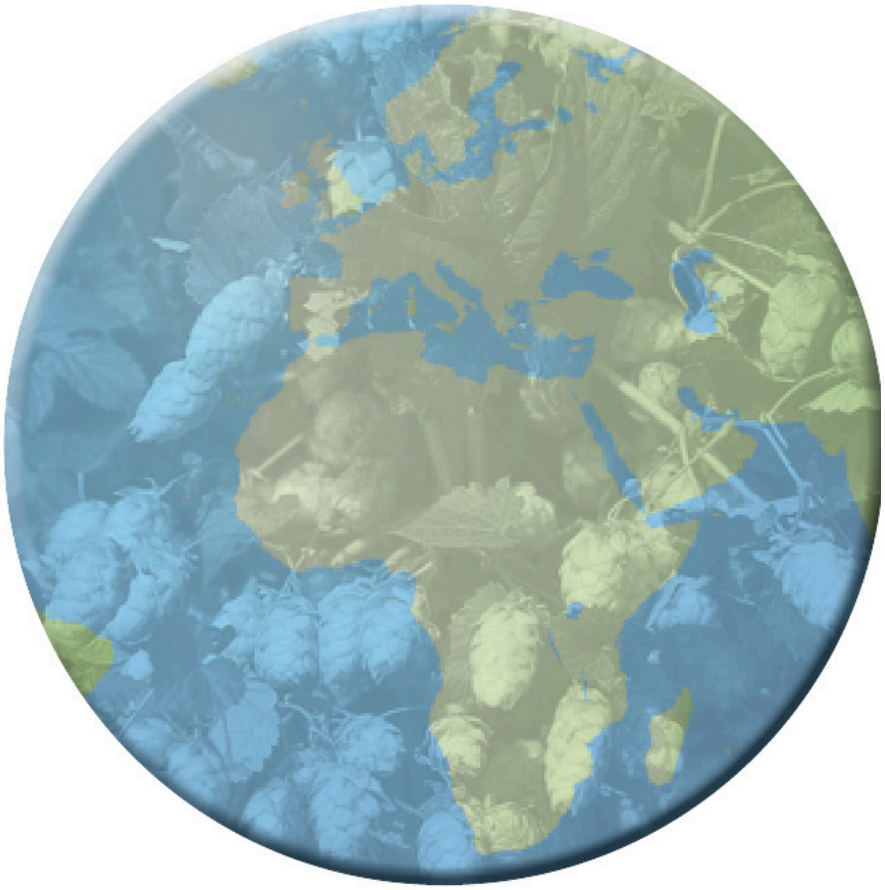
the best of Brew Your Own

BREWING INGREDIENTS: HOPS

HOP GROWING REGIONS

BY JOSH WEIKERT

Sometimes it seems as though hops will grow almost anywhere — and in all honesty, they probably will — but because of a combination of geography, climate, and the needs and wants of modern brewers a few specific regions around the world produce the overwhelming majority of the world's hops. This isn't an accident. Hops grow best under specific (and sometimes contradictory) conditions, and there are only a few places in the world where those conditions come together to produce hops to meet the demand from brewers around the world. Moreover, each of these regions has found its niche in producing specific types of hops with particular flavor or compositional characteristics, and it is becoming increasingly common to hear brewers discussing *terroir* (a French term often used in winemaking to describe the environment where the grapes were produced), and the contributions of local environments to the overall flavor of the beer.



In light of that, as brewers it's in our interests to get a good handle on what hops come from what regions, why, and where new opportunities might exist for hop production. It's a wide world of hops out there!

GROWING HOPS

The first thing to know before we discuss regions is that hops love the sun. John Snyder, co-founder of Yakima Valley Hops in Yakima, Washington, notes that a major reason that places like the Yakima Valley are such prolific hops producers is the peculiar desire of hops for long, sunny days and cool nights. As a result, it's not surprising that we look to specific ranges of latitude to find good hops growing regions – 35–55 degrees north and south latitude brings much of the northern US, Europe, and New Zealand into play. During summer in these far northern (or southern) areas you get lots of hours of sunlight without a lot of punishing heat (though hops are pretty hardy, and can definitely handle some hot days).

