsaw, or keyhole saw to cut the hole. The fan should just fit inside the hole. To secure the fan, use eight #6-32 machine screws with washers and nuts along with four flat brackets (Figure 3). I made brackets from #4 mirror hanging eyes.

For top mounting, come in about a ¼ of a inch from each side of the fan trace and cut the hole. Use four of the #6-32 machines screws, washers, and nuts to secure the fan.

Once your fan is mounted, choose a spot for the controls, drill a 5⁄16" hole for the potentiometer shaft to fit through, and also drill a hole for the power switch (the size of which will depend on the switch you choose). I recommend positioning the controls near the fan, as this makes for a cleaner, shorter wiring run.

Most potentiometers and switches were not designed to be mounted to materials thicker than about a ¼ of an inch, so you'll need to glue them in place. An all-purpose adhesive like Gorilla Glue is ideal, but I found that craft-grade high-temperature hot glue works admirably.

When the rack supports are dry, you can glue the top on.

8

Connect the positive wire from the power supply to one of the lugs on the SPST switch (it doesn't matter which one), and use a short piece of shielded wire to connect the other lug on the switch to lug 3 of the potentiometer. Connect lugs 2 and 3 of potentiometer to each other. Connect the red (positive) wire from the fan to lug 1 of the potentiometer. Finally, connect the black (ground) wire from the fan to the ground wire of the power supply. The complete wiring, left unsoldered for clarity, is shown in Figure 4. I recommend soldering all connections — except for the ground wires which can be spliced together with a small wire cap connector — but it's not 100% required.

Now that the wiring is finished, and the glue is *still* curing, let's move on to the hop-drying rack. Cut four pieces of wood

To glue the supports to the inside, use clamps and scrap stock to secure.

7

stock for the rack's frame. The lengths for these should be about a ¼-shorter than the interior width of your oast, and at least an inch shorter in depth, but this will vary some depending on how you join them. As with the oast box itself, I used butt joints to join the rack and reinforced the joints with staples. Corner clamps make this job very easy, but they aren't required (Figure 5). When the glue is dry, cut a piece of vinyl screening about an inch wider on each side than the frame itself. Staple the screen to the frame along the side edges (Figure 6), and also add a row of staples along the bottom side edges. Make as many racks as you need for your hop harvest.

By now, the glue securing the oast joints will be dry, so you can add the interior supports that the rack will sit on. I'd suggest using at least ½" (0.23 cm) thick stock for these. Cut two pieces (per rack) about 2" (5 cm) shorter than the interior depth of your oast. I glued the supports to the oast using clamps and scrap stock to secure it and used a bubble level to get it even (Figure 7).

When the rack supports are cured and dry, glue the top section to the rest of the oast (Figure 8). Now all that remains is to attach the front section to the oast with hinges. I chose to have the front open forward like an oven, but you could also have it open from the side like a cabinet or refrigerator. To keep the door closed, you'll need some type of latching mechanism. I used a window-style sash lock. Drying time in your oast will depend on temperature and humidity, but an overnight run should get your hops dried or nearly so.

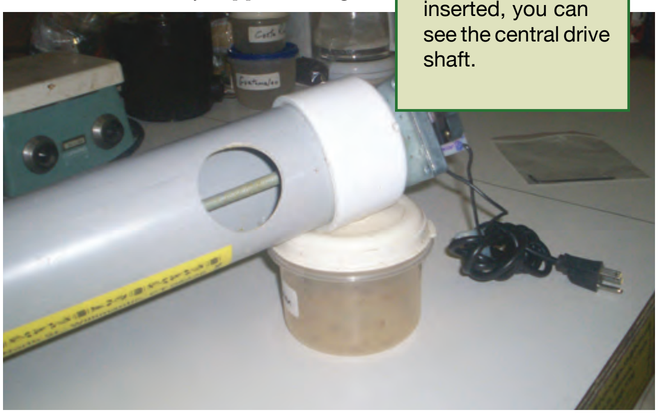
Forrest Whitesides is NOT *a professional carpenter, but he does drink a lot of tasty homebrew, which makes him a pretty smart guy.*

Continuous Wort

Build this device to dribble hops into your wort.

Story and photos by **Paul Zocco**

A few years ago, Sam Calagione of Dogfish Head started producing some unusual IPAs, barleywines and other over-the-top beers. Conventional brewing practice dictates the addition of hops at specific times during the boil. In contrast, Dogfish Head has designed a series of beers that are continuously hopped throughout the entire boiling process. Their 60-minute IPA, 90-minute IPA and 120-minute IPAs have hops added throughout their 60, 90 and 120 minute boils.



Through the hole where the hops are inserted, you can see the central drive shaft.

Being an avid homebrewer, I wanted to brew beers like these guys were making . . . big, hoppy beers full of too much of everything, especially hops. Being somewhat of a gadget type person, I also wanted to build and use a continuous wort hopper, similar to the one at Dogfish Head.

I wanted a device that would drop a steady stream of hop pellets into my kettle throughout the entire boil. My plan was to come up with something like Dogfish Head's hop feeder, which they call Sir Hops-a-Lot. Of course, mine would be a lot smaller, made from easily obtained components and everyday tools. The result of my quest was my "homebrewed" continuous wort hopper, which I named the Zopinator.

The planning phase involved a lot of deliberation and a few failed designs. I toyed with the idea of using a small motor driven auger, but decided against it. Instead, I opted to use a one RPM motor as a drive for a spinning, perforated disk inside a tubular reservoir.

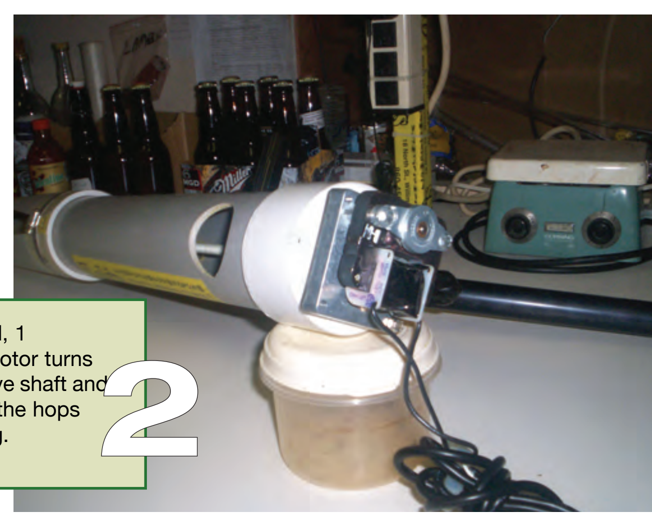
One Part Design . . .

I found a one RPM motor at Grainger, a national equipment supply company, for around $35.00 (U.S.). It is equipped with a 3/8" steel drive shaft. The motor must turn an 18" (46 cm) length of 3/8" threaded rod that will operate a rotating port (valve). To attach the motor drive to the port, I made up a simple coupling by drilling a 3/8" hole through a piece of steel round stock (1" long, 3/4" in diameter). I drilled small holes (2 opposed on each end) and threaded them with a 1/4" X 20-thread tap. A couple of 1/4" Allen screws on each end lock onto the motor shaft on the motor end, and also connect to the drive shaft on the other end of the coupling. Inserted into the drive end would be a length (16–18"/41–46 cm, depending on the length of your PVC pipe) of 3/8" threaded steel rod. The threaded shaft turns a small rotating "valve" that allows hops to drop through.

The main housing for the Zopinator is a 2' (61 cm) length of 4" diameter PVC pipe. The 1 RPM motor easily mounts to a conventional PVC end cap. The length of the pipe is not a critical dimension, but 2' (61 cm) keeps the motor a safe distance from the steam exiting during the boiling cycle.

So, with the motor mounted on one end and a threaded shaft attached via your homemade coupling, you now have a drive that operates a valve on the other end. This is where the design got a little tricky.

I attached a common PVC coupling to the pipe on the opposite end of the motor. I then cut a 1/16" thick disc of plastic to the exact inside diameter of the coupling. I wanted a pretty tight fit so it could revolve inside the coupling so hop pellets wouldn't "leak out," but not so tight that it would be restrictive. The inside of a PVC coupling has a small step in it that could act as a surface the plastic valve could be in contact with. After a little filing and sanding, the plastic disc fit nicely inside the coupling. I then drilled a 3/8" hole in the center of the disk and attached it to the 3/8" threaded drive rod so that it had a locking nut and a washer on both sides of the plastic valve, effectively locking it in place.



A small, 1 RPM motor turns the drive shaft and keeps the hops coming.

2

Next, I drilled a 3/8" hole about halfway up the PVC and attached the entire assembly to a camera tripod. Any support you choose must stand a foot or so (at least 30 cm) above your boil kettle so the hops can drop in. A 45° angle down toward the brew kettle seemed to be enough to allow the hops to drop fairly consistently.

. . . One Part Trial and Error

The hop pellets I sell at my homebrew shop have a similar diameter,

3 The business end of the hopper. Pellet hops drop through the hole in the rotating disk.

but are various lengths. This was an early concern of mine. I wondered if the hops would bunch up as they packed down and would not drop through the hole as planned. However, with the Zopinator on a roughly 45° angle, the hops did drop out pretty consistently. Occasionally, however, the hops would pack up above the hole and not drop. To solve this problem, I drilled four small holes in the valve about 1" (2.5 cm) from the center mounting hole. To these, I attached four small bolts. These turn along with the rotating plastic valve, effectively keeping the hops from bunching up.

After drilling and cutting increasingly larger openings in the thin plastic disk, I came up with an orifice size that was suitable. Finally, I drilled a 1" (2.5 cm) hole about an inch (2.5 cm) or so below the motor location as a place to insert the hop pellets.

Test Check One Two

On testing day, I loaded the Zopinator with pellet hops, set a timer and placed a small scale below the hopper. I observed that the pellets dropped a few at a time, a little time would pass and then a few more would drop. It seemed inconsistent. However, over time, the non-linear drop rate evens out and things worked smoothly. When measured in 10 minute increments, the hop rate remained constant.

Crunching the Numbers

Theoretically, to calculate total IBUs for a continuous hop addition, you would have to calculate an IBU value for each hop pellet (or group of hop pellets) that fell in the wort then add these values together. To make the calculations a little less daunting, I grouped the hop additions into the amount of hops dropped in a 10-minute period — about 1.1 ounces (31 g).

For a continuous addition throughout a 60-minute boil, using hops with 5% alpha acids, I calculated 94 IBUs. (Your calculations may vary, depending on the assumptions you make and — of course — the drop rate of your hopper.)

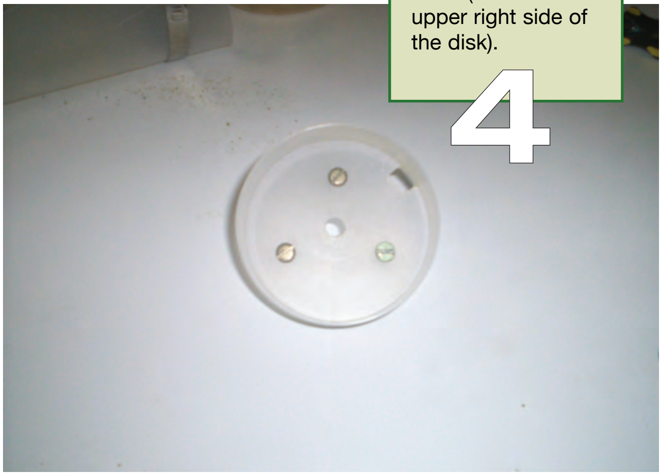
To achieve less hop bitterness, you could use lower alpha hops, run the hopper for a shorter amount of time or boil a larger amount of wort. (A 10-gallon/38 L batch, made with the above procedures, would yield 47 IBUs.)

To achieve more bitterness, you could add higher alpha hops or run the hopper longer (say, for 90 minutes instead of 60). You could also "spike" the wort with added hops at specific times.

The original purpose of the Zopinator was to aid in making unusual hoppy beers. I wanted their hop profiles a little bit different than the regular run of the mill ales. I find that in BJCP beer competitions, judges seem to like a little change from the regular, and award high points to unusual examples (that are still within style guidelines).

In truth, the real reason I designed and built the Zopinator was to do the same as Sam of Dogfish fame did . . . that is, to brew some real off centered beers with some profound hop flavors and aromas that would show off what we homebrewers (and adventurous commercial brewers) live for — individuality. Now, whenever I design a beer recipe, I put my "signature" on it with the Zopinator.

Paul T. Zocco is the owner of Zok's Homebrewing Supplies, Willimantic, Connecticut. The terms "Sir Hops-a-Lot" and "continual hopping" are trademarks of Dogfish Head.



4 A closer look at the disk, with its "hop hole" (seen in the upper right side of the disk).

5 The hopper, mounted on a tripod, ready to drop a steady stream of pellets into some wort.

recipes

60-Minute IPA clone (Dogfish Head Craft Brewery)

(5 gallons/19 L, all-grain)
OG = 1.064 FG = 1.019
IBU = 60 SRM = 6 ABV = 5.8%

Ingredients

12 lbs. 15 oz. (5.86 kg) 2-row pale malt
6.4 oz. (0.18 kg) Thomas Fawcett amber malt
11.2 AAU Warrior hops (60-35 mins) (0.70 oz./20 g of 16% alpha acids)
3.6 AAU Simcoe hops (35-25 mins) (0.28 oz./7.9 g of 13% alpha acids)
5.6 AAU Palisade hops (25-0 mins) (0.70 oz./20 g of 8% alpha acids)
1 tsp. Irish moss (15 mins)
0.70 oz. (20 g) Palisade hops (whirlpool, 0 mins)
0.59 oz. (17 g) Amarillo hops (dry hops)
0.59 oz. (17 g) Simcoe hops (dry hops)
0.59 oz. (17 g) Glacier hops (dry hops)
Wyeast 1187 (Ringwood Ale) or other English ale yeast (1.5 qt./~1.5 L starter @ SG 1.030)
⅞ cup corn sugar (for priming)

Step by Step

Mash at 152 °F (67 °C) for 60 minutes. Boil wort for 60 minutes. Begin hopping wort with a continuous stream of Warrior hops at a rate of 0.28 oz. (7.9 g) per 10 minutes. Warrior should run out with 35 minutes left in boil. (Target IBU for Warrior additions = 39 IBUs.) Refill hopper with Simcoe hops and resume hopping until 25 minute remaining mark. (Target IBU for Simcoe additions = 10.5 IBUs.) Refill hopper with Palisade hops for remaining part of boil. (Target IBU for Palisade additions = 10.5 IBUs.) Add Irish moss with 15 minutes remaining. Add whirlpool hops after boil and begin cooling. Aerate cooled wort and pitch yeast. Ferment initially at 71 °F (22 °C), but let temperature rise to 74 °F (23 °C) towards the end of fermentation. Warm condition for 3 days (to remove diacetyl), then cool beer and add dry hops, allowing 2 weeks contact time.

Extract with grains version:

Steep 1.5 lbs. (0.68 kg) of 2-row pale malt and 6.4 oz. (0.18 kg) of Thomas Fawcett amber malt at 152 °F (67 °C) in 2.25 qts. (2.1 L) of water. (This is technically a partial mash, so follow temperature and volume guidelines closely.) After 45 minutes, rinse grains with 1 qt. (~1 L) of 170 °F (77 °C) water. Add water to "grain tea" to make 4 gallons (15 L). (To save time, heat ~3.5 gallons (13 L) of water during "steep.") Stir in 4.0 lbs. (1.8 kg) Muntons Light dried malt extract and bring to a boil. During the boil, do not let wort volume drop below 3.5 gallons (13 L). Add boiling water if wort volume dips near this mark. Follow the hopping instructions given in the all-grain recipes. With 15 minutes left in the boil, turn off the heat and stir in 2.0 lbs. 14 oz. (1.3 kg) of Muntons Light liquid malt extract and Irish moss. Resume heating once extract is dissolved. After chilled wort is transferred to fermenter, add water to make 5 gallons (19 L). See the all-grain instructions for remaining details.

90-Minute IPA clone (Dogfish Head Craft Brewery)

(5 gallons/19 L, all-grain)
OG = 1.088 FG = 1.021
IBU = 90 SRM =13 ABV = 8.7%

Ingredients

16.5 lbs. (7.5 kg) Pilsner malt
1.66 lbs. (0.75 kg) amber malt (35 °L)
16 AAU Amarillo hops (90-0 mins) (2.0 oz./57 g of 8.0% alpha acids)
8.0 AAU Simcoe hops (90-0 mins) (0.62 oz./17 g of 13% alpha acids)
8.0 AAU Warrior hops (90-0 mins) (0.53 oz./15 g of 15% alpha acids)
1 oz. (28 g) Amarillo hops (dry hops)
0.5 oz (14 g) Simcoe hops (dry hops)
0.5 oz. (14 g) Warrior hops (dry hops)
1 tsp. Irish moss (15 mins)
Wyeast 1099 (Whitbread) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash in at 122 °F (50 °C), then raise the temperature to 149 °F (65 °C) until conversion is complete. Mash out to 170 °F (77 °C). Boil the wort for 105 minutes. Starting with 90 minutes left in the boil, begin slowly and evenly adding hops to the kettle. (This works out to a little over 0.25 oz. (7 g) of hops every 7.5 minutes.) Start fermentation at 71 °F (22 °C) and let raise to 74 °F (23 °C). Dry hop in secondary at 71 °F for 3-5 days, then cool to 32 °F (0 °C).

Extract with grains version:

Replace Pilsner malt with 8.0 lbs. (3.6 kg) dried malt extract and 1.75 lbs. (0.79 kg) of Pilsner malt. Steep crushed grains in 1.1 gallons (4 L) of water at 150 °F (66 °C) for 45 minutes. Follow the remaining instructions in the all-grain recipe.

Darth Porter clone (Stone Brewing Company)

(5 gallons/19 L, all-grain)
OG = 1.076 FG = 1.019
IBU = 63 SRM = 51 ABV = 7.3%

Ingredients

13 lb. 10 oz. (6.2 kg) Pilsner malt
12 oz. (0.34 kg) chocolate malt
8.0 oz. (0.23 kg) Caramunich® malt
8.0 oz. (0.23 kg) crystal malt (90 °L)
4.0 oz. (0.11 kg) black patent malt (or Carafa® malt)
13.5 AAU Perle hops (60 mins) (1.5 oz./43 g of 9% alpha acids)
6.5 AAU Hallertau hops (30 mins) (1.0 oz./28 g of 6.5% alpha acids)
0.5 oz. (15 g) Hallertau hops (15 mins)
Wyeast 2206 (Bavarian Lager yeast) or White Labs WLP820 (Octoberfest/Märzen Lager) yeast
1 cup corn sugar (for priming)

Step by Step

Mash at 154 °F (68 °C). Boil wort for 60 minutes. Ferment at ale temperatures, then rack to barrel and age six months to a year (or more). Pull samples from all of your barrels every few months and taste them.

Extract option

Omit Pilsner malt and add 3.25 lb. (1.5 kg) Briess Light dried malt extract and 5.75 lb. (2.6 kg) Weyermann Pilsner liquid malt extract. Steep grains in 3 qts. (~3 L) of water at 154 °F (68 °C) for 45 minutes. Rinse with 1.5 qts. (~1.5 L) of water at 170 °F (77 °C). Add water to make 3 gallons (11 L), add dried malt extract and bring to a boil. Boil for 60 minutes, stirring in liquid malt extract for final 15 minutes of boil.

Fuller's ESB clone (Fuller, Smith & Turner p.l.c., England)

(5 gallons/19 L, all-grain)
OG = 1.060 FG = 1.014
IBU = 35 SRM = 15 ABV = 5.9%

Ingredients

9 lbs. 2 oz. (4.1 kg) English 2-row pale ale malt (3 °L)
2.0 lbs. (0.91 kg) flaked maize
1 lb. 2 oz. (0.51 kg) crystal malt (60 °L)
5.25 AAU Target hops (60 mins) (0.53 oz./15 g of 10% alpha acids)
2.6 AAU Challenger hops (60 mins) (0.34 oz./10 g of 7.5% alpha acids)
0.83 AAU Northdown hops (15 mins) (0.1 oz./2.7 g of 8.5% alpha acids)
1.66 AAU Goldings hops (15 mins) (0.33 oz./9.4 g of 5% alpha acids)
¼ tsp yeast nutrients
1 tsp Irish moss
Wyeast 1968 (London ESB) or White Labs WLP002 (English Ale) yeast (2 qt./2 L starter)
0.75 cups corn sugar (for priming)

Step by Step

Heat 15 qts. (14 L) of water to 165 °F (74 °C) and stir in crushed grains and flaked maize. Mash at 154 °F (68 °C) for 60 minutes. Stir boiling water into mash to boost temperature to 168 °F (76 °C) and hold for 5 minutes. Recirculate for 20 minutes then begin running off wort. Sparge with 170 °F (77 °C) water. Boil wort for 90 minutes, adding hops to boil for the times indicated in recipe. Add yeast nutrients and Irish moss with 15 minutes left in boil. Cool wort and transfer to fermenter. Aerate wort and pitch yeast. Ferment at 70 °F (21 °C). Rack to secondary when fermentation is complete. Bottle a few days later, when beer falls clear.

Fuller's ESB clone (Fuller, Smith & Turner p.l.c., England)

(5 gallons/19 L, extract with grains)
OG = 1.060 FG = 1.014
IBU = 35 SRM = 14 ABV = 5.9%

Ingredients

1.45 lbs. (0.66 kg) Muntons Light dried malt extract
4.0 lbs. (1.8 kg) Muntons Light liquid malt extract (late addition)
1 lb. 2 oz. (0.51 kg) English pale ale malt (3 °L)
1 lb. 2 oz. (0.51 kg) crystal malt (60 °L)
1 lb. 5 oz. (0.60 kg) corn sugar
5.25 AAU Target hops (60 mins) (0.53 oz./15 g of 10% alpha acids)
2.6 AAU Challenger hops (60 mins) (0.34 oz./10 g of 7.5% alpha acids)
0.83 AAU Northdown hops (15 mins) (0.1 oz./2.7 g of 8.5% alpha acids)
1.66 AAU Goldings hops (15 mins) (0.33 oz./9.4 g of 5% alpha acids)
1/4 tsp yeast nutrients
1 tsp Irish moss
Wyeast 1968 (London ESB) or White Labs WLP002 (English Ale) yeast (2 qt./2 L starter)
0.75 cups corn sugar (for priming)

Step by Step

In a large soup pot, heat 3.4 quarts (3.2 L) of water to 165 °F (74 °C). Steep grains in this water, at around 154 °F (68 °C), for 45 minutes. Begin heating 2.25 gallons (8.5 L) of water in your brewpot. When steep is over, remove 1.1 qts. (~1.1 L) of water from brewpot and add to the "grain tea" in steeping pot. Place colander over brewpot and place steeping bag in it. Pour grain tea through grain bag. Heat liquid in brewpot to a boil, then stir in dried malt extract, add first charge of hops and begin the 60 minutes boil. With 15 minutes left in boil, add sugar, remaining hops, yeast nutrients and Irish moss. Then turn off heat and stir in liquid malt extract. At the end of the boil, cool wort and transfer to fermenter. Add water to make 5.0 gallons (19 L), aerate wort and pitch yeast. Ferment at 70 °F (21 °C). Rack to secondary when fermentation is complete. Bottle a few days later, when beer falls clear.

Left Hand Twin Sisters Double IPA clone

(5 gallons/19 L, all-grain)
OG = 1.085 FG = 1.016
IBU = 87 SRM = 15 ABV = 9.0%

Ingredients

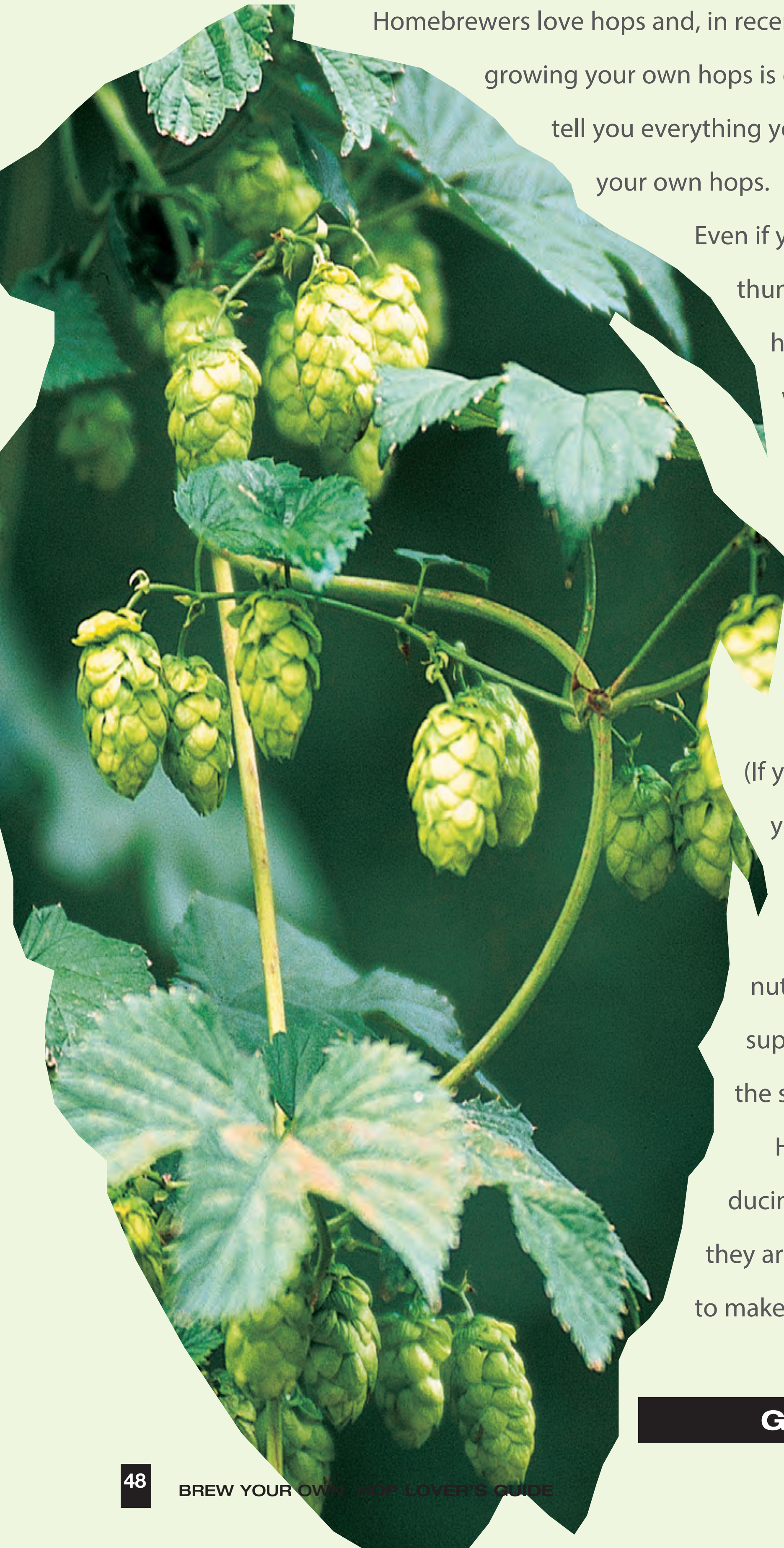
15.5 lbs. (7.0 kg) Castle pale malt
1.5 lbs. (0.68 kg) rye malt
0.5 lbs. (0.23 kg) biscuit malt
0.5 lbs. (0.23 kg) crystal malt (40 °L)
13.75 AAU Tomahawk hops (60 mins) (0.92 oz./26 g of 15% alpha acids)
7.5 AAU Glacier hops (45 mins) (0.63 oz./18 g of 12% alpha acids)
3.75 AAU Cascade hops (30 mins) (0.75 oz./21 g of 5% alpha acids)
3.75 AAU Liberty hops (15 mins) (0.94 oz./27 g of 4% alpha acids)
3.0 AAU Liberty hops (5 mins) (0.75 oz./21 g of 4% alpha acids)
1.25 oz. (35 g) Crystal hops (dry hops)
Wyeast 1272 (American II) or White Labs WLP005 (California V) yeast (3 qt./~3 L yeast starter)
0.75 cups corn sugar (for priming)

Step by Step

Mash at 152 °F (67 °C). Boil for 90 minutes. Ferment at 68 °F (20 °C).

Extract with grains option:

Omit pale malt and add 3.5 lbs. (1.6 kg) Muntons Light dried malt extract and 6.5 lbs. (3.0 kg) Muntons Light liquid malt extract. In your brewpot, heat 3.5 quarts (3.3 L) of water to 163 °F (73 °C). Add crushed grains to a nylon steeping bag and steep for 45 minutes at 152 °F (67 °C). While grains are steeping, heat 1.5 quarts (1.4 L) of water to 170 °F (77 °C). After steep, put a colander over your brewpot and put the grain bag in it. Rinse grains with 170 °F (77 °C) sparge water. Add water to brewpot to make 4.0 gallons (15 L). Bring "grain tea" and water to a boil and add dried malt extract. Boil for 60 minutes, adding hops at times indicated. Keep a small pot of boiling water handy and keep the boil volume topped up to 4.0 gallons (15 L). Stir in the liquid malt extract at the end of the boil and let it steep for 15 minutes before cooling. Cool wort and transfer to fermenter. Top up to 5 gallons (19 L) with cool water and aerate thoroughly. Pitch yeast and follow the fermentation instructions in the all-grain recipe.



Homebrewers love hops and, in recent years, many have discovered that growing your own hops is easy and rewarding. In this article, we'll tell you everything you need to grow, harvest and process your own hops.

Even if you are not a gardener, or lack a "green thumb," you can grow hops successfully at home without a lot of fuss. Hops require well-drained soil and lots of sun. They are planted from underground stems (called rhizomes) and they spring back every year from these rhizomes. The vining stems (technically caled bines) should be trained onto a trellis, as the plant can grow up to 30 ft. (9 m) high. (If you plant along the side of your house, you can drop twine from the edge of the roof.)

Hops require a fair amount of nutrients as they grow, but these can be supplied by a yearly addition of compost to the soil above the rhizome.

Hops eventually flower and begin producing cones. Once these cones turn yellow, they are ready to be harvested, dried and used to make your next hoppy homebrew.

Growing your own hops is

growing HOPS

by **Bill Pierce** and **Chris Colby**

One of the easier ways you can put the "home" in homebrewing is to grow your own hops. Growing hop plants is relatively easy and offers a high probability of success, even for homebrewers who know little about gardening. Plus, the hops you harvest can add a special touch to your favorite homebrew.

A Hint of Hop History

Hops likely were originally native to Asia and later were cultivated by the Greeks and Romans for their tender shoots, that were cooked and eaten much like asparagus. However, the dried cones were not used for bittering and flavoring beer until the Middle Ages, and it was only in the late 1500s that they came into regular use in England.

Today, commercial hop cultivation in the United States is centered in the Yakima Valley of central Washington and to some extent in the Willamette Valley of Oregon. There is also some acreage in Idaho. Historical hop growing regions also have included California, central Wisconsin, central New York and western Massachusetts. In fact, hops have been raised commercially throughout most of Europe and North America, and homebrewers now successfully grow them in every US state and Canadian province.

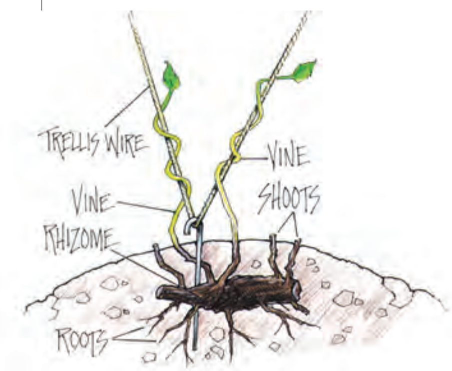
What it Takes

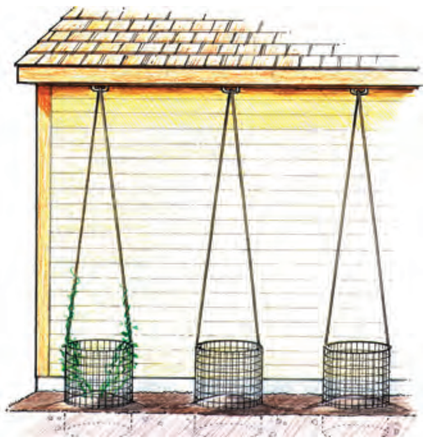
The requirements for growing hop plants include well-drained soil, sufficient moisture, a sunny location, room for the plants to climb and a growing season of at least 120 days without a hard freeze. The roots also like a dormant season and will withstand harsh winters.

The hop vines are annual, dying off each winter. The vines are technically bines, since they have many sharp "hairs" that help secure them to their supporting structure. This contrasts with true vines, which have tendrils (or other appendages) that help them climb. Informally, it is common for people to refer to the bines as vines. The rhizomes (underground stems), however, are perennial, sending up new green shoots in the early spring.

Over several seasons, the plants develop an extensive rhizome and root structure and grow best in a fairly large space, but there are those who manage to raise hops in large tubs on a sunny deck. Surplus beer kegs will work if they have holes for adequate drainage.

Only the female hop plants produce the distinctive cones, technically known as strobiles, that are used in brewing. (Despite the usage of the term "leaf hops," the leaves are not used in brewing. A better term is "whole hops.") The presence of male plants will cause the production of seeds that reduce the bittering and the useful yield. Some English hops are purposely grown in the presence of male hops, and are seeded. This is why digging up and replanting of wild hops is not





When planting rhizomes (top), face the root side down. The shoots will train clockwise up a trellis. An easy option is against a south-facing wall of your house (bottom).

easy and fun. Plus, once established, you'll never run out of hops.

recommended. Buy female plants that have been selected for cultivation.