The second thing hops love — after sun — is water. This creates a bit of a dilemma for hop growers, since there simply aren't many places where you get lots of sun as well as lots of rain. The reason for this water greediness is that hop plants will grow by as much as one foot (0.3 m) per day during the summer, and this creates a real demand for water. In regions that don't naturally see lots of rainfall, hops can become very irrigation-intensive.

Hops also need space. Not laterally, but vertically — in fact, one advantage of growing hops is that a single acre can accommodate more than 1,000 individual plants. Trellises for hops are typically 18–20 feet (~5–6 m) in height, which provides ample opportunity for the hop bines (not vines — bines) to climb, and similar varieties can be planted fairly close to each other (within a couple of feet) without endangering their ability to grow.

TERROIR

Beyond these general conditions, much can (and probably should) be made of the specific contributions that are made by the place in which hops are grown. *Terroir*, as a concept, suggests that a specific place – its climate, geological history, soil composition, microbiota, and more – will impart flavors that are unique to that place. Just as certain breweries have a "house flavor" that devotees can identify and actively seek out, hop regions and even specific hop farms (and even specific fields) have unique attributes that impart subtle (or not-so-subtle) flavors in the hops.

Yakima Valley's John Snyder tells us that although hops farmers are constantly experimenting and tinkering with their harvests and fields, they have a great sense of how small

changes in the conditions and microclimates on their farms impact the final product. Much is also made of soil composition and the processes through which individual farmers replenish their soil with nutrients, whether through crop rotation, use of fertilizers, or mixing hop byproducts back into the soil. Every farm, John says, has its own secret method, and hops farms are often multi-generational affairs that allow for an almost dynastic quality, with methods being passed down from one generation to the next.

In the history of hops migration — moving with farmers as they settled in new places — there are stories of great success, but also of dramatic failures. For example, the hops of Flanders, Belgium proved a poor fit for the United Kingdom. Also, early British settlers in the Americas often struggled with hops that simply wouldn't take in the New World. Some lost their bittering capacity, while others grew poorly in the new soil, while others took off like the weeds they are but produced very little (or even foul-smelling) essential oils. These were not simply changes wrought by a different latitude or weather condition or soil chemical — it was all of those, and more. Ali Capper of Stocks Farm Homebrew Hops in Worcestershire, England notes that, for example, hops grown in the UK tend to have lower levels of myrcene (an essential oil) than identical strains grown in the US and New Zealand — "that's *terroir* in action!"

Put simply, a Cascade or Hallertau hop plant will produce a very different product from one region to the next.

HOP GROWING REGIONS

Here are some of the major hops-producing regions, a run-down on their regional attributes, and a list of hops common to the farms in the region:

US: PACIFIC NORTHWEST

The Pacific Northwest (PNW) of the United States (Oregon, Idaho, and Washington, particularly) is the new epicenter of the hop-producing world. The United States overtook Germany as the world's leading producer of hops in 2015, thanks almost entirely to this region, which by percentage produces nearly all (about 95%) of the 80-100 million pounds (~36,000,000–45,000,000 kg) of hops produced in the US. The region is fed by high capacity (with hops cultivation increasing by 17% last year according to an industry group), nearly-ideal conditions with nearly 300 days of sunshine punctuated by regular rain, and the structural bonus of melting snow pack to help water the hops and keep the ground well-saturated. It is also fed by high demand, with breweries in the US and around the world seeking out the region's famed high-alpha acid hops for efficient bittering and their oils-rich hops that are bursting with citrus, floral, and pine flavors — especially since many of the varieties available feature both attributes.