Where to Go

Many homebrew shops, mail-order and online suppliers offer hop rhizomes for sale in late winter or early spring. If your local homebrew shop does not carry rhizomes, an internet search for "hop rhizomes" will bring up a number of sellers.

Rhizomes are underground stems that look somewhat like ginger root. (In fact, the ginger "root" you buy in a supermarket is really a ginger rhizome). Check for availability in the spring. Rhizomes should stored in a cool location prior to planting. For the best results, wrap the rhizome in wet newspaper and place it in a plastic bag in your refrigerator.

The varieties offered for sale may vary somewhat from year to year, depending on availability and disease restrictions. Not all of them will do equally well in a particular region or location. If you have hop-growing members in your homebrew club, they will likely have some information on what has worked well or poorly in your region. Most rhizomes available for purchase will be roughly the size and shape of a human finger.

For most North American homebrewers, the hop varieties that have produced the most successful homegrown hops are those varieties developed in North America. These include Willamette, Mt. Hood, Chinook, Nugget and especially Cascade, which are prolific and reliably produce high yields almost everywhere. Other varieties have mixed results, but you are free to try them. Keep in mind that when English or German hops are grown in the US, their character changes. And, if you live in a location with long, hot summers, be aware that most varieties of aroma hops do not deal well with heat.

Hops Spring Eternal

Hops are an early season crop and can be planted soon after the soil can be worked. This likely will be anywhere from early February to mid-May, depending on your location. If you are an experienced gardener, you can think of them as being similar to peas in terms of their planting time. They will tolerate moderate frosts well, although a hard freeze — below 28 °F (-3 °C) for 24 hours or more — will damage the young shoots.

Location, Location, Location

Choose a sunny spot with good drainage. You will later need strings or wires for the bines to twine around as they grow. These can be stretched from stakes in the ground to tall poles or the edge of a building, ideally the south-facing side. If you live in the southern part of the United States, plant the hops where they get sun in the morning, but are at least partially shaded during the hottest hours of the late afternoon.

Hops are prolific climbers; they can reach a height of 25 to 30 feet (8–10 m). However, they can be trained to grow vertically for part of that distance and then extended horizontally or at an angle along an elevated trellis or lattice. It's worth planning for the best configuration that fits your growing space.

The soil should be porous and relatively rich. A soil pH of 6.5–8.0 is optimal for hops. This covers the range that most vegetables crops are happy with (6.5–7.0). Till the soil to a depth of about 12 inches (30 cm), adding a little sand if it is overly dense. Dig holes at least 12 inches (30 cm) deep and 3 to 5 feet (~ 1–1.5 m) apart, so that the plants don't grow together. In the bottom of each hole place an inch or two (3–5 cm) of organic compost or a balanced, mild commercial vegetable fertilizer or well-seasoned manure. Refill the hole and plant the rhizome, with any rootlets pointing downward, an inch or two (2.5–5.0 cm) under the soil surface. Fill the hole the rest of the way with soil, tamp it down lightly and cover with some mulch such as straw or grass clippings. Water well but do not flood the ground. If drainage is a concern, you can add some potting mix to the soil you dug from the hole and make a small hill for planting the rhizome.

Growth and Maintenance

Within a couple of weeks, depending on the soil temperature, the shoots should begin to emerge. Commercial growers cut back the first shoots to emerge, and wait for the next round to train to the wires. It's best to select the three or four strongest shoots from each plant and trim back the others. Once they reach a length of 12 to 18 inches (30–45 cm), twine the shoots (in a clockwise direction, when viewed from the top) around the wires or strings and let them climb. On a warm, sunny day in late spring, it's not uncommon for them to grow 6 inches (15 cm) per day.

Early in the growing season, hops require a lot of nitrogen. The compost buried with the rhizome should be sufficient, but be prepared to add more fertilizer if the established leaves are light green or yellow. The youngest leaves — near the growing tip of the bine — are often a few shades lighter than the established leaves, which should be dark green. Small leaves, thin bines and weak growth can also be a sign of nitrogen deficiency (although it can also occur if the plant is not getting enough sun).

The plants will require fairly frequent watering throughout most of the growing season, although the ground should not have standing water. If you are in a dry climate you should probably consider drip irrigation or a soil soaker. In order to prevent mildew – a common problem plaguing hops – do not drench the foliage.

Non-Human Hopheads

Hops have a few enemies, animals that enjoy hops as much as the most rabid IPA fan. Rabbits and deer are fond of the young and tender shoots; you may wish to protect the plants with chicken wire when they are small.

Bothersome insects include aphids, spider mites and Japanese beetles. Because you will be brewing with the cones, use low-toxicity measures to control pests. Ladybugs (available at some garden shops) are a natural predator of aphids, while mild insecticidal soap sprays are the best defense against serious infestations of the others. Generally these problems become less severe as the season progresses. Also, homebrewers living in parts of the world where hops were not traditionally grown report fewer problems with diseases and pests.

After the summer solstice, the plants gradually will switch their energies from growing foliage to producing small, burr-like flowers and eventually the cones. These will continue to appear and grow throughout the summer. The number of cones your bines develop will depend on the age of the plants and the growing conditions. Don't despair if you have few or even no cones in the first season. Almost all hop growers report much higher yields after a year or two as the plants develop a more extensive root system.

Once the plant has flowered, its demand for phosphorous will increase. Again, the compost added at the beginning of the season should be sufficient to meet the plant's needs. However, a small addition of a phosphorous-rich fertilizer — or even a balanced, general-purpose fertilizer — may help. When it comes to fertilizer additions (at any stage of hop growth), more is not always better. If the established leaves look healthy, keep any addition light.

Once the bines have reached 10–15 feet (3.0–4.5 m), some commercial growers remove the leaves from the bottom 3–4 feet (0.9–1.2 m) of the plants, to improve air circulation in the hopyard.

Bringing in the Cones

Typically by late August or early September, and a bit earlier in warmer climates, the first cones will be ready for harvesting. It's a little tricky to determine when hop cones are ready to be harvested, but here are a few tips:

Color The color of a mature cone should be a light yellowish-green and the individual "leaves," technically known as bracts and bracteoles, should be starting to separate. Additionally, the tips of the bracteoles will turn brown.

Lupulin Glands There should be dots of powdery yellow lupulin glands on the bracts toward the stem.

Touch Test When you squeeze a cone it should feel slightly dry and papery and spring back a little after you release it. If it is somewhat moist, dense and unyielding, it is not ready. After touching a ripe cone your fingers should have a little lupulin on them and you should detect the typical smell of hop oils.

The cones mature over a period of a couple of weeks, so you can harvest them progressively. If you do this you will need a ladder or other means in order to pick only the ripe cones. Be careful to avoid falling; it's best not to have a homebrew before or during climbing. The alternative is to cut the strings or wires and lower them to where they can be reached. Unfortunately this may require discarding some of the cones that have not yet ripened.

Drying the Cones

Once harvested, the cones will need to be dried. Wet hop cones will soon begin to mold and quickly become useless for brewing purposes. Commercial hops are dried in ovens called oasts. There are several ways for homebrewers to dry their homegrown hops.

A food dehydrator works very well for drying hops. This device can dry the hops quickly, and at a controlled temperature. Commercially-grown hops are dried at 140–150 °F (60–66 °C). This dries them quickly, but also blows off some of the volatile oils. Hop growers need to quickly dry their entire crop, so the temperature they dry hops at is a compromise between quality and processing time. As a homebrewer, you can dry your hops in a food dehydrator at 120–130 °F (49–54 °C). At these temperatures, drying will take the better part of a day. When the central stems inside the cones (the strigs) are brittle, the hops are dry.

You can also dry a small amount of hops on a cookie sheet in an oven set to less than 150 °F (65 °C). Leave the oven door open and provide good ventilation. A slower but often more convenient method is to find a warm, dry location such as an attic or garage. Spread out the cones on a window screen supported by sawhorses, with a fan set on the floor underneath. The cones should be dry within 2–3 days if the high temperature each day is 85 °F (30 °C) or more.

When the cones are dry they will still be light yellowish-green in color, but they will feel brittle and papery and be a fraction of their weight when picked, due to the loss of moisture. At this point place them in zippered plastic bags intended for freezing, squeeze out as much of the air as possible, label them and store in the freezer until ready for brewing.

The bines will wither and die off after the harvest. Cut back the dead foliage in the fall to within about an inch (3 cm) of the ground. It can be composted with other yard wastes; some people make hop wreaths for the winter holidays. Place some straw or other mulch over the plants before the ground freezes or goes dormant. This is also the best time to fertilize the soil.

An application of 15–20 lbs. (~7–9 kg) of compost per plant is a good starting point for a healthy plant next season. Work the compost into the top few inches (~5–8 cm) of the soil. Alternatively, you can mix one part compost with two to three parts garden soil or potting mix and apply a couple inches of the mixture to the top of the hop bed. The rhizomes will send up shoots again in the spring.

If you wish to replant the hops in another location or donate cuttings to your fellow homebrewers, you should dig up the rhizomes in the late fall. Select and cut healthy-looking sections about as thick and slightly longer than your finger. Surround each one with a little damp soil and mulch, and place in a zippered plastic storage bag. Store in a dark, cool location such as a basement or refrigerator. They can be planted again in the early spring.

Bitter Fruits

Commercial hops are analyzed for the alpha acid percentage so that the brewer knows their expected contribution in terms of bittering. Unfortunately it's difficult for the home hop grower and homebrewer to determine this without access to a lab. You can estimate the bittering based on the published alpha acid ratings of commercial hops of the same variety, but these vary from season to season.

It's easy to brew a test batch of beer with homegrown hops and then compare it to other beers of known bittering. By this means and with a little calculation you can approximate the alpha acid content. Consider that fresh, homegrown hops may outweigh your need to calculate your IBUs to three decimal places. You can also send a sample of your hops or the beer brewed with them to a commercial laboratory for alpha acid or bittering analysis. The fees for such services are generally in the range of $25–$50.

Many homebrewers use homegrown hops only for flavor and aroma additions, where the bittering is less of a factor and the fresh qualities of your own hops are far more important and appreciated.

Bill Pierce was BYO*'s "Advanced Homebrew" columnist. Chris Colby is Editor of* BYO.

The level of bitterness in beer can be described in terms of International Bitterness Units (or IBUs). Although homebrewers cannot measure the amount of IBUs in their beer (without access to some specialized equipment), they can estimate the expected level of bitterness based on how "strong" their hops are (as measuered in percent alpha acids) and how long they boil them. Calculating your expected IBU level requires that you know the alpha acid rating of your hops, the weight of your hops, the volume of your batch of beer and a factor called the hop utilization.

Hop utilization is a measure of how much you extract from your hops and there are several published estimates of hop utilization available. Which hop utilization curve best describes the brewing equipment and practices of a brewer must be decided by the brewer.

The calculation of IBUs is only one tool to help a brewer achieve his desired hop profile; he (or she) also needs to get to know their system, assess their ingredients and taste their beer critically.

Learn how to estimate the expected

calculating IBUs

by Chris Colby

Calculating Bitterness

In alcoholic beverages, sweetness is usually balanced by another flavor. In wine (and some styles of beer), it is balanced by acidity. In most styles of beer, however, the sweetness is balanced by bitterness from the hops.

The level of bitterness in beer can be expressed in International Bitterness Units (IBUs), which are defined as the milligrams of iso-alpha acids per liter of beer. Different styles of beer have typical ranges of bitterness, and the table on page 54 lists this for selected styles, as given by the Beer Judge Certification Program (BJCP).

Homebrewers, however, don't add iso-alpha acids directly to their beer. (Some commercial brewers do, though.) Homebrewers boil hops in their wort and alpha acids in the hops are converted to iso-alpha acids. How much of the alpha acids from the hops get converted to iso-alpha acids depends primarily on how long they are boiled and how dense the wort is. Many other variables affect isomerization to a lesser extent. The expected level of IBUs in homebrew can be estimated by using the following formula:

$$IBU = [W_{mg} \times AA \times U]/V_L$$

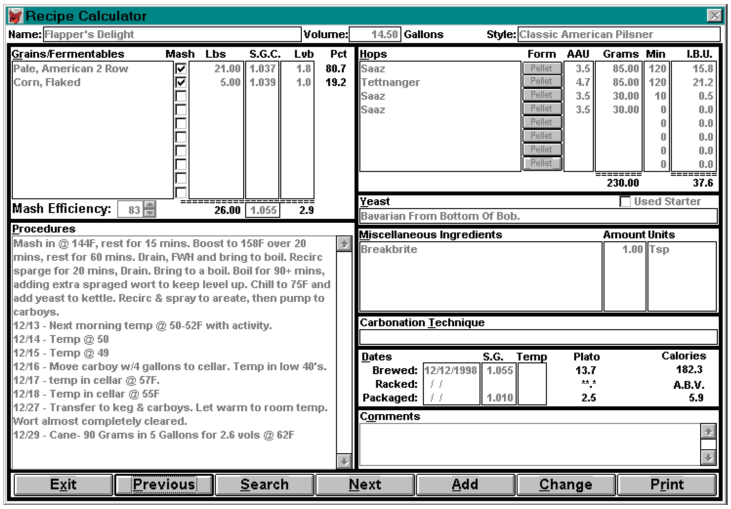
or

$$IBU = [W_{oz} \times AA \times U \times 7489]/V_{gal}$$

where "W" is the weight — in either milligrams or ounces, depending on which formula you use — of the hops. (To convert from grams — a unit you would likely measure your hops in — to milligrams, multiply by 1000.) "AA" is the fraction of alpha acids in the hops, expressed as a number between zero and one. For example, if your hops were rated at 6.5% alpha acids, you would use 0.065 for the value for AA.

"U" is the utilization factor, the fraction of the alpha acids that end up contributing towards the bitterness of the beer. "U" is also expressed as a number between zero and one. The value for U is affected by many things, including boil time, wort gravity and the form of hops used (pellet, plug or whole). The hop utilization table on page 55 gives ranges of values of U for various boil times.

The number 7489 in the lower equation is simply a conversion factor to correct for the fact that English units are being used.



It's easy to calculate the expected level of bitterness in your beer (in IBUs).

level of bitterness in your beer, based on the homebrew recipe.

Table 1

Typical IBUs for Selected Beer Styles	
Berliner Weisse	3–8
American Pilsner	8–15
Cream Ale	15–20
English Bitter	25–35
English ESB	25–40
American Pale Ale	30–45
English IPA	40–60
American IPA	40–70
Imperial IPA	60–120
English Barleywine	35–70
American Barleywine	50–120
Brown Porter	18–35
Robust Porter	25–50
Dry Stout	30–45
Foreign Export Stout	30–70
Kölsch	20–30
Hefe-weizen	8–15
Witbier	10–20
Belgian Tripel	20–40
Bohemian Pilsner	35–45
Octoberfest	20–28
Doppelbock	16–26

Using this formula, you can calculate the IBU contribution of each hop addition you make during the boil. The total number of IBUs in your beer is the sum of all the hop additions.

Example of Calculating IBUs

Let's say you plan to brew 5.0 gallons (19 L) of pale ale at a starting specific gravity of 1.050. You plan to add 2.0 oz. (57 g) of Northern Brewer hops with 8.5% alpha acid and boil them for 1 hour. With 30 minutes to go in the boil, you add 1.5 oz. (43 g) of Fuggles hops with 4.0% alpha acids. After choosing the appropriate values of U from Table 2 on page 55, we get:

IBU = [57000 X 0.085 X 0.231]/19 +
[43000 X 0.040 X 0.177]/19
= 58.905000 + 16.023159 = 75

If you worked this out on your calculator, you might notice that number displayed is 74.928159. However, in our equation, the weight of the hops, alpha acid rating and volume were each only known to two significant figures. Thus, the calculated value was only expressed to two significant figures. Expressing more digits than the number of significant figures we supply implies a level of precision beyond what is warranted.

On a related note, keep in mind that the value of your IBU estimation depends a great deal on the quality of the numbers you enter. The main variables in the equation are weight, volume and utilization. Most homebrewers can only weigh their hops to the nearest quarter ounce (~ 7 g); if a single hop addition totaled 2.0 oz. (56 g), this means you could at best measure it to within 12.5%. And, if you calibrate your brew pot (perhaps by making an accurate dipstick), you may only be able to measure your volume to within a couple cups (~500 mL). This would amount to a least a few percentage points of possible variation. The less accurately you measure these variables, the less useful your IBU calculations will be.

Utilization Curves

You might wonder where the numbers for hop utilization in Table 2 come from. The table we give is a hop utilization table created by homebrewer Glen Tinseth. Using some existing data, he came up with an equation relating boil time to utilization. He also came up with an equation relating wort specific gravity to utilization. The numbers in the table are calculated values based on these equations.

Other authors have presented other equations, tables or graphs purporting to describe hop utilization and homebrewers often ask which hop utilization curves are best. In reality, no hop utilization curve is inherently better than another. On your system, one curve may reflect the hop utilization you are actually achieving better than the others. However, on a friend's system, another curve might yield a better estimate.