Notable hops from the region include the classics like Willamette and the American "C" hops (Cascade, Columbus, Centennial, etc.), the now-omnipresent Citra® and CTZ varieties, and true American originals like Amarillo®. It's also worth noting that many contemporary American hops varieties were developed in cooperation with the US Department of Agriculture (USDA), though experimental hops programs are now standard at PNW hops farms.

GERMANY

Much like the American Pacific Northwest, the German region of Hallertau benefits from good growing conditions and significant local demand (the breweries of Munich being just a short drive away). The regional appellation of Hallertau attaches itself to a variety of hops from the region, and Hallertau Mittelfrüh was once the predominate hop in the country (thanks, in part, to noble patronage from the Duke of Bavaria). Since that time, it has faced increased competition thanks to an active and productive breeding program at the Hull Hop Research Institute, which since 1926 has been experimenting with hybrids and selective breeding of classic German hops. Regional *terroir* is still a big part of the equation, though: Most of the Hull-bred hops are derived from traditional "landrace" hops (openly-pollinated, domesticated varieties).

Notable hops from the region include Hallertau Mittelfrüh (still quite popular) with its spice and fruity flavors, the more-herbal Tettnang (a member of the Saazer family of hops), and newer (and stronger!) hops like Mandarina Bavaria (which, as its name suggests, imparts significant orange and tangerine flavors) and Polaris, a high-alpha acid hop with a unique pineapple-mint flavor.

CZECH REPUBLIC

Another classic brewing center with the right conditions and royal assistance (this time from Holy Roman Emperor Charles IV), the Czech Republic is renowned for the Saaz hop, which derives its name from the major city in the region (Zatec) and accounts for nearly two thirds of all Czech hops production. Although not an especially ideal region for hop growing, historically consistent demand for Saaz as a uniquely "Bohemian" hop has allowed the Czech Republic to stake out the fifth position on the list of top hops-producing countries, and what Saaz and its cousins lack in bittering potential they make up for in earthy, herbal, and floral flavors.

Notable hops include (obviously) Saaz, but, more recently, Czech hops farmers have produced higher-alpha varieties like Premiant and Bor, which offer some of the same Saazer flavors but with double-digit percentage alpha acid content.

UNITED KINGDOM

The United Kingdom has been a hop-centric agricultural center for its entire existence — it was under James I that the United Kingdom became the United Kingdom (merging England, Scotland, and Wales), and James was actively managing the hops industry of his kingdom as early as 1603, approving a Parliamentary ban on imported hops over their lack of quality. No less a sage than Charles Dickens praised the beauty of English hops fields, which he documented while traveling through Kent by train. In the modern era, after decades of shrink-

ing production, British hops production has rebounded, thanks in large part to a growing craft beer scene, experimental breeding at Wye College, and global demand for the impressive array of earthy and herbal flavors to be found in their hops. Kent is the most productive region, and farmers in the area (which is known as the "Garden of England") point to the mild weather and sea-salt breezes off the North Sea as the source of the refined flavor profile of East Kent hops.

Notable hops from the region include East Kent Goldings (a classic herbal dry hop developed, much like the German varieties, from wild hops in the 17th and 18th centuries), Fuggle (which features prominently in many English pale ale recipes), and more-recent high-alpha varieties like Admiral and Phoenix. Ali Capper, co-operator of Stocks Farm, a hops farm in Worcestershire, England, points out that the specific growing conditions of England contribute to the success of hops like Goldings: "Goldings will not grow very well in the main hop growing region in the USA . . . as it is simply too hot and dry in the summer. So for the perfect hop growing region you must grow a locally bred hop, one that can grow well in the local conditions."