Most homebrewers use recipe formulation software to calculate IBUs, and most software packages allow you to select different hop utilization curves. These are given by the name of the author and the most commonly used curves are those proposed by Tinseth, Rager, Garetz and Mosher. Most homebrewers try calculating their IBUs using all the available options, then pick the curve they feel best reflects the bitterness of beers brewed in their homebrewery.

To get an accurate estimate of the real hop utilization achieved on your system, you would need to brew several batches of beer, get the IBU numbers from a lab analysis and back calculate your hop utilization from these numbers. In practice, few homebrewers do this. It would not be too hard, however, to brew several batches, compare them in a taste test to commercial beers of known bitterness and do the same thing. Of course, the resulting estimate of your hop utilization would depend on how accurately you could assess IBUs in your beer — and scientists estimate that most beer drinkers can only discriminate IBUs to the nearest 5 IBUs.

What Does It Mean?

One important fact to keep in mind is that the IBU number you calculate is an estimate, not a measurement, of the bitterness in your beer. Most homebrewers only guess at the real utilization values they achieve on their system by picking a hop utilization curve that "seems right." However, even if you carefully measured your actual achieved utilization, there still would be some natural variation from batch to batch. (The same thing occurs when you calculate the average extract efficiency on your system — on any given batch, you might not hit your estimated original gravity right on the nose. Unlike with OG, however, there is no simple way to measure IBUs in homebrew, although you can send your beer out to a professional lab for analysis.)

Since the calculated IBU number is only an estimate, you need to taste your beer, assess its bitterness, and make any needed changes the next time you brew. The IBU calculators found in homebrew software are great tools, but you also need to use employ your taste buds when developing recipes.

Other Factors

All hop utilization curves take boil time into account and most also factor in wort thickness. However, there are many other factors that can influence hop utilization.

The form of hop you use — whole, plug or pellet — affects your utilization. Generally, homebrewers assume that hop pellets get 10% better utilization than whole hops. (Plugs are thought to get about 2% better utilization than whole hops.) Adding your hops as first wort hops also changes the equation. Since first wort hops steep in hot wort before being boiled, brewers usually factor in an additional 10% utilization.

Another factor that influences bitterness is the aging of the hops. The alpha-acid percentage of the hops may have decreased since the measurement was made. The amount of decrease would depend on what temperature the hops were stored at, whether they were exposed to oxygen and their form. (Hop pellets store better when exposed to oxygen than whole hops.)

Unfortunately, the homebrewer usually has no way of determining the storage history of his hops. To take aging into account, you need to multiply their alpha-acid percent by a factor of the percentage of the alpha-acids that were lost — and, under most circumstances, this can only be guessed at. You can help yourself out immensely in this respect by finding a source that packages your hops in oxygen-barrier bags and keeps them frozen.

Enclosing your hops in a bag versus simply throwing them in your brewpot can also have an effect. Bagging hops is thought to reduce your efficiency by about 10%, although estimates vary wildly.

Bitterness is decreased during fermentation, and your pitching rate affects this — more yeast leads to more loss of bitterness, although this loss is assumed to be constant by the equations. (It is also likely that different strains of brewers yeast absorb different amounts of bittering compounds.)

At this point, a cynical homebrewer might say that IBU calculations are based on two variables that don't always get measured very accurately, one that is next to made up — and then this number is perhaps modified by a lost list of factors you can only guess at. However, despite these limitations, IBU calculations can give you a good idea of the level of bitterness in your beer. If you use these calculations in conjunction with your own brewing and tasting experience, you can learn to control your level of bitterness to a reasonable degree. This is especially true if you brew a beer, taste it critically and rebrew the same beer (from the same ingredients) a short time thereafter.

Don't Forget The Oils

In homebrewing, an extensive amount has been written about estimating IBUs. However, hops provide more than just bitterness to the beer. They also provide flavors and aromas, which mostly come from the oils of the hop. When adjusting the amount of hops to account for the alpha acid rating, keep in mind that you are changing the amount of oils you are adding to your wort as well. To preserve the intended flavor and aroma of a recipe, smell your late addition hops before the boil starts. If you need to adjust the amount of late hops, do this first. Then, perform your IBU calculations again, adjusting the amount of bittering hops required to hit your target IBU value.

Chris Colby, Editor of BYO, *only likes numbers when they mean something.*

Hop Utilization vs. Boil Time and Original Gravity

Table 2

Boil Time (min) — Original Gravity (specific gravity): 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
6	0.059	0.054	0.049	0.045	0.041	0.038
12	0.106	0.097	0.088	0.081	0.074	0.068
18	0.142	0.130	0.119	0.109	0.099	0.090
24	0.171	0.157	0.143	0.131	0.120	0.109
30	0.194	0.177	0.162	0.148	0.135	0.124
36	0.212	0.194	0.177	0.162	0.148	0.135
42	0.226	0.206	0.189	0.172	0.158	0.144
48	0.237	0.216	0.198	0.181	0.165	0.150
54	0.246	0.224	0.205	0.188	0.171	0.157
60	0.252	0.231	0.211	0.193	0.176	0.160
70	0.261	0.238	0.218	0.199	0.182	0.166
80	0.266	0.243	0.222	0.203	0.186	0.170
90	0.270	0.247	0.226	0.206	0.188	0.172
120	0.275	0.252	0.230	0.210	0.192	0.176

recipes

Yeti Imperial Stout clone (Great Divide Brewing Company)

(5 gallons/19 L, all-grain)
OG = 1.090 FG = 1.018
IBU = 75 SRM = 98 ABV = 9.3%

Ingredients

15.25 lbs (6.9 kg) American 2-row malt
1.0 lb (0.45 kg) crystal malt (120 °L)
12 oz. (0.34 kg) chocolate malt
12 oz. (0.34 kg) black patent malt
10 oz. (0.28 kg) roasted barley
8.0 oz. (0.23 kg) flaked wheat
8.0 oz. (0.23 kg) flaked rye
14.3 AAU Chinook hops (60 min) (1.1 oz./31 g of 13% alpha acids)
7.2 AAU Chinook hops (30 min) (0.55 oz./16 g of 13% alpha acids)
5.3 AAU Centennial hops (15 min) (0.50 oz./14 g of 10.5% alpha acids)
0.5 oz. (14 g) Centennial hops (5 min)
Wyeast 1056 (American Ale) or White Labs WLP001 (California Ale) yeast (3 qt./~3 L yeast starter)
0.75 cups corn sugar (for priming)

Step by Step

Mash at 150 °F (66 °C). Boil for 60 minutes, adding hops as indicated above. Ferment at 70 °F (21 °C).

Partial mash option:

Reduce the amount of 2-row pale malt to 2.0 lbs. (0.91 kg). Add 9.0 lbs. (4.1 kg) of Mun-tons Light liquid malt extract to the recipe. Heat 2.3 gallons (8.7 L) of water to 161 °F (72 °C). Submerge grain bag(s) and partial mash at 150 °F (66 °C) for 30-45 minutes. (Note: this is just over 6 lbs. (~ 3 kg) of grains, you may need more than one grain bag.) Remove grains, rinse grain bag(s) slowly with 1.0 gallon (3.8 L) of water at 170 °F (77 °C). Add water to brewpot to make 4.0 gallons (15 L) of wort; stir in roughly two-thirds of the malt extract. Bring to a boil. Boil for 60 minutes, adding hops at the times indicated in the ingredient list. Add remaining malt extract with 15 minutes left in boil. Cool wort, transfer to fermenter, top up to 5 gallons (19 L), aerate and pitch yeast. Ferment at 70 °F (21 °C).

5 Barrel Pale Ale clone (Odell Brewing Company)

(5 gallons/19 L, all-grain)
OG = 1.052-1.054 FG = 1.013
IBU = 36 SRM = 11 ABV = 5.1%

Ingredients

8.0 lbs. (3.6 kg) pale ale malt
1.75 lbs. (0.79 kg) Gambrinus ESB Malt
0.5 lbs. (0.23 kg) crystal malt (40 °L)
0.75 lbs. (0.34 kg) Munich malt
9.5 AAU Cascade hops (90 mins) (1.9 oz./54 g of 5% alpha acids)
0.5 oz. (14 g) Fuggles hops (0 mins)
0.5 oz. (14 g) First Gold hops (0 mins)
1.0 oz. (28 g) Glacier whole hops (hopback)
0.66 oz. (19 g) Willamette whole hops (hopback)
0.5 oz. (14 g) Centennial whole hops (hopback)
1.0 oz. (28 g) Glacier hops (dry hop)
1.0 oz. (28 g) Willamette hops (dry hop)
0.25 oz. (7 g) Centennial hops (dry hop)
ale yeast (1.5 qt./~1.5 L yeast starter)
1.0 cup corn sugar (for priming)

Step by Step

Mash at 150–152 °F (66–67 °C). Boil 90 minutes. After cool down, pitch your favorite ale yeast, but not one which produces diacetyl. At end of fermentation, chill to as close to 32 °F (0 °C) as you can for 1-2 weeks.

Extract option:

Omit pale ale malt. Reduce ESB malt to 1.75 lbs. (0.79 kg). Add 1.5 lbs. (0.68 kg) light dried malt extract at beginning of boil and 3 lb. 10 oz. (1.8 kg) light liquid malt extract as a late addition.

Sierra Nevada Stout clone (Sierra Nevada Brewing Company)

(5 gallons/19 L, all-grain)
OG = 1.065 FG = 1.019
IBU = 60 SRM = 40 ABV = 5.8%

Ingredients

9.0 lbs. (4.1 kg) American pale malt
3.0 lbs. (1.4 kg) Munich malt (10 °L)
1.0 lb. (0.45 kg) American black patent malt (500 °L)
0.67 lbs. (0.30 kg) American crystal malt (60 °L)
14 AAU Magnum hops (60 mins) (1.0 oz./28 g of 14% alpha acids)
5.8 AAU Cascade hops (10 mins) (1.0 oz./28 g of 5.75% alpha acids)
2.0 oz. (57 g) Willamette hops (0 min)
Wyeast 1056 (American Ale), White Labs WLP001 (California Ale) or Safale US-05 yeast
1 cup corn sugar (for priming)

Step by Step

Mash 154 °F (68 °C) for 60 minutes in 16 qts. (15 L) of mash liquor. Boil wort for 60 minutes. Ferment for 7 days at 68 °F (20 °C). Rack to secondary and condition for 14 days at 68 °F (20 °C).

Sierra Nevada Stout clone (Sierra Nevada Brewing Company)

(5 gallons/19 L, partial mash)
OG = 1.065 FG = 1.019
IBU = 60 SRM = 40 ABV = 5.8%

Ingredients

0.33 lbs. (0.15 kg) American pale malt
3.0 lbs. (1.4 kg) Munich malt (10 °L)
1.0 lb. (0.45 kg) American black patent malt (500 °L)
0.67 lbs. (0.30 kg) American crystal malt (60 °L)
2.0 lbs. (0.91 kg) Briess Light dried malt extract
4.0 lbs. (1.8 kg) Briess Light liquid malt extract (late addition)
14 AAU Magnum hops (60 mins) (1.0 oz./28 g of 14% alpha acids)
5.8 AAU Cascade hops (10 mins) (1.0 oz./28 g of 5.75% alpha acids)
2.0 oz. (57 g) Willamette hops (0 min)
Wyeast 1056 (American Ale), White Labs WLP001 (California Ale) or Safale US-05 yeast
1 cup corn sugar (for priming)

Step by Step

Mash at 154 °F (68 °C) for 60 minutes in 7.5 qts. (7.1 L) of mash liquor. Combine partial mash wort with dried malt extract and enough water to make at least 3.5 gallons (13 L). Boil wort for 60 minutes. Add liquid malt extract with 15 minutes left in boil. Ferment at 68 °F (20 °C). Rack to secondary and condition beer for 14 days at 68 °F (20 °C).

ad index

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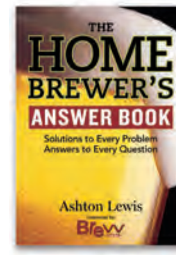

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Throughout Brew Your Own's Hop Lover's Guide, we've given you plenty of hearty, hoppy homebrew recipes. (See the recipe index on page 2 for a complete rundown.) But, we wanted to throw in just a few more of our favorites — including some dark beers, because pale ales and IPAs aren't the only brews that a hophead would be interested in.

For the best results, read the recipe carefully before brewing and follow the instructions. (Don't for example, skip the hot whirlpool step in the New World Porter clone.) Select fresh aromatic hops and — if you're an extract brewer — boil an adequate amount of wort to allow you to extract the full amount of bitterness from the hops. (Most of the extract recipes give this info; if not, see the chapter regarding extract brewing for more information.)

Arguably, the most important aspect of making good homebrew is running a good fermentation. Always pitch an adequate amount of yeast. (Most of our recipes suggest a proper yeast starter size.) In addition, keep your fermentation temperature steady and in the recommended range for the yeast strain. These steps, along with adequate cool wort aeration, will contribute to a well-run fermentation and that, in turn, leads to great homebrew. Happy (and hoppy) brewing!

We serve up a wide variety of

hoppy RECIPES

OK, hop lovers, you've surely noticed that we've spread recipes throughout this Hop Lover's Guide. Well, we've got just a few more. When you brew these beers, keep in mind the advice found in this special issue as well as sound brewing practices. Water chemistry, a vigorous boil and a controlled fermentation mean as much to the final beer as the selection of malt and hops listed here. Also, remember that the amount of hops in the recipes and estimated IBUs are starting points. Following BYO's standard recipe assumptions, these recipes should get you in the right ballpark of hoppiness. But the subtle details of your ingredients, system and procedures make a difference. For the absolute best brews, brew the recipe as written first, then taste it critically. Smell the hop aroma. Taste the hop bitterness and flavor. Assess the balance between the hops and the malt. Write these findings down in your brewing notebook then make the tweaks needed to the recipe and procedures to take the quirks of your hops, brewing equipment and procedures into account and brew the beer again. Happiness is a hoppy beer, brewed to perfection.

recipes

Old Rasputin Imperial Stout clone (North Coast Brewing Company, California)

(5 gallons/19 L, extract with grains)
OG = 1.091 FG = 1.022
IBU = 75 SRM = 61 ABV = 8.9%

Ingredients

3.75 lbs. (1.7 kg) Briess Light dried malt extract
6.6 lbs. (3.0 kg) Coopers Light liquid malt extract (late addition)
1.0 lb. (0.45 kg) Hugh Baird Carastan malt (35 °L)
0.5 lb. (0.23 kg) Hugh Baird Brown malt (60 °L)
0.5 lb. (0.23 kg) chocolate malt
1.0 lb. (0.45 kg) crystal malt (120° L)
0.25 lb. (0.11 kg) roasted black barley
21.5 AAU Cluster hops (60 mins) (3.1 oz./87 g of 7% alpha acid)
8.0 AAU Northern Brewer hops (2 mins) (0.88 oz./25 g of 9% alpha acid)
8.9 AAU Centennial hops (2 mins) (0.74 oz./21 g of 12% alpha acid)
1 tsp. Irish moss (15 mins)
White Labs WLP001 (California Ale) or Wyeast 1056 (American Ale) yeast (3 qt./~3 L yeast starter)
0.75 cup of corn sugar (for priming)

Step by Step

Place crushed malts in a nylon steeping bag and steep in 5.0 qts. (4.7 L) of water at 150 °F (66 °C) for 30 minutes. Rinse grains with 2.5 qts. (~2.3 L) of water at 170 °F (77 °C). Add water to make 4 gallons (15 L), stir in dried malt extract and bring to a boil. Add the Cluster (bittering) hops and boil for 60 minutes. Add the liquid malt extract and Irish moss with 15 minutes left in the boil. Add the aroma hops (Northern Brewer and Centennial) for the last two minutes of the boil.

When you are done boiling, cool wort by submerging brewpot in sink (with the lid on) until the side of the brewpot no longer feels warm. Transfer wort to fermenter and top up to 5 gallons (19 L) with cool water. Aerate wort and pitch yeast. Ferment at 68 °F (20 °C) for 10 to 14 days. Bottle your beer, age for two to three weeks and enjoy! (Yes, that's right, this beer is so well-balanced that North Coast releases it to the public in less than a month.)

All-grain version:

Replace the malt extract with 16 lbs. (7.3 kg) of pale malt. Mash your grains at 152 °F (67 °C) or 45 minutes. Use 24 qts. (23 L) of mash water. Collect about 10 gallons (38 L) and boil to reduce volume to 5.0 gallons (19 L). Ferment at 68 °F (20 °C) for 10 to 14 days.

New World Porter clone (Avery Brewing Co., Colorado)

(5 gallons/19 L, all-grain)
OG = 1.067 FG = 1.017
IBU = 44 SRM = 63 ABV = 6.5%

Ingredients

9 lbs. 7.5 oz. (4.3 kg) 2-row pale malt
2.33 lbs. (1.06 kg) Munich malt (10 °L)
1 lb. 2.66 oz. (0.53 kg) crystal

hoppy homebrew recipes, from pale ales to porters to stouts.

malt (120 °L)
9.33 oz. (0.26 kg) Carapils® malt
9.33 oz. (0.26 kg) chocolate malt
7 oz. (0.20 kg) black patent malt
4.24 AAU Columbus hops (60 mins)
(0.33 oz./9.2 g of 13% alpha acids)
3.24 AAU Columbus hops (30 mins)
(0.25 oz./7.1 g of 13% alpha acids)
12.5 AAU Columbus hops (0 mins)
(0.96 oz./27 g of 13% alpha acids)
8.2 AAU Fuggles hops (0 mins)
(1.64 oz./46 g of 5% alpha acids)
1.2 oz. (34 g) Fuggles hops (dry hop)
Wyeast 1028 (London Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

Mash 156 °F (69 °C). Boil 90 minutes. Whirlpool for 15 minutes before cooling. Ferment at 70 °F (21 °C).

New World Porter clone (Avery Brewing Co., Colorado)

(5 gallons/19 L, extract with grains)

OG = 1.067 FG = 1.017
IBU = 44 SRM = 63 ABV = 6.5%

Ingredients

2.0 lbs. (0.91 kg) Briess Light dried malt extract
4.88 lbs (2.21 kg) Briess Light liquid malt extract (late addition)
1.33 lbs. (0.60 kg) Munich malt (10 °L)
1 lb. 2.66 oz. (0.53 kg) crystal malt (120 °L)
9.33 oz. (0.26 kg) Carapils® malt
9.33 oz. (0.26 kg) chocolate malt
7.0 oz. (0.20 kg) black patent malt
4.24 AAU Columbus hops (60 mins)
(0.33 oz./9.2 g of 13% alpha acids)
3.24 AAU Columbus hops (30 mins)
(0.25 oz./7.1 g of 13% alpha acids)
12.5 AAU Columbus hops (0 mins)
(0.96 oz./27 g of 13% alpha acids)
8.2 AAU Fuggles hops (0 mins)
(1.64 oz./46 g of 5% alpha acids)
1.2 oz. (34 g) Fuggles hops (dry hop)
Wyeast 1028 (London Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

In your brewpot, heat 5.8 qts. (5.5 L) of water to 167 °F (75 °C). Steep crushedgrains at 156 °F (69 °C) for 45 minutes. Check temperature every 10 minutes; if steeping temperature drops below 156 °F (69 °C), heat to 161 °F (72 °C). In a separate pot, heat 4.4 qts. (4.1 L) of rinse water to 170 °F (77 °C). Rinse grains and bring "grain tea" (wort) to a boil. Boil for 60 minutes, adding hops at times indicated. Add liquid malt extract with 15 minutes left in the boil. At end of boil, stir wort and let sit for 15 minutes before cooling. Cool wort, transfer to fermenter, top up to 5.0 gallons (19 L) and aerate wort. Pitch yeast and ferment at 70 °F (21 °C).

Indian Brown Ale clone (Dogfish Head Brewing, Delaware)

(5 gallons/19 L, all-grain)

OG = 1.070 FG = 1.016
IBU = 50 SRM = 32 ABV = 6.9%

Ingredients

10.75 lbs. (4.88 kg) Pilsner malt
15.2 oz. (0.43 kg) flaked maize
10.9 oz. (0.31 kg) amber malt
10.8 oz. (0.31 kg) crystal malt (60 °L)
6.5 oz. (0.18 kg) coffee malt
2.2 oz. (62 g) roasted barley
6 oz. (0.17 kg) brown sugar
11.5 AAU Warrior hops (60 mins)
(0.72 oz./20 g of 16% alpha acids)
6 AAU Golding hops (10 mins)
(1.2 oz./34 g of 5% alpha acids)
6 AAU Liberty hops (0 mins)
(1.33 oz./38 g of 4.5% alpha acids)
0.25 oz. (7.1 g) Goldings hops (dry hop)
0.25 oz. (7.1 g) Liberty hops (dry hop)
White Labs WLP005 (British Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

Caramelize sugar in kettle prior to runoff. Mash at 152 °F (67 °C) in 3.75 gallons (14 L) of water. Boil 90 minutes. Ferment at 70 °F (21 °C).

Indian Brown Ale clone (Dogfish Head Brewing, Delaware)

(5 gallons/19 L, extract with grains)

OG = 1.070 FG = 1.016
IBU = 50 SRM = 32 ABV = 6.9%

Ingredients

1.25 lbs. (0.57 kg) Muntons Light dried malt extract
5.25 lbs (2.3 kg) Muntons Light liquid malt extract (late addition)
1.0 lb. (0.45 kg) Pilsner malt
15.2 oz. (0.43 kg) brewers corn syrup
10.9 oz. (0.31 kg) amber malt
10.8 oz. (0.31 kg) crystal malt (60 °L)
6.5 oz. (0.18 kg) coffee malt
2.2 oz. (0.06 kg) roasted barley
6 oz. (0.17 kg) brown sugar
11.5 AAU Warrior hops (60 mins)
(0.72 oz./20 g of 16% alpha acids)
6 AAU Golding hops (10 mins)
(1.2 oz./34 g of 5% alpha acids)
6 AAU Liberty hops (0 mins)
(1.33 oz./38 g of 4.5% alpha acids)
0.25 oz. (7 g) Goldings hops (dry hop)
0.25 oz. (7 g) Liberty hops (dry hop)
White Labs WLP005 (British Ale) yeast
0.75 cups corn sugar (for priming)

Step by Step

In your brewpot, add just enough water to the brown sugar to dissolve it. Heat sugar solution to a boil and caramelize sugar (without scorching it). Then, add 4.3 qts. (4.1 L) of water to your brew-pot and heat to 163 °F (73 °C). Place crushed grains in a steeping bag and steep grains at around 152 °F (67 °C) for 45 minutes. During the steep, heat 3.2 qts. (3.1 L) of rinse water to 170 °F (77 °C) in a separate pot. After steep, rinse grains and add water to make at least 2.5 gallons (9.5 L) of "grain tea" (wort) and bring to a boil. Add dried malt extract and corn syrup and boil the wort for 60 minutes, adding hops at times indicated in recipe. Add the liquid malt extract with 15 minutes left in boil. Cool wort and transfer to fermenter. Top up to 5.0 gallons (19 L) with water and aerate. Pitch yeast and ferment at 70 °F (21 °C).

Anchor Steam clone (Anchor Brewing Co., California)

(5 gallons/19 L, all-grain)

OG = 1.051 FG = 1.013
IBU = 33 SRM = 12 ABV = 4.9%

Ingredients

9.66 lbs. (4.4 kg) 2-row pale malt
1.0 lb. (0.45 kg) crystal malt (60 °L)
7 AAU Northern Brewer hops (60 mins)
(0.8 oz./22 g of 9% alpha acids)

3.3 AAU Northern Brewer hops
(15 mins)
(0.4 oz./10 g of 9% alpha acids)
0.5 oz. (14 g) Northern Brewer hops
(0 mins)
1 tsp Irish moss
Wyeast 2112 (California Lager) or
White Labs WLP810 (San
Francisco Lager) yeast
(2 qt./2 L yeast starter)
⅞ cup corn sugar
(for priming)

Step by Step

Heat 3.33 gallons (12.6 L) of water to 165 °F (74 °C), stir in crushed grains and mash at 154 °F (68 °C). Mash for 60 minutes then stir in boiled water to raise grain bed temperature to 168 °F (76 °C). Hold for 5 minutes. Recirculate until wort is clear (about 20 minutes), then begin running wort off to kettle. Sparge with 170 °F (77 °C) water. Boil wort for 90 minutes, adding hops at times indicated in recipe. Add Irish moss with 15 minutes left in boil. Cool wort and transfer to fermenter. Aerate wort and pitch yeast. Ferment at 64 °F (18 °C). Rack to secondary when fermentation is complete. Bottle when beer falls clear.

Anchor Steam clone (Anchor Brewing Co., California)

(5 gallons/19 L, extract with grains)

OG = 1.051 FG = 1.013
IBU = 33 SRM = 13 ABV = 4.9%

Ingredients

1.875 lbs. (0.85 kg) Northwestern Gold dried malt extract
3.75 lbs. (1.7 kg) Northwestern Gold liquid malt extract (late addition)
1.0 lb. (0.45 kg) 2-row pale malt
1.0 lb. (0.45 kg) crystal malt (60 °L)
7 AAU Northern Brewer hops (60 mins)
(0.8 oz./22 g of 9% alpha acids)
3.3 AAU Northern Brewer hops
(15 mins)
(0.4 oz./10 g of 9% alpha acids)
0.5 oz. (14 g) Northern Brewer hops
(0 mins)
1 tsp Irish moss (15 mins)
Wyeast 2112 (California Lager) or
White Labs WLP810 (San
Francisco Lager) yeast
(2 qt./2 L yeast starter)
⅞ cup corn sugar
(for priming)

Step by Step

In a large soup pot, heat 3.0 quarts (2.8 L) of water to 165 °F (74 °C). Add crushed grains to grain bag. Submerge bag and let grains steep around 154 °F (68 °C) for 45 minutes. While grains steep, begin heating 2.25 gallons (8.5 L) of water in your brewpot. When steep is over, remove 1 qt. of water from brewpot and add to the "grain tea" in steeping pot. Place a colander over your brewpot and place your steeping bag in it. Pour grain tea (with water added) through the grain bag. Heat liquid in brewpot to a boil, then stir in dried malt extract, add first charge of hops and begin the 60 minutes boil. With 15 minutes left in boil, add hops and Irish moss. Then turn off heat and stir in liquid malt extract. Stir well to dissolve extract, then resume heating. (Keep the boil clock running while you stir.) At the end of the boil, add last charge of hops, then cool wort and transfer to fermenter. Add water to make 5 gallons (19 L), aerate wort and pitch yeast. Ferment at 64 °F (18 °C). Rack to secondary when fermentation is complete. Bottle when beer falls clear.

Young's Special London Ale clone (Young & Co.'s Brewery p.l.c., England)

(5 gallons/19 L, all-grain)

OG = 1.064 FG = 1.015
IBU = 30 SRM = 14 ABV = 6.4%

Ingredients

12 lbs. 3 oz. (5.5 kg) Maris Otter malt
15 oz. (0.43 kg) crystal malt (60 °L)
7.0 AAU Fuggles hops (60 mins)
(1.4 oz./40 g of 5% alpha acids)
2.5 AAU Goldings hops (15 mins)
(0.5 oz./14 g of 5% alpha acids)
0.5 oz. (14 g) Goldings hops (0 min)
0.25 oz. (7.1 g) Goldings whole hops
(dry hop)
0.25 oz. (7.1 g) Target whole hops
(dry hop)
1 tsp. Irish moss (15 mins)
Wyeast 1318 (London Ale III) yeast
(1.75 qt./~1.75 L yeast starter)
0.75 cup corn sugar
(for priming)

Step by Step

Mash grains at 153 °F (67 °C) in 16.5 quarts (15.5 L) of water. Mash for 60 minutes. Collect 6.5 gallons (25 L) of wort. Boil wort for 90 minutes, adding hops at the times indicated in ingredients list. Ferment at 69 °F (21 °C).

Young's Special London Ale clone (Young & Co.'s Brewery p.l.c., England)

(5 gallons/19 L, extract with grains)

OG = 1.064 FG = 1.015
IBU = 30 SRM = 14 ABV = 6.4%

Ingredients

2 lbs. 9 oz. (1.2 kg) Coopers Light dried malt extract
4 lbs. 12 oz. (2.2 kg) Muntons Light liquid malt extract (late addition)
1 lb. 1 oz. (0.48 kg) Maris Otter malt
15 oz. (0.43 kg) crystal malt (60 °L)
7.0 AAU Fuggles hops (60 mins)
(1.4 oz./40 g of 5% alpha acids)
2.5 AAU Goldings hops (15 mins)
(0.5 oz./14 g of 5% alpha acids)
0.5 oz. (14 g) Goldings hops (0 min)
0.25 oz. (7.1 g) Goldings hops (dry hop)
0.25 oz. (7.1 g) Target hops (dry hop)
1 tsp. Irish moss (15 mins)
Wyeast 1318 (London Ale III) yeast
(1.75 qt./~1.75 L yeast starter)
0.75 cup corn sugar
(for priming)

Step by Step

Put crushed grains in a nylon steeping bag. Steep at 153 °F (67 °C) in 3.0 quarts (2.8 L) for 45 minutes. Rinse grains with 1.5 quarts (1.4 L) of water at 170 °F (77 °C). Add dried malt extract and water to make 3.0 gallons (11 L). Boil the wort for 60 minutes, adding hops at the times indicated. With 15 minutes left in the boil, turn off the heat and stir in the liquid malt extract. Add Irish moss and resume heating. Cool wort and transfer to fermenter. Add water to make 5.0 gallons (19 L) of wort. Aerate wort and pitch yeast. Ferment at 69 °F (21 °C).

hoppy CHARTS

Choosing the right hop variety for your beer is at least partly subjective. You may, for example, be looking for an aggressive American "C-hop" character or a mild, noble hop profile and rely mostly on your past experiences to pick the right hop for your beer. However, you may also have some objective measures in mind, too, such as alpha acid percentage, cohumulone percentage or oil content. With that in mind, we've compiled a series of charts describing every hop variety for which information is available.

We compiled these charts primarily from data published by HopUnion, Brewers Supply Group, Yakima Chief, Hopsteiner, Hops from England and New Zealand Hops Limited. For a few of the newest hop varieties, we got the information from the grower's website. An internet search for any of these names will take you to the "raw data" and even more information about these hops.

The first two charts list hop varieties sorted by their median alpha and beta acid content. (The median is the midpoint between two numbers, in this case the low and high reported alpha acid or beta acid content. The actual median value isn't presented in the chart — just add the two numbers and divide by two if you want to calculate this.) The tables list the varieties starting with the highest alpha or beta acid content and progressing to the lowest.

Hop sellers report alpha and beta acid as a weight-to-weight percentage. For example, if 100 g of hop cones yielded 5 g of alpha acids, the alpha acid percentage would be 5%. In most cases, different sources reported different low and high values. In the chart, we gave the most inclusive range. For example, if one source gave the alpha acid range of a hop variety as 4 to 6% and another source gave it as 5 to 7%, we list it as 4–7%. The actual alpha acid rating of any hops you purchase should be reported on the package.

The third chart lists median cohumulone values from low to high. Cohumulone, along with humulone and adhumulone, is one the three most abundant alpha acids in hops. Some brewers view cohumulone as having an aggressive or harsh character. Cohumulone values are reported by hop sellers as a percentage of the total alpha acids. Those brewers looking for a smooth hop profile usually pick hops with less than 30% cohumulone. (Some rabid lupulophiles, however, actively seek out hops with a little "bite" from cohumulone for their hoppiest brews.)

The fourth chart lists hop by their oil content. Hop sellers typically report oil content in milliliters of oil per 100 g of hop cones, although sometimes it is given as a percentage. Just as alpha acids vary from year to year and field to field, so do oils. Many commercial brewers of hoppy beers adjust their hop schedules to account for changing oil profiles.

Finally, we present a chart of hop varieties listed in alphabetical order — from Admiral to Zeus. All the information from the sorted charts appears here as well as a general description of the hop's flavor and aroma and possible substitutions.

With all this information at your fingertips, choosing hop varieties for your beers should be easier. Remember that, although these numbers are helpful guides, your sense of smell and taste should also be consulted when making any hopping decision. Enjoy the charts and good luck with your brewing!

Hop data sorted by a variety of useful criteria to help you choose hops.