NEW ZEALAND/AUSTRALIA

"Down Under" hops have been quite the rage of late, and their popularity is very much driven by their unique *terroir*. Much like the Pacific Northwest, New Zealand and Southern Australia benefit from the unique combination of high latitudes, abundant sun, and frequent rain. But the flavors produced by the combination of local conditions, local varieties of hops, and cross-breeding with traditional hops from the rest of the world's growing regions have created an entire family of new hops that feature exceptionally high alpha acid content and bright lemony flavors that are unique to hops from the region. The relative scarcity of these hops also adds to their desirability. Since much of the southern hemisphere's "hop belt" is covered in water, there are few hop-producing regions there, but New Zealand and Australia are busily expanding hops cultivation to make their products easier to get.

Notable hops include the white-wine-like Nelson Sauvin, the lime-flavored Motueka and Wakatu, and the citrus-bomb Riwaka.

FRANCE AND SLOVENIA

We probably don't think of France as often as some other regions around the world when we think of beer and brewing, but it would be a mistake to overlook the French contribution to hop culture, which remains strong in some parts of the country (particularly the Alsace region). Hop cultivation in the area dates to at least the 13th century, and the same regional characteristics that produce outstanding wine grapes lend a helping hand to the area's hops production. Likewise, Slovenia deserves to be counted among the world's top hop producers thanks to the popularity of its dominant hop.

There may only be one hop that we consider resolutely "French," but it's a great one! France is home to the Strisselspalt hop, grown in the Rhine River valley. A landrace hop, it shares a lot of the characteristics of the Hallertau varieties, and contributes a well-rounded spice, herbal, floral, and fruity aroma to a wide range of regional beers (both German and French!). Meanwhile, in Slovenia, the Styrian Goldings hop was developed (confusingly) from Fuggle, but the local conditions made it much fruitier while retaining the earthy character of its English forerunner.

NO PLACE LIKE HOME?

Ultimately, a good working knowledge of hops regions is valuable in that we can more-precisely dial in our recipes. It also allows us to consider and appreciate the kind of things that make our beer work, and when we might need to make adjustments. Knowing whether it was a rainy spring in Bohemia or a dry summer in Yakima will tell you what hops options you might have — and when you might want to start hunting elsewhere!

Which brings me to my final point: Place really does matter. Be creative and thoughtful in your hops selections, and beer you love will surely follow. It's a wide world of hops out there — do your research and take advantage of it. BYO

Photo courtesy of BSG

Hops being harvested at a hop farm in New Zealand.

CHOOSING & USING DIFFERENT HOP FORMS

BY JON STIKA

Hops have been the herb of choice to preserve and flavor beer for centuries, but only during the last several decades has there been such a wide variety of hop products available to homebrewers. For the purpose of this article, hop "cones" are the whole female flowers of the hop (Humulus lupulus), which can be dried or fresh (also known as "wet").

The forms of hops typically available to homebrewers today include fresh wet hop cones (home grown, or from local commercial sources), whole leaf dried hop cones, plugs of compressed dried hops, pellets of pulverized hops extruded into small cylindrical pieces, hop hash of hop lupulin glands typically collected off of pelletizing equipment, and hop extracts of liquid hop resins extracted from hops, such as HopShot® or Iso-Hop®. Each of these forms of hops have advantages and disadvantages that will determine how and when you may choose to use them in your own homebrewing process.

Photos by Charles A. Parker/Images Plus

ADVANTAGES & DISADVANTAGES

While the main focus of this article is on the forms of hops, it is important to look at the points in the process where hops become part of a batch of brew. For those who may be relatively new to homebrewing beer and the use of hops, the chart below offers a brief summary of some of the ways hops can be used and the terminology associated with those uses.

WET HOPS

Wet hops are the least processed form of hops, as they are fresh from the plant. If you grow your own hops or live near someone who does, you may be able to get wet hops to add to your brew. Wet hops may be added at any point in the brewing process just as whole leaf hops might be used. Because wet hops are fresh, they may lend a green, vegetal flavor if used exclusively, or in excess, in a given batch. Fresh hops have a much higher moisture content than dried hops so you will need to use roughly seven times the weight of fresh hops as what would be specified for dried hops in a recipe. Fresh hops rarely include an alpha acid analysis, so using them as first wort hops or in the boil is a bit of a gamble as to the bitterness they will contribute to your beer. If an alpha acid analysis is not available, use the mid-range alpha acid level typically associated with a particular variety of

When	Details	Common Term
Mash	Adding hops to the mash prior to vorlauf and sparging	Mash hopping
First wort	Adding hops to the wort prior to boiling for a softer, more rounded bitterness	First wort hops
Boil	The standard approach to adding hops or hop products to achieve bitterness, flavor and aroma	Boil
Post boil	Adding hops or hop products immediately before and/or during cooling of the wort in the kettle	Flame out or hop bursting
Post boil	Hot wort is strained through a sieve containing whole hops to extract flavor and aroma	Hopback
Fermentation	Hops or hop products added to fermenting beer, typically during secondary fermentation	Dry hop
Packaging	Hops or hop products added to finished beer in the keg or cask	Cask hop
Serving	Hops or hop products added to beer at serving to increase bitterness, flavor or aroma	HopRocket or Randall

hops when calculating the bitterness contribution. Wet hops can be tossed into the kettle loose, or contained in a cheesecloth or other mesh bag so they can be removed to prevent clogging of valves or tubing used to transfer wort to the fermenter.

The advantage of using wet hops is the ability to capture as much fresh aroma and flavor that is available from the just-picked cones. Using fresh, locally grown hops in your brew also provides you an opportunity to participate in the energy conservation and source-identity advantages currently popular among craft brewers. The disadvantages of using wet hops include availability, increased hop material volume (and corresponding wort loss), and the potential for picking up some vegetal flavor (which is normally considered a flaw in beer flavor). Limit wet hop additions to near the end of the boil, after flame-out/hop bursting to derive the most flavor and aroma from the hops while limiting the vegetal flavors that may occur from the hops being in an extended boil. Wort loss can be minimized by using mesh bags to contain the hops and then hanging the bags above the kettle for sufficient time to let the wort drain before discarding the spent cones.

WHOLE LEAF

Whole leaf hops are hop cones that have been picked from the bine and dried to less than 10% moisture content. This form of hops is readily available from homebrew shops and suppliers, keeps well in a sealed container in the freezer, and almost always includes an alpha acid analysis. Whole leaf hops are typically sold in the US in quantities of an ounce to a pound. They originate from hop producers in a compressed bale weighing approximately 200 pounds (91 kg) and are then broken down into smaller quantities for retail sale, often in vacuum-sealed plastic bags. Whole leaf hops can be added to any point of the brewing process to add bitterness, flavor and aroma to the finished beer.

Advantages of using whole leaf hops are that they are easily stored, weighed, and added at virtually any point in the brewing process loose, or contained in a mesh bag. They are also readily available from homebrew suppliers and include an alpha acid analysis for use in bittering calculations. The disadvantages of using whole leaf hops are similar to wet hops in that they absorb wort or beer and thus result in some loss of the final product. They are also a bit more difficult to weigh due to the volume they can occupy in a container in which they are weighed. The one major disadvantage I have, personally, with whole leaf hops is the amount of space they take up in the freezer.

PELLETS

Pelleted hops are perhaps the most common and convenient form of hops used by homebrewers. They are compact and so are convenient to store and use. They come with alpha acid analysis and are packaged in vacuum-sealed Mylar or plastic packages, sometimes purged with nitrogen gas to reduce oxidation and preserve freshness. Hop pellets are made by pulverizing whole dried hops and then extruding the resulting material through a die that compresses and casts the pieces into cylindrical pellets of roughly an eighth of an inch (3 mm) in diameter of various short lengths. The sticky resins released from the lupulin glands of the hop cones naturally bind the ground hop material together into the relatively stable pellets.