Alpha Acids (Descending)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Summit	16	19	28	28	4.5	5	2.4	2.6
Tomahawk	14	18	29	34	4.5	5.8	2	3.5
Warrior	15	17	28	28	4.5	5.5	1	2
Bravo	14	17	29	34	3	4	1.6	2.4
El Dorado	14	16	30	30	7	8	2.5	2.8
Newport	13	17	36	38	7.2	9.1	1.6	3.4
Columbus	11	18	30	35	4.5	5.8	2	3.5
Herkules (German)	12	17	32	38	4	5.5	1.6	2.4
Taurus (German)	12	17	20	25	4	6	0.9	1.4
Zeus	12	17	27	35	4	6	1	2
Millenium	12	16.5	30	30	4.8	4.8	2	2
Galaxy (Australian)	13.5	14.8	35	35	5.8	6	2.4	2.7
Magnum (German)	12	16	24	30	4.2	7	1.5	2.1
Pacific Gem	13	15	39	39	8	8.4	1.4	1.4
Sun	12	16	30	40	4.5	7	2.5	5.0
Admiral (U.K.)	11.5	16	42	44	5	6	1	1.7
Merkur (German)	12	15	16	20	3.5	7	2.2	2.8
Satus	12.5	14	32	53	8.5	9	1.5	1.8
Nelson Sauvin (N.Z.)	12	14	24	25	6	8	1.5	1.5
Simcoe	12	14	15	20	4	5	2	2.5
Sorachi Ace (Japan)	10	16	23	23	6	7	2	2.8
Nugget	11	14.5	27	27	4	5	1.5	2.2
Green Bullet (NZ)	11	14	41	43	6.5	7	1.1	1.1
Chinook	10	14	29	34	3	4	1.5	2.5
Citra	11	13	22	24	3.5	4.5	2.2	2.8
Galena	10	14	40	40	7	9	0.8	1.2
Herald (UK)	11	13	35	37	4.8	5.5	1	1.9
Horizon	10	14	16	22	6.5	8.5	1.2	2.6
Magnum (US)	10	14	24	30	4.5	7	1.9	3.0
Eroica (German)	9	14	36	42	2.5	5	0.8	1.3
Olympic	10	13	26	40	3.8	6.1	0.9	2.6
Pilgrim (UK)	9	13	36	38	4.3	5	1.2	2.4
Super Alpha (NZ)	10	12	36	39	7	8.5	1.3	1.3
Target (U.K.)	9.5	12.5	29	35	4.5	5.7	1.2	2.6
Marynka (Polish)	9	12	26	33	10.2	13	2	2
Premiant (Czech)	8	12.5	23	23	4.5	8	1.1	1.3
Phoenix (U.K.)	8	12	39	39	4.2	5.5	1.2	2.5
Centennial	8	11.5	28	30	3.5	4.5	1.5	2.3
Amarillo	8	11	21	24	6	7	1.5	1.9
Pioneer (U.K.)	7	11	36	40	3.5	4	1	1.8
Boadicea (UK)	8	9	26	26	2.7	4.4	1.3	1.5
Brewer's Gold (US)	7	10	40	48	3.5	4.5	2	2.4
Northern Brewer (German)	7	10	28	33	3.5	5	1.6	2.1
Pride of Ringwood	7	10	33	39	4	6	1	2
Aurora (Styrian)	7	9.5	22	26	2.7	4.4	0.9	1.6
First Gold (U.K.)	6.5	9.5	31	36	3	4.2	0.7	1.5
Northdown (U.K.)	6	10	24	30	4.4	6.2	1.2	2.5
Northern Brewer (US)	6	10	20	30	3	5	1.2	2
Perle (German)	6	10	25	32	3.5	5.5	0.8	1.3
Bullion (U.K.)	6.5	9	35	40	3.2	6	2	3
Palisade	5.5	9.5	24	29	6	8	1.4	1.6
Perle (U.S.)	5.5	9.5	29	29	3.1	5	0.7	1.2

Alpha Acid (continued)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Brewer's Gold (German)	5	9	40	48	2.5	3.5	1.8	2.2
Cascade (NZ)	6	8	37	37	5	5.5	1.1	1.1
Challenger (U.K.)	5	9	20	25	3	4.5	1	1.7
Cluster	5.5	8.5	36	42	4	6	0.4	0.8
Motueka (NZ)	6.5	7.5	29	29	5	5.5	0.8	0.8
Sterling	4.5	9	21	28	4	6	0.6	1.9
Mt. Rainier	5	8.1	21	24	5	7	0.2	0.5
Opal (German)	5	8	13	17	3.5	5.5	0.8	1.3
WGV	5	8	34	34	2.0	2.7	0.8	1.2
Santiam	5	7.9	22	24	6	8	1.3	1.5
Hallertauer Gold	6	6.5						
Hallertauer Tradition	6	6.5	24	29	3	6	0.5	1.5
Bramling Cross (UK)	5	7	34	34	2.3	3.2	0.7	1.0
Cascade	4.5	7	35	40	4.5	7	0.8	1.5
Progress (U.K.)	4	7.5	27	27	1.8	2.7	0.5	0.8
Tradition (German)	4.5	7	26	29	3.7	6.5	0.7	1.4
Glacier	5.5	5.5	11	13	7.6	8.2	0.7	1.6
Kent Golding (U.K.)	4	7	20	25	2	3.5	0.6	1
Mt. Hood	3	8	22	27	3.6	7.5	1.0	2.3
Pacifica (NZ)	5	6	25	25	6	6	1	1
Riwaka (NZ)	4.5	6.5	29	36	4	5	0.8	0.8
Sovereign	4.5	6.5	26	30	2.1	3.1	0.8	0.8
Bobeck (Styrian)	3.5	7	27	31	4	6.1	0.7	4
Golding (U.S.)	4	6.5	20	25	2	3	0.4	1.2
Spalt Select (German)	4	6.5	23	23	3.3	4.3	0.5	0.9
Willamette	3.5	7	32	32	3	4.7	0.9	1.5
Select (German)	4	6	21	25	3.5	4.5	0.5	1
Smaragd (German)	4	6	13	18	3.5	5.5	0.7	1.7
Styrian Golding	4.0	6	28	28	2	3	0.5	1.0
Vanguard	4	6	14	15	5	7	0.8	1.2
Ahtanum	3.5	6.3	30	35	5.0	6.5	0.8	1.5
Fuggle (U.S.)	4	5.5	25	32	1.5	2.0	0.7	1.2
Spalt (German)	4	5.5	23	28	4	5	0.5	1.1
Celeia (Styrian)	3	6	26	29	2	3.3	0.6	3.6
Fuggle (U.K.)	3	6	23	30	2	3.1	0.7	1.4
Hallertauer (US)	3.5	5.5	18	24	3.5	5.5	0.6	1
Liberty	3	6	24	30	2.9	5.0	0.6	1.0
Northwest Golding	4	5						
Tettnang (German)	3	6	23	29	3.5	5	0.1	1
Hallertauer Mittelfrüh (German)	3	5.5	22	22	3.5	5.5	1	1.5
Tettnang (U.S.)	3.0	5.2	20	25	2.7	4.5	0.5	1.0
Spalt Select (U.S.)	3	5	20	25	3	4.5	0.5	0.9
Strisselspalt (France)	3	5	20	25	3	5.5	0.6	0.9
Crystal	2	5.5	20	26	4.5	6.7	0.8	2.1
Hersbrucker (German)	2	5.5	23	23	3.8	6.2	0.6	1.1
Lublin (Polish)	3	4.5	25	30	2.5	3.5	0.7	1.2
Saaz (U.S.)	2.5	5	24	28	2.8	5.0	0.4	1
Saphir (German)	2.5	5	11	15	6.5	6.5	1.5	1.5
Saaz (Czech)	2	5	24	28	3	4.5	0.4	0.7
Ultra	2	5	25	30	3.6	4.7	0.8	1.2

Beta Acids (Descending)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Marynka (Polish)	9	12	26	33	10.2	13	2	2
Satus	12.5	14	32	53	8.5	9	1.5	1.8
Pacific Gem	13	15	39	39	8	8.4	1.4	1.4
Newport	13	17	36	38	7.2	9.1	1.6	3.4
Galena	10	14	40	40	7	9	0.8	1.2
Glacier	5.5	5.5	11	13	7.6	8.2	0.7	1.6
Super Alpha (NZ)	10	12	36	39	7	8.5	1.3	1.3
El Dorado	14	16	30	30	7	8	2.5	2.8
Horizon	10	14	16	22	6.5	8.5	1.2	2.6
Palisade	5.5	9.5	24	29	6	8	1.4	1.6
Nelson Sauvin (N.Z.)	12	14	24	25	6	8	1.5	1.5
Santiam	5	7.9	22	24	6	8	1.3	1.5
Green Bullet (NZ)	11	14	41	43	6.5	7	1.1	1.1
Sorachi Ace (Japan)	10	16	23	23	6	7	2	2.8
Amarillo	8	11	21	24	6	7	1.5	1.9
Saphir (German)	2.5	5	11	15	6.5	6.5	1.5	1.5
Premiant (Czech)	8	12.5	23	23	4.5	8	1.1	1.3
Pacifica (NZ)	5	6	25	25	6	6	1	1
Mt. Rainier	5	8.1	21	24	5	7	0.2	0.5
Vanguard	4	6	14	15	5	7	0.8	1.2
Galaxy (Australian)	13.5	14.8	35	35	5.8	6	2.4	2.7
Cascade	4.5	7	35	40	4.5	7	0.8	1.5
Sun	12	16	30	40	4.5	7	2.5	5.0
Ahtanum	3.5	6.3	30	35	5.0	6.5	0.8	1.5
Magnum (US)	10	14	24	30	4.5	7	1.9	3.0
Magnum (German)	12	16	24	30	4.2	7	1.5	2.1
Crystal	2	5.5	20	26	4.5	6.7	0.8	2.1
Mt. Hood	3	8	22	27	3.6	7.5	1.0	2.3
Admiral (U.K.)	11.5	16	42	44	5	6	1	1.7
Northdown (U.K.)	6	10	24	30	4.4	6.2	1.2	2.5
Cascade (NZ)	6	8	37	37	5	5.5	1.1	1.1
Motueka (NZ)	6.5	7.5	29	29	5	5.5	0.8	0.8
Merkur (German)	12	15	16	20	3.5	7	2.2	2.8
Herald (UK)	11	13	35	37	4.8	5.5	1	1.9
Columbus	11	18	30	35	4.5	5.8	2	3.5
Tomahawk	14	18	29	34	4.5	5.8	2	3.5
Target (U.K.)	9.5	12.5	29	35	4.5	5.7	1.2	2.6
Tradition (German)	4.5	7	26	29	3.7	6.5	0.7	1.4
Bobeck (Styrian)	3.5	7	27	31	4	6.1	0.7	4
Cluster	5.5	8.5	36	42	4	6	0.4	0.8
Pride of Ringwood	7	10	33	39	4	6	1	2
Zeus	12	17	27	35	4	6	1	2
Warrior	15	17	28	28	4.5	5.5	1	2
Sterling	4.5	9	21	28	4	6	0.6	1.9
Hersbrucker (German)	2	5.5	23	23	3.8	6.2	0.6	1.1
Taurus (German)	12	17	20	25	4	6	0.9	1.4
Olympic	10	13	26	40	3.8	6.1	0.9	2.6
Phoenix (U.K.)	8	12	39	39	4.2	5.5	1.2	2.5
Millenium	12	16.5	30	30	4.8	4.8	2	2
Herkules (German)	12	17	32	38	4	5.5	1.6	2.4
Summit	16	19	28	28	4.5	5	2.4	2.6
Pilgrim (UK)	9	13	36	38	4.3	5	1.2	2.4

Beta Acids (continued)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Bullion (U.K.)	6.5	9	35	40	3.2	6	2	3
Riwaka (NZ)	4.5	6.5	29	36	4	5	0.8	0.8
Perle (German)	6	10	25	32	3.5	5.5	0.8	1.3
Nugget	11	14.5	27	27	4	5	1.5	2.2
Hallertauer Tradition	6	6.5	24	29	3	6	0.5	1.5
Spalt (German)	4	5.5	23	28	4	5	0.5	1.1
Hallertauer Mittelfrüh (German)	3	5.5	22	22	3.5	5.5	1	1.5
Hallertauer (US)	3.5	5.5	18	24	3.5	5.5	0.6	1
Simcoe	12	14	15	20	4	5	2	2.5
Smaragd (German)	4	6	13	18	3.5	5.5	0.7	1.7
Opal (German)	5	8	13	17	3.5	5.5	0.8	1.3
Northern Brewer (German)	7	10	28	33	3.5	5	1.6	2.1
Tettnang (German)	3	6	23	29	3.5	5	0.1	1
Strisselspalt (France)	3	5	20	25	3	5.5	0.6	0.9
Ultra	2	5	25	30	3.6	4.7	0.8	1.2
Perle (U.S.)	5.5	9.5	29	29	3.1	5	0.7	1.2
Brewer's Gold (US)	7	10	40	48	3.5	4.5	2	2.4
Centennial	8	11.5	28	30	3.5	4.5	1.5	2.3
Northern Brewer (US)	6	10	20	30	3	5	1.2	2
Citra	11	13	22	24	3.5	4.5	2.2	2.8
Select (German)	4	6	21	25	3.5	4.5	0.5	1
Liberty	3	6	24	30	2.9	5.0	0.6	1.0
Saaz (U.S.)	2.5	5	24	28	2.8	5.0	0.4	1
Willamette	3.5	7	32	32	3	4.7	0.9	1.5
Spalt Select (German)	4	6.5	23	23	3.3	4.3	0.5	0.9
Eroica (German)	9	14	36	42	2.5	5	0.8	1.3
Pioneer (U.K.)	7	11	36	40	3.5	4	1	1.8
Saaz (Czech)	2	5	24	28	3	4.5	0.4	0.7
Challenger (U.K.)	5	9	20	25	3	4.5	1	1.7
Spalt Select (U.S.)	3	5	20	25	3	4.5	0.5	0.9
First Gold (U.K.)	6.5	9.5	31	36	3	4.2	0.7	1.5
Tettnang (U.S.)	3.0	5.2	20	25	2.7	4.5	0.5	1.0
Boadicea (UK)	8	9	26	26	2.7	4.4	1.3	1.5
Aurora (Styrian)	7	9.5	22	26	2.7	4.4	0.9	1.6
Bravo	14	17	29	34	3	4	1.6	2.4
Chinook	10	14	29	34	3	4	1.5	2.5
Brewer's Gold (German)	5	9	40	48	2.5	3.5	1.8	2.2
Lublin (Polish)	3	4.5	25	30	2.5	3.5	0.7	1.2
Bramling Cross (U.K.)	5	7	34	34	2.3	3.2	0.7	1.0
Kent Golding (U.K.)	4	7	20	25	2	3.5	0.6	1
Celeia (Styrian)	3	6	26	29	2	3.3	0.6	3.6
Sovereign	4.5	6.5	26	30	2.1	3.1	0.8	0.8
Fuggle (U.K.)	3	6	23	30	2	3.1	0.7	1.4
Styrian Golding	4.0	6	28	28	2	3	0.5	1.0
Golding (U.S.)	4	6.5	20	25	2	3	0.4	1.2
WGV	5	8	34	34	2.0	2.7	0.8	1.2
Progress (U.K.)	4	7.5	27	27	1.8	2.7	0.5	0.8
Fuggle (U.S.)	4	5.5	25	32	1.5	2.0	0.7	1.2

Cohumulone (Ascending)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Glacier	5.5	5.5	11	13	7.6	8.2	0.7	1.6
Saphir (German)	2.5	5	11	15	6.5	6.5	1.5	1.5
Vanguard	4	6	14	15	5	7	0.8	1.2
Opal (German)	5	8	13	17	3.5	5.5	0.8	1.3
Smaragd (German)	4	6	13	18	3.5	5.5	0.7	1.7
Simcoe	12	14	15	20	4	5	2	2.5
Merkur (German)	12	15	16	20	3.5	7	2.2	2.8
Horizon	10	14	16	22	6.5	8.5	1.2	2.6
Hallertauer (US)	3.5	5.5	18	24	3.5	5.5	0.6	1
Hallertauer Mittelfrüh (German)	3	5.5	22	22	3.5	5.5	1	1.5
Taurus (German)	12	17	20	25	4	6	0.9	1.4
Amarillo	8	11	21	24	6	7	1.5	1.9
Challenger (U.K.)	5	9	20	25	3	4.5	1	1.7
Mt. Rainier	5	8.1	21	24	5	7	0.2	0.5
Kent Golding (U.K.)	4	7	20	25	2	3.5	0.6	1
Golding (U.S.)	4	6.5	20	25	2	3	0.4	1.2
Tettnang (U.S.)	3.0	5.2	20	25	2.7	4.5	0.5	1.0
Spalt Select (U.S.)	3	5	20	25	3	4.5	0.5	0.9
Strisselspalt (France)	3	5	20	25	3	5.5	0.6	0.9
Sorachi Ace (Japan)	10	16	23	23	6	7	2	2.8
Citra	11	13	22	24	3.5	4.5	2.2	2.8
Premiant (Czech)	8	12.5	23	23	4.5	8	1.1	1.3
Santiam	5	7.9	22	24	6	8	1.3	1.5
Spalt Select (German)	4	6.5	23	23	3.3	4.3	0.5	0.9
Select (German)	4	6	21	25	3.5	4.5	0.5	1
Crystal	2	5.5	20	26	4.5	6.7	0.8	2.1
Hersbrucker (German)	2	5.5	23	23	3.8	6.2	0.6	1.1
Aurora (Styrian)	7	9.5	22	26	2.7	4.4	0.9	1.6
Nelson Sauvin (N.Z.)	12	14	24	25	6	8	1.5	1.5
Sterling	4.5	9	21	28	4	6	0.6	1.9
Mt. Hood	3	8	22	27	3.6	7.5	1.0	2.3
Northern Brewer (US)	6	10	20	30	3	5	1.2	2
Pacifica (NZ)	5	6	25	25	6	6	1	1
Spalt (German)	4	5.5	23	28	4	5	0.5	1.1
Boadicea (UK)	8	9	26	26	2.7	4.4	1.3	1.5
Tettnang (German)	3	6	23	29	3.5	5	0.1	1
Saaz (U.S.)	2.5	5	24	28	2.8	5.0	0.4	1
Saaz (Czech)	2	5	24	28	3	4.5	0.4	0.7
Palisade	5.5	9.5	24	29	6	8	1.4	1.6
Hallertauer Tradition	6	6.5	24	29	3	6	0.5	1.5
Fuggle (U.K.)	3	6	23	30	2	3.1	0.7	1.4
Magnum (German)	12	16	24	30	4.2	7	1.5	2.1
Nugget	11	14.5	27	27	4	5	1.5	2.2
Magnum (US)	10	14	24	30	4.5	7	1.9	3.0
Northdown (U.K.)	6	10	24	30	4.4	6.2	1.2	2.5
Progress (U.K.)	4	7.5	27	27	1.8	2.7	0.5	0.8
Liberty	3	6	24	30	2.9	5.0	0.6	1.0
Tradition (German)	4.5	7	26	29	3.7	6.5	0.7	1.4
Celeia (Styrian)	3	6	26	29	2	3.3	0.6	3.6