The main advantages of hop pellets is that they are readily available, keep well in a freezer, take up less storage space than whole hops, include an alpha acid analysis and are easy to measure into any desired amount. Pelleted hops are perhaps the most used by homebrewers because of these benefits. One disadvantage of hop pellets are their slightly lower content of volatile aromatics compared to wet hops or whole leaf hops. This can be compensated for by adding a bit more pelleted hops than a corresponding measure of wet hops or whole leaf hops when they are used at the end of the boil or for dry hopping. Pelleted hops also disintegrate into smaller pieces when added to wort or beer and therefore leave more residue at the bottom of the kettle, carboy, or keg. If pelleted hops are contained in a bag or other container they should not be confined too tightly so they are able to disperse and provide the full contact with wort or beer.

HOP HASH

Hop hash consists of hop lupulin glands (the yellow bits found at the base of the hop cone bractioles) that have been broken apart and collect on surfaces of milling equipment used to make hop pellets. The resulting concentrated lupulin powder is much higher in alpha acids and aromatic oils by weight than whole leaf hops or pellets. Because most of the dried hop cone material is gone, hop hash produces a flavor and aroma without the "grassy" flavors associated with using a large amount of wet hops or whole leaf hops in a recipe. Hop hash

Hop hash

comes with an alpha acid analysis that must be considered carefully when making bitterness calculations due to the higher concentration of alpha acid typically associated with less processed hop products such as pellets. Hop hash can be substituted for whole leaf hops, plugs, or pellets throughout the brewing process with due consideration given to its potency. It can be used to give beers a tremendous hop flavor and aroma when added post-boil in a given recipe. Start low, with an ounce (28 g), as a late boil addition or as a dry hop as you experiment with hop hash, a little goes a long way!

The advantage to using hop hash is primarily for its concentrated alpha acid and oil content that provides the most hop bang for the amount of storage space needed to keep it on hand. It also leaves less residue behind in kettle or keg than whole leaf or pellet hops. Hop hash also produces less grassy flavors in the finished beer because it contains so little green material from the hop cone itself. Hop hash comes with an alpha acid analysis that is significantly higher than whole hops or hop pellets, and thus must be measured and used judiciously. Disadvantages of hop hash are the limited availability of specific hop varieties and that the material is a bit sticky to measure and handle.

LUPULIN POWDER

Another very new form of hops is a powder that was exclusively developed by YCH Hops from Yakima, Washington, called "lupulin powder." This hop dust is made with a proprietary process of cooling and milling hops, which extracts resins and oils. It is done at very cold (cryogenic) temperatures, using nitrogen to prevent oxidation. This form of hops, also known as "Cryo HopsTM," are currently only available to commercial brewers. YCH plans to release one of them, however — LupuLN2® — to homebrewers in the near future.

EXTRACTS

Hop extracts are made by stripping alpha and beta acids and aromatic compounds from fresh hops using carbon dioxide to get all the goodness hops can contribute to beer without the leafy material or pulverized hop particles from whole leaf hops or pellets. Variety-specific hop extracts are not currently available to homebrewers, only commercial brewers. The hop extracts that are currently available to homebrewers are a bit less refined and sold as HopShots® which are packaged in 5 mL (0.17 fl. oz.) plastic syringes (minus the needle). One milliliter of the extract produces approximately ten IBUs (international bittering units) of bitterness when boiled for an hour in a 5-gallon (19-L) batch of 1.050 specific gravity (12.4 °Plato) wort. These extracts are best used for bitterness rather than flavor or aroma and are not specific to a particular variety of hop like the commercially available extracts.

The advantage of HopShot® products is that they allow homebrewers to add the bittering power of hops to the boil without the associated hop residues or wort loss associated with hop pellets or whole leaf hops. The disadvantage is that the variety-specific hop extracts that contain all of the attributes of the original whole hop are currently only available to commercial brewers. The HopShot® products do not contribute specific or significant hop flavor or aroma that would be derived from whole hops or hop pellets do, only bitterness. If you are brewing a big beer, such as an IPA or barleywine that requires a great deal of hop bitterness, hop extracts may save you some of the mess and beer loss associated with hop residues. Whole leaf or pellet hops can be added later in the boil to produce hop flavor and aroma for your recipe.

Another type of hop extract available to homebrewers consists solely of hop alpha acids extracted with liquid carbon dioxide, that are then isomerized into their bitter form and so do not need to be boiled to develop bitterness in your beer. This type of pre-isomerized extract can be added to a finished beer that is lacking in bitterness to correct final bitterness at packaging. The product currently available to homebrewers is called IsoHop®, and is sold in one ounce (29.6 mL) bottles that can be stored in a refrigerator. Since this product does not contain essential hops oils, it is only suitable for adjusting bitterness, not flavor or aroma in beer. Follow the manufacturer's instructions for determining the quantity of IsoHop® extract to add to your beer to achieve the desired bitterness.

The advantage of pre-isomerized hop extract is that it can be added to your wort or beer post-boil and thus allow you to make last minute adjustments to beer bitterness, even right up until packaging. It is easily stored in a refrigerator and convenient to use when needed. The disadvantage of this form of hop extract is that it does not supply any hop flavor or aroma, only bitterness to your beer.

GET HOPPING

With the wide range of hop products currently (or at least seasonally) available these days ranging from fresh wet hops to pre-isomerized hop extracts, homebrewers have an unprecedented array of options to work with to achieve the desired effect hops can have on their beer. BYO

Hop extract

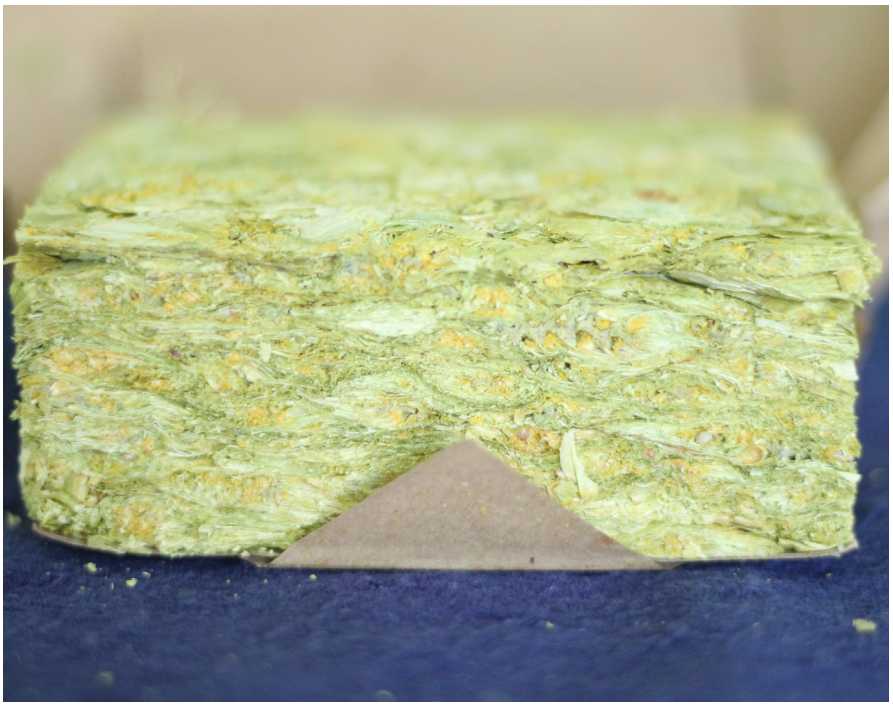
EVALUATING HOP OIL CONTENT

BY MICHAEL TONSMEIRE

There are no "Cascade" or "Saaz" aroma molecules, rather the relative proportions of hop oils drive their aroma contributions. The same four oils constitute 60–90% of the essential oils in every hop variety. Hop oils constitute less than 4% of a hop cone's weight yet they provide most of the hop aroma, that combination of citrus, green, spice, and herb. Hop oil analysis provides an understanding of how to substitute and creatively pair hop varieties rather than simply referencing recipes or charts. With so many hop varieties released each year, evaluating oil content will enable you to cut through marketing hype and dial in hop combinations that fit your preferences.