Cohumulone (continued)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Lublin (Polish)	3	4.5	25	30	2.5	3.5	0.7	1.2
Ultra	2	5	25	30	3.6	4.7	0.8	1.2
Summit	16	19	28	28	4.5	5	2.4	2.6
Warrior	15	17	28	28	4.5	5.5	1	2
Sovereign	4.5	6.5	26	30	2.1	3.1	0.8	0.8
Styrian Golding	4.0	6	28	28	2	3	0.5	1.0
Perle (German)	6	10	25	32	3.5	5.5	0.8	1.3
Fuggle (U.S.)	4	5.5	25	32	1.5	2.0	0.7	1.2
Centennial	8	11.5	28	30	3.5	4.5	1.5	2.3
Perle (U.S.)	5.5	9.5	29	29	3.1	5	0.7	1.2
Motueka (NZ)	6.5	7.5	29	29	5	5.5	0.8	0.8
Bobeck (Styrian)	3.5	7	27	31	4	6.1	0.7	4
Marynka (Polish)	9	12	26	33	10.2	13	2	2
El Dorado	14	16	30	30	7	8	2.5	2.8
Millenium	12	16.5	30	30	4.8	4.8	2	2
Northern Brewer (German)	7	10	28	33	3.5	5	1.6	2.1
Zeus	12	17	27	35	4	6	1	2
Tomahawk	14	18	29	34	4.5	5.8	2	3.5
Bravo	14	17	29	34	3	4	1.6	2.4
Chinook	10	14	29	34	3	4	1.5	2.5
Target (U.K.)	9.5	12.5	29	35	4.5	5.7	1.2	2.6
Willamette	3.5	7	32	32	3	4.7	0.9	1.5
Columbus	11	18	30	35	4.5	5.8	2	3.5
Riwaka (NZ)	4.5	6.5	29	36	4	5	0.8	0.8
Ahtanum	3.5	6.3	30	35	5.0	6.5	0.8	1.5
Olympic	10	13	26	40	3.8	6.1	0.9	2.6
First Gold (U.K.)	6.5	9.5	31	36	3	4.2	0.7	1.5
WGV	5	8	34	34	2.0	2.7	0.8	1.2
Bramling Cross (U.K.)	5	7	34	34	2.3	3.2	0.7	1.0
Herkules (German)	12	17	32	38	4	5.5	1.6	2.4
Galaxy (Australian)	13.5	14.8	35	35	5.8	6	2.4	2.7
Sun	12	16	30	40	4.5	7	2.5	5.0
Herald (UK)	11	13	35	37	4.8	5.5	1	1.9
Pride of Ringwood	7	10	33	39	4	6	1	2
Newport13	17	36	38	7.2	9.1	1.6	3.4	
Pilgrim (UK)	9	13	36	38	4.3	5	1.2	2.4
Cascade (NZ)	6	8	37	37	5	5.5	1.1	1.1
Super Alpha (NZ)	10	12	36	39	7	8.5	1.3	1.3
Bullion (U.K.)	6.5	9	35	40	3.2	6	2	3
Cascade	4.5	7	35	40	4.5	7	0.8	1.5
Pioneer (U.K.)	7	11	36	40	3.5	4	1	1.8
Pacific Gem	13	15	39	39	8	8.4	1.4	1.4
Eroica (German)	9	14	36	42	2.5	5	0.8	1.3
Phoenix (U.K.)	8	12	39	39	4.2	5.5	1.2	2.5
Cluster	5.5	8.5	36	42	4	6	0.4	0.8
Galena	10	14	40	40	7	9	0.8	1.2
Green Bullet (NZ)	11	14	41	43	6.5	7	1.1	1.1
Satus	12.5	14	32	53	8.5	9	1.5	1.8
Admiral (U.K.)	11.5	16	42	44	5	6	1	1.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Oils (Descending)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Sun	12	16	30	40	4.5	7	2.5	5.0
Columbus	11	18	30	35	4.5	5.8	2	3.5
Tomahawk	14	18	29	34	4.5	5.8	2	3.5
El Dorado	14	16	30	30	7	8	2.5	2.8
Galaxy (Australian)	13.5	14.8	35	35	5.8	6	2.4	2.7
Newport	13	17	36	38	7.2	9.1	1.6	3.4
Merkur (German)	12	15	16	20	3.5	7	2.2	2.8
Summit	16	19	28	28	4.5	5	2.4	2.6
Bullion (U.K.)	6.5	9	35	40	3.2	6	2	3
Citra	11	13	22	24	3.5	4.5	2.2	2.8
Magnum (US)	10	14	24	30	4.5	7	1.9	3.0
Sorachi Ace (Japan)	10	16	23	23	6	7	2	2.8
Bobeck (Styrian)	3.5	7	27	31	4	6.1	0.7	4
Simcoe	12	14	15	20	4	5	2	2.5
Brewer's Gold (US)	7	10	40	48	3.5	4.5	2	2.4
Celeia (Styrian)	3	6	26	29	2	3.3	0.6	3.6
Marynka (Polish)	9	12	26	33	10.2	13	2	2
Millenium	12	16.5	30	30	4.8	4.8	2	2
Herkules (German)	12	17	32	38	4	5.5	1.6	2.4
Bravo	14	17	29	34	3	4	1.6	2.4
Chinook	10	14	29	34	3	4	1.5	2.5
Brewer's Gold (German)	5	9	40	48	2.5	3.5	1.8	2.2
Horizon	10	14	16	22	6.5	8.5	1.2	2.6
Target (U.K.)	9.5	12.5	29	35	4.5	5.7	1.2	2.6
Centennial	8	11.5	28	30	3.5	4.5	1.5	2.3
Northdown (U.K.)	6	10	24	30	4.4	6.2	1.2	2.5
Phoenix (U.K.)	8	12	39	39	4.2	5.5	1.2	2.5
Nugget	11	14.5	27	27	4	5	1.5	2.2
Northern Brewer (German)	7	10	28	33	3.5	5	1.6	2.1
Magnum (German)	12	16	24	30	4.2	7	1.5	2.1
Pilgrim (UK)	9	13	36	38	4.3	5	1.2	2.4
Olympic	10	13	26	40	3.8	6.1	0.9	2.6
Amarillo Satus	12.5	14	32	53	8.5	9	1.5	1.8
Mt. Hood	3	8	22	27	3.6	7.5	1.0	2.3
Northern Brewer (US)	6	10	20	30	3	5	1.2	2
Palisade	5.5	9.5	24	29	6	8	1.4	1.6
Nelson Sauvin (NZ)	12	14	24	25	6	8	1.5	1.5
Saphir (German)	2.5	5	11	15	6.5	6.5	1.5	1.5
Pride of Ringwood	7	10	33	39	4	6	1	2
Zeus	12	17	27	35	4	6	1	2
Warrior	15	17	28	28	4.5	5.5	1	2
Crystal	2	5.5	20	26	4.5	6.7	0.8	2.1
Herald (UK)	11	13	35	37	4.8	5.5	1	1.9
Pacific Gem	13	15	39	39	8	8.4	1.4	1.4
Santiam	5	7.9	22	24	6	8	1.3	1.5
Pioneer (U.K.)	7	11	36	40	3.5	4	1	1.8
Boadicea (UK)	8	9	26	26	2.7	4.4	1.3	1.5
Admiral (U.K.)	11.5	16	42	44	5	6	1	1.7
Challenger (U.K.)	5	9	20	25	3	4.5	1	1.7
Super Alpha (NZ)	10	12	36	39	7	8.5	1.3	1.3

Oils (continued)

Variety	AA% (low)	AA% (high)	Co (low)	Co (high)	Beta (low)	Beta (high)	Oil (low)	Oil (high)
Sterling	4.5	9	21	28	4	6	0.6	1.9
Hallertauer Mittelfrüh (German)	3	5.5	22	22	3.5	5.5	1	1.5
Aurora (Styrian)	7	9.5	22	26	2.7	4.4	0.9	1.6
Premiant (Czech)	8	12.5	23	23	4.5	8	1.1	1.3
Smaragd (German)	4	6	13	18	3.5	5.5	0.7	1.7
Willamette	3.5	7	32	32	3	4.7	0.9	1.5
Glacier	5.5	5.5	11	13	7.6	8.2	0.7	1.6
Cascade	4.5	7	35	40	4.5	7	0.8	1.5
Ahtanum	3.5	6.3	30	35	5.0	6.5	0.8	1.5
Taurus (German)	12	17	20	25	4	6	0.9	1.4
Green Bullet (NZ)	11	14	41	43	6.5	7	1.1	1.1
Cascade (NZ)	6	8	37	37	5	5.5	1.1	1.1
First Gold (U.K.)	6.5	9.5	31	36	3	4.2	0.7	1.5
Perle (German)	6	10	25	32	3.5	5.5	0.8	1.3
Opal (German)	5	8	13	17	3.5	5.5	0.8	1.3
Eroica (German)	9	14	36	42	2.5	5	0.8	1.3
Tradition (German)	4.5	7	26	29	3.7	6.5	0.7	1.4
Fuggle (U.K.)	3	6	23	30	2	3.1	0.7	1.4
Galena	10	14	40	40	7	9	0.8	1.2
Pacifica (NZ)	5	6	25	25	6	6	1	1
Vanguard	4	6	14	15	5	7	0.8	1.2
Hallertauer Tradition	6	6.5	24	29	3	6	0.5	1.5
Ultra	2	5	25	30	3.6	4.7	0.8	1.2
WGV	5	8	34	34	2.0	2.7	0.8	1.2
Perle (U.S.)	5.5	9.5	29	29	3.1	5	0.7	1.2
Lublin (Polish)	3	4.5	25	30	2.5	3.5	0.7	1.2
Fuggle (U.S.)	4	5.5	25	32	1.5	2.0	0.7	1.2
Hersbrucker (German)	2	5.5	23	23	3.8	6.2	0.6	1.1
Bramling Cross (UK)	5	7	34	34	2.3	3.2	0.7	1.0
Motueka (NZ)	6.5	7.5	29	29	5	5.5	0.8	0.8
Riwaka (NZ)	4.5	6.5	29	36	4	5	0.8	0.8
Spalt (German)	4	5.5	23	28	4	5	0.5	1.1
Hallertauer (US)	3.5	5.5	18	24	3.5	5.5	0.6	1
Liberty	3	6	24	30	2.9	5.0	0.6	1.0
Kent Golding (U.K.)	4	7	20	25	2	3.5	0.6	1
Sovereign	4.5	6.5	26	30	2.1	3.1	0.8	0.8
Golding (U.S.)	4	6.5	20	25	2	3	0.4	1.2
Strisselspalt (France)	3	5	20	25	3	5.5	0.6	0.9
Select (German)	4	6	21	25	3.5	4.5	0.5	1
Tettnang (U.S.)	3.0	5.2	20	25	2.7	4.5	0.5	1.0
Styrian Golding	4.0	6	28	28	2	3	0.5	1.0
Saaz (U.S.)	2.5	5	24	28	2.8	5.0	0.4	1
Spalt Select (German)	4	6.5	23	23	3.3	4.3	0.5	0.9
Spalt Select (U.S.)	3	5	20	25	3	4.5	0.5	0.9
Progress (U.K.)	4	7.5	27	27	1.8	2.7	0.5	0.8
Cluster	5.5	8.5	36	42	4	6	0.4	0.8
Tettnang (German)	3	6	23	29	3.5	5	0.1	1
Saaz (Czech)	2	5	24	28	3	4.5	0.4	0.7
Mt. Rainier	5	8.1	21	24	5	7	0.2	0.5

Alphabetical

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Admiral (U.K.)	AA 11.5-16%	Co 42-44%	Beta 5-6%	Oils 1-1.7%	Ale	U.K. Target, U.K. Northdown	Known for its bittering potential.
Ahtanum	AA 3.5-6.3%	Co 30-35%	Beta 5.0-6.5%	Oils 0.8-1.5%	Large, American Ale	U.K. Challenger, Cascade	Floral, citrus, sharp, and piney.
Amarillo	AA 8-11%	Co 21-24%	Beta 6 7%	Oils 1.5-1.9%	Ale, IPA	Cascade, Centennial	Citrusy, flowery.
Aurora (Styrian)	AA 7-9.5%	Co 22-26%	Beta 2.7-4.4%	Oils 0.9-1.6%	Ales	Styrian Goldings	
Bramling Cross (U.K.)	AA 5-7%	Co 34%	Beta 2.3-3.2%	Oils 0.7-1.0%	ESB, bitter, pale ale	U.K. Kent Golding, U.K. Progress, Whitbread Golding Variety	Quite mild, fruity currant aroma.
Bravo	AA 14-17%	Co 29-34%	Beta 3-4%	Oils 1.6-2.4%	American-style IPA		
Brewer's Gold (US)	AA 7-10%	Co 40-48%	Beta 3.5-4.5%	Oils 2-2.4%	English ale	Bullion	Bittering hop with neutral aroma character.
Brewer's Gold (German)	AA 5-9%	Co 40-48%	Beta 2.5-3.5%	Oils 1.8-2.2%	Ale, heavier lagers	Northdown, Northern Brewer, Galena, Bullion	Black currant, fruity, spicy
Boadicea (UK)	AA 8-9%	Co 26%	Beta 2.7-4.4%	Oils 1.31.5%			Spicy
Bobeck (Styrian)	AA 3.5-7%	Co 27-31%	Beta 4-6.1%	Oils 0.7-4%	English Ales	Fuggles	
Bullion (U.K.)	AA 6.5-9%	Co 35-40%	Beta 3.2-6%	Oils 2-3%	Stout	Columbus, Northern Brewer, German Brewer's Gold bittering.	A rich hop primarily used for intense blackcurrant aroma.
Cascade	AA 4.5-7%	Co 35-40%	Beta 4.5-7%	Oils 0.8-1.5%	Pale ale, IPA, porter, barleywine	Centennial, Amarillo, possibly Columbus	Pleasant, flowery, spicy, and citrusy. Can have a
Cascade (NZ)	AA 6-8%	Co 37%	Beta 5-5.5%	Oils 1.1%	Pale ales, IPA	US Cascade	grapefruit flavor.
Celeia (Styrian)	AA 3-6%	Co 26-29%	Beta 2-3.3%	Oils 0.6-3.6%	Ales and lagers	Saaz, Goldings	Quality aroma hop
Centennial	AA 8-11.5%	Co 28-30%	Beta 3.5-4.5%	Oils 1.5-2.3%	All ale styles, has been used with wheat beer	Cascade, Columbus or blend of the two	Medium with floral and citrus tones.
Challenger (U.K.)	AA 5-9%	Co 20-25%	Beta 3-4.5%	Oils 1-1.7%	English-style ales, porter, stout, ESB, Northern Brewer	Bitter U.S. or German Perle,	Mild to moderate, quite spicy.
Chinook	AA 10-14%	Co 29-34%	Beta 3-4%	Oils 1.5-2.5%	Pale ale, IPA, stout, porter, lager	Nugget, Columbus, 50:50 mixture of Galena and Cluster	Mild to medium-heavy, spicy, piney, and grapefruity.
Citra	AA 11-13%	Co 22-24%	Beta 3.5-4.5%	Oils 2.2%-2.8%	Pale ale, IPA	Amarillo	Gooseberry, passion fruit.
Cluster	AA 5.5-8.5%	Co 36-42%	Beta 4-6%	Oils 0.4-0.8%	Ale and lager (good aroma for ale, good bittering for lager)	Galena	Medium and quite spicy.

Alphabetical (continued)

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Columbus	AA 11-18%	Co 30-35%	Beta 4.5-5.8%	Oils 2-3.5%	IPA, pale ale, stout	Nugget, Chinook, Galena, U.K. Target, Northern Brewer	Pleasant, with pungent aroma.
Crystal	AA 2-5.5%	Co 20-26%	Beta 4.5-6.7%	Oils 0.8-2.1%	Lager, Pilsner, ESB	Mt. Hood, Hersbrucker, French Strisslespalt, Liberty	Mild & pleasant, spicy and flowery.
El Dorado	AA 14-16%	Co 30%	Beta 7-8%	Oils 2.5-2.8%			Candy-like
Eroica (German)	AA 9-14%	Co 36-42%	Beta 2.5-5%	Oils 0.8-1.3%	Wheat	Galena, Nugget, Chinook	Strong but pleasant aroma.
First Gold (U.K.)	AA 6.5-9.5%	Co 31-36%	Beta 3-4.2%	Oils 0.7-1.5%	Ale, ESB	U.K. Kent Golding, maybe Crystal	A little like Golding family; spicy.
Fuggle (U.S.)	AA 4-5.5%	Co 25-32%	Beta 1.5-2.0%	Oils 0.7-1.2%	Any English-style beer or American ale	U.K. Fuggle, Willamette, Styrian Golding, U.S. Tettnanger	Mild and pleasant, earthy and fruity.
Fuggle (U.K.)	AA 3-6%	Co 23-30%	Beta 2-3.1%	Oils 0.7-1.4%	All English-style ales, ESB, bitter, lager	U.S. Fuggle, Willamette, Styrian Golding	Mild, pleasant, hoppy, and robust.
Galaxy (Australian)	AA 13.5-14.8%	Co 35%	Beta 5.8-6%	Oils 2.4-2.7%	IPAs	Citra	
Galena	AA 10-14%	Co 40%	Beta 7-9%	Oils 0.8-1.2%	Ale, porter, stout, ESB, bitter	Nugget, Columbus, Pride of Ringwood, Chinook	Medium but pleasant hoppiness, citrusy.
Glacier	AA 5.5%	Co 11-13%	Beta 7.6-8.2%	Oils 0.7-1.6%	Any	Willamette, US Fuggle, Stryrian Goldings	
Golding (U.S.)	AA 4-6.5%	Co 20-25%	Beta 2-3%	Oils 0.4-1.2%	Pale ale, ESB, all English-style beer	U.K. Golding, Styrian Golding, Whitbread Golding Variety, U.K. hoppy. Progress, and possibility the Fuggle family.	Mild, extremely pleasant, and gently hoppy
Green Bullet (NZ)	AA 11-14%	Co 41-43%	Beta 6.5-7%	Oils 1.1%	Any	Styrian Golding	Dual purpose hop.
Hallertauer (US)	AA 3.5-5.5%	Co 18-24%	Beta 3.5-5.5%	Oils 0.6-1%	Lager, pilsner, bock, wheat	Liberty, Ultra, Hallertauer Tradition	Very mild, pleasant, and slightly flowery, some spicy.
Hallertauer Gold (German)	AA 6-6.5%				Any	Crystal, Mt. Hood	Known for its aromatic proper ties similar to Hallertauer.
Hallertauer Mittelfrüh (German)	AA 3-5.5%	Co 22%	Beta 3.5-5.5%	Oils 1-1.5%	Lager, bock, wheat, maybe Pilsner	Hersbrucker, Liberty, German Tradition Ultra	Mild and pleasant.
Hallertauer Tradition (German)	AA 6-6.5%	Co 24-29%	Beta 3-6%	Oils 0.5-1.5%	Mild-flavored beers	Crystal, Liberty	Known for its aromatic properties. A replacement for Hallertauer Mittelfrüh.
Herald (UK)	AA 11-13%	Co 35-37%	Beta 4.8-5.5%	Oils 1-1.9%	Any	any English hop	New dual-purpose hop
Herkules (German)	AA 12-17%	Co 32-38%	Beta 4-5.5%	Oils 1.6-2.4%	Pilseners and other lagers	Any high alpha-hop	

Alphabetical (continued)

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Hersbrucker (German)	AA 2-5.5%	Co 23%	Beta 3.8-6.2%	Oils 0.6-1.1%	Lager, pilsner, bock, wheat	Mt. Hood, French Strisselspalt	Mild to semi-strong, pleasant, hoppy.
Horizon	AA 10-14%	Co 16-22%	Beta 6.5-8.5%	Oils 1.2-2.6%	Ale, lager	Magnum or a high-alpha hop	Pleasantly hoppy.
Kent Golding (U.K.)	AA 4-7%	Co 20-25%	Beta 2-3.5%	Oils 0.6-1%	All English-style ales, ESB, bitter	U.S. Golding, Whitbread Golding Variety, U.K. Progress	Gentle, fragrant, and pleasant.
Liberty	AA 3-6%	Co 24-30%	Beta 2.9-5.0%	Oils 0.6-1.0%	Lager, pilsner, bock, wheat	Hallertauer Tradition, Hallertauer, Mt. Hood	Mild and clean aroma, slightly spicy character.
Lublin (Polish)	AA 3-4.5%	Co 25-30%	Beta 2.5-3.5%	Oils 0.7-1.2%	Pilsner	U.S. Saaz, Czech Saaz, U.S. Tettnanger	Mild and typical of noble aroma types, spicy, herbal.
Magnum (US)	AA 10-14%	Co 24-30%	Beta 4.5-7%	Oils 1.9-3.0%	All beers	Northern Brewer, Northdown	High alpha variety.
Magnum (German)	AA 12-16%	Co 24-30%	Beta 4.2-7%	Oils 1.5-2.1%	All beers, particularly lager, Pilsner, stout	Northern Brewer, Northdown	Known for bittering value and quality.
Marynka (Polish)	AA 9-12%	Co 26-33%	Beta 10.2-13%	Oils 2%	Any	new, not known	Intense aroma.
Merkur (German)	AA 12-15%	Co 16-20%	Beta 3.5-7%	Oils 2.2-2.8%	Lagers	Magnum, Taurus	
Millenium	AA 12-16.5%	Co 30%	Beta 4.8%	Oils 2%	Ales	Nugget, Columbus	Mild, herbal, similar to Nugget.
Motueka (NZ)	AA 6.5-7.5%	Co 29%	Beta 5-5.5%	Oils 0.8%	Lagers, especially Bo. Pils	Saaz	New aroma hop.
Mt. Hood	AA 3-8%	Co 22-27%	Beta 3.6-7.5%	Oils 1.0-2.3%	Lager, Pilsner, bock, wheat	Liberty, Crystal, French Strisselspalt, Hersbrucker	Mild, pleasant, and clean, somewhat pungent and resiny.
Mt. Rainier	AA 5-8.1%	Co 21-24%	Beta 5-7%	Oils 0.2-0.5%		Hallertau	
Newport	AA 13-17%	Co 36-38%	Beta 7.2-9.1%	Oils 1.6-3.4%	Any	Galena, Nugget, Fuggle, Magnum, Brewer's Gold	Fairly pungent.
Northdown (U.K.)	AA 6-10%	Co 24-30%	Beta 4.4-6.2%	Oils 1.2-2.5%	All ales, porter	Challenger, Northern Brewer, Magnum	Fruity with some spiciness.
Nelson Sauvin (N.Z.)	AA 12-14%	Co 24-25%	Beta 6-8%	Oils 1.5%	Any	none	Unique hop with grape-like flavor
Northern Brewer (U.S.)	AA 6-10%	Co 20-30%	Beta 3-5%	Oils 1.2-2%	ESB, bitter, English pale ale, porter, California (steam) beer	German Northern Brewer, Nugget, Chinook	Medium-strong with some wild tones.
Northern Brewer (German)	AA 7-10%	Co 28-33%	Beta 3.5-5%	Oils 1.6-2.1%	ESB, bitter, English pale ale, porter	Chinook, U.S. Northern Brewer	Medium-strong with some wild tones.
Northwest Golding	AA 4-5%				Ale, porter, stout, ESB, bitter		Known for aromatic properties.

Alphabetical (continued)

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Nugget	AA 11-14.5%	Co 27%	Beta 4-5%	Oils 1.5-2.2%	Light lager	Columbus, Chinook, Northern Brewer, U.K. Target, Galena	Quite heavy and herbal.
Olympic	AA 10-13%	Co 26-40%	Beta 3.8-6.1%	Oils 0.9-2.6%	Ales	Chinook	Mild to medium, citrusy aroma, spicy.
Opal (German)	AA 5-8%	Co 13-17%	Beta 3.5-5.5%	Oils 0.8-1.3%	Light ales	Styrian Goldings	
Pacific Gem (NZ)	AA 13-15%	Co 39%	Beta 8-8.4%	Oils 1.4%	Any	perhaps Fuggles	Bittering hop with a woody character.
Pacifica (NZ)	AA 5-6%	Co 25%	Beta 6%	Oils 1%	Lagers	Hallertau Mittlefrüh	
Palisade	AA 5.5-9.5%	Co 24-29%	Beta 6-8%	Oils 1.4-1.6%	Ales	Perhaps Cascade	Some “American” characteristics.
Perle (U.S.)	AA 5.5-9.5%	Co 29%	Beta 3.1-5%	Oils 0.7-1.2%	Pale ale, porter, German styles	German Perle, Northern Brewer, Challenger, Cluster, Galena, Chinook	Known for its aromatic and bittering properties, pleasant and slightly spicy.
Perle (German)	AA 6-10%	Co 25-32%	Beta 3.5-5.5%	Oils 0.8-1.3%	Pale ale, porter, lager	U.S. Perle, Northern Brewer	Moderately intense, good and hoppy, fruity and a little spicy.
Phoenix (U.K.)	AA 8-12%	Co 39%	Beta 4.2-5.5%	Oils 1.2-2.5%	All ales	U.K. Northdown, U.K. Kent Golding, U.K. Challenger	Similar to U.K. Challenger.
Pioneer (U.K.)	AA 7-11%	Co 36-40%	Beta 3.5-4%	Oils 1-1.8%	Ale, ESB	Kent Golding	A mild, typical English aroma.
Pilgrim (UK)	AA 9-13%	Co 36-38%	Beta 4.3-5%	Oils 1.2-2.4%	Ales	Target, Challenger	
Premiant (Czech)	AA 8-12.5%	Co 23%	Beta 4.5-8%	Oils 1.1-1.3%	Any	unknown	New hops with spicy aroma
Pride of Ringwood (Australia)	AA 7-10%	Co 33-39%	Beta 4-6%	Oils 1-2%	Australian lager	Galena, Cluster	Quite pronounced, woody, earthy, herbal.
Progress (U.K.)	AA 4-7.5%	Co 27%	Beta 1.8-2.7%	Oils 0.5-0.8%	Ale, bitter, ESB, porter	U.K. Kent Golding, Fuggle	Moderately strong, good aroma.
Riwaka (NZ)	AA 4.5-6.5%	Co 29-36%	Beta 4-5%	Oils 0.8%	Any	Saaz	Citrusy aroma hop
Saaz (Czech)	AA 2-5%	Co 24-28%	Beta 3-4.5%	Oils 0.4-0.7%	Pilsner	U.S. Saaz, Sterling, Polish Lublin	Very mild with pleasant hoppy notes, earthy, spicy, and herbal.
Saaz (U.S.)	AA 2.5-5%	Co 24-28%	Beta 2.8-5.0%	Oils 0.4-1%	Pilsner, lager, wheat	Czech Saaz, Sterling, Polish Lublin	Mild and pleasant, earthy and spicy.

Alphabetical (continued)

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Santiam	AA 5-7.9%	Co 22-24%	Beta 6-8%	Oils 1.3-1.5%	Lager, American ale, Pilsner German Spalt Select	German Tettnanger, German Spalt, Noble characteristics.	
Saphir (German)	AA 2.5-5%	Co 11-15%	Beta 6.5%	Oils 1.5%	Lagers	Any noble hops	Mild aroma hop.
Satus	AA 12.5-14%	Co 32-53%	Beta 8.5-9%	Oils 1.5-1.8%	Galena		Known for its bittering and aromatic properties.
Select (German)	AA 4-6%	Co 21-25%	Beta 3.5-4.5%	Oils 0.5-1%	Any	Saaz, Tettnang, Spalt	noble-type aroma
Simcoe	AA 12-14%	Co 15-20%	Beta 4-5%	Oils 2-2.5%	American pale ales, IPAs	Magnum, Summit	A bittering and aromatic hop.
Smaragd (German)	AA 4-6%	Co 13-18%	Beta 3.5-5.5%	Oils 0.7-1.7%	Alt, Kölsch		Fine aroma
Sorachi Ace (Japan)	AA 10-16%	Co 23%	Beta 6-7%	Oils 2.0-2.8%	Any	none	Bittering hop with lemony aroma.
Sovereign	AA 4.5-6.5%	Co 26-30%	Beta 2.1-3.1%	Oils 0.8%	English Ales	Fuggle	Intense fruity aroma.
Spalt (German)	AA 4-5.5%	Co 23-28%	Beta 4-5%	Oils 0.5-1.1%	Lager	U.S. Saaz, U.S. Tettnanger, German Spalt Select	Mild and pleasant, slightly spicy.
Spalt Select (German)	AA 4-6.5%	Co 23%	Beta 3.3-4.3%	Oils 0.5-0.9%	Lager, and any beer where noble aroma is wanted	U.S. Saaz, U.S. Tettnanger, German Spalt Select	Very fine Spalter-type aroma.
Spalt Select (U.S.)	AA 3-5%	Co 20-25%	Beta 3-4.5%	Oils 0.8-1.2%	German lagers	Tettnanger, Saaz	Medium intensity and pleasant hoppy qualities. Medium-strong aroma with wild American tones.
Sterling	AA 4.5-9%	Co 21-28%	Beta 4-6%	Oils 0.6-1.9%	Lager, ale, Pilsner	Czech Saaz, Polish Lublin	Herbal, spicy, pleasant aroma, hint of floral and citrus.
Strisselspalt (France)	AA 3-5%	Co 20-25%	Beta 3-5.5%	Oils 0.6-0.9%	Pilsner, lager, wheat	Mt. Hood, Crystal, Hersbrucker	Medium intensity, pleasant, hoppy.
Styrian Golding (Slovenia)	AA 4.0-6%	Co 28%	Beta 2-3%	Oils 0.5-1.0%	All English-style ales, ESB, bitter, lager	U.S. Fuggle, U.K. Fuggle, Willamette	Delicate, slightly spicy.
Summit	AA 16-19%	Co 28%	Beta 4.5-5%	Oils 2.4-2.6%	American ales	Simcoe	Ultra high-alpha bittering hop
Sun	AA 12-16%	Co 30-40%	Beta 4.5-7%	Oils 2.5-5.0%	Any	any high-alpha	High-alpha hop with intense character

Alphabetical (continued)

Name	alpha acid %	cohumulone percentage	beta acid percentage	oil content	typical beer style	possible substitutes	flavor description
Super Alpha (NZ)	AA 10-12%	Co 36-39%	Beta 7-8.5%	Oils 1.3%	Any		
Target (U.K.)	AA 9.5-12.5%	Co 29-35%	Beta 4.5-5.7%	Oils 1.2-2.6%	All ale and lager	Fuggle, Willamette, Magnum	Pleasant English hop aroma, quite intense.
Taurus (German)	AA 12-17%	Co 20-25%	Beta 4-6%	Oils 0.9-1.4%	Lagers	Magnum, Citra	
Tettnang (U.S.)	AA 3.0-5.2%	Co 20-25%	Beta 2.7-4.5%	Oils 0.5-1.0%	German ales and lagers, American lagers, wheat	German Spalt, Santiam, Czech Saaz	An aromatic hop, mild and slightly spicy.
Tettnang (German)	AA 3-6%	Co 23-29%	Beta 3.5-5%	Oils 0.1-1%	Lager, ale	German Spalt, German Spalt Select, U.S. Tettnanger, Saaz	Mild and pleasant, slightly herbal. spicy,
Tomahawk	AA 14-18%	Co 29-34%	Beta 4.5-5.8%	Oils 2-3.5%	Ales	Columbus	Primarily a bittering hop.
Tradition (German)	AA 4.5-7%	Co 26-29%	Beta 3.7-6.5%	Oils 0.7-1.4%	Lager, Pilsner	Hersbrucker, Hallertauer Mittelfrüh	Very fine and similar to Hallertauer Mittelfrüh.
Ultra	AA 2-5%	Co 25-30%	Beta 3.6-4.7%	Oils 0.8-1.2%	Lager, Pilsner, wheat, finish hop in ales	Liberty, Hallertauer Tradition, Saaz Saaz-like qualities.	Very good to outstanding, some properties similar to Hallertauer. Aromatic.
Vanguard	AA 4-6%	Co 14-15%	Beta 5-7%	Oils 0.8-1.2%	Lagers	Hallertauer Mittelfrüh, Hersbrucker	Aroma similar to continental European types.
Warrior	AA 15-17%	Co 28%	Beta 4.5-5.5%	Oils 1-2%	Ale, stout	Nugget, Columbus, Magnum	A bittering and aromatic hop.
WGV (Whitbread Golding Variety) (U.K.)	AA 5-8%	Co 34%	Beta 2.0-2.7%	Oils 0.8-1.2%	Ale	U.K. Kent Golding, U.K. Progress	Quite pleasant and hoppy, moderately intense.
Willamette	AA 3.5-7%	Co 32%	Beta 3-4.7%	Oils 0.9-1.5%	Pale ale, ESB, bitter, English-style ale, porter, stout	U.S. Fuggle, U.S. Tettnanger, Styrian Golding	Mild and pleasant, slightly spicy, fruity, floral, a little earthy
Zeus	AA 12-17%	Co 27-35%	Beta 4-6%	Oils 1-2%	Ales	Columbus	Aromatic and pleasant.