To judge the contribution of a particular oil, add a large charge at flame-out and dry-hopping using a blend of at least three hop varieties high in your target oil. Blending hops in this way dilutes variety-specific aromatics. Alternatively, you can buy a beer brewed with several hops rich in the particular oil. For example Odell Brewing Co.'s (Fort Collins, Colorado) Myrcenary, as the name implies, is brewed with hops high in myrcene (including Cascade and Chinook). London's Fuller's Brewery Extra Special Bitter is finished with Northdown, East Kent Goldings, and Challenger, making it a good choice for humulene. Many Czech-style Pilsners are rich in farnesene thanks to Saaz or Sterling. Caryophyllene is a bit trickier, but Moonlight Brewing's (Fulton, California) delicious Reality Czeck is hopped exclusively with American Perle. You can also take this lesson in the opposite direction though, blending too many hop varieties together without thought often produces generically "hoppy" beers because the oils average out.

Myrcene volatilizes particularly easily, much of it will be destroyed even with late-boil additions. If you want to retain more into the finished beer, partially cool the wort (180–190 °F, 82–88 °C) before adding the flame-out addition, and then allow the hops to steep for 30 minutes before continuing the chill. Dry hopping is an even more efficient option. Processing and storage of the hops also plays a crucial role; pelletizing destroys much of the myrcene, but also makes it easier for what remains to transfer into the wort.[1]



Photos by Michael Tonsmeire

Brewer's cut (sample) from a bale of Cascade hop cones.

SHIFTING CONCENTRATIONS

While we can talk generally about which hops are high in a particular oil, the average amount for each oil can shift by as much as 10% from one year to the next. Farm-to-farm differences can be even more dramatic. Professional brewers receive an oil analysis, which is often combined with a trip to the growing region to evaluate lots of hops for selection. As homebrewers we are at the mercy of the market. Producers usually blend several lots of pelletized hops to reduce variation (whole hops generally aren't blended).[2] Get in the habit of smelling every package of hops you open. Learn how each variety should smell and be willing to return or toss hops that smell old or off.

COMMERCIAL HOP BLENDS

In addition to blending pellets from different lots of the same variety, Hopunion mixes multiple varieties to create proprietary blends. The most popular blend, Falconer's Flight®, was first released in 2010, with a portion of the profits going to the Glen Hay Falconer Foundation. Described as "Distinct tropical, floral, lemon, and grapefruit characteristics," the goal is to allow brewers to use a combination of sought-after varieties without needing to buy and store each in quantity. Hopunion also produces 7C's® (a blend of seven "C" hops) and Zythos®.

Jesse Umbarger, who selects the lots that go into the blends every year, relies on sensory analysis rather than the oil content of the available hops. He explained, "I am looking for the bales of hops that possess the characteristics that the hop should possess traditionally, bright, dank (sometimes a positive), etc." The goal of all three blends is to maintain consistent character from harvest-to-harvest,

in a way that is impossible for a single variety, especially as a homebrewer. Jesse explains, "With a hop blend such as Falconer's Flight®, if one of the nine varieties has a major shift in aroma or typical characteristics the overall influence or change to the blend is reduced by one-ninth." Using nine hops (including two experimental varieties), allows Hopunion to provide a reliable supply at a reasonable price.

While I have tasted some delicious beers hopped exclusively with blends (e.g., DC Brau's On the Wings of Armageddon is all Falconer's Flight®), I prefer having control over exactly what varieties I'm adding to my beer. I'm not as worried about sensory changes compared to a commercial brewery, and I'd rather rely on my own sensory analysis (even if that sometimes means throwing away hops).

DESIGNING YOUR BLENDS

One of my favorite brewers of hoppy beers is Alpine Beer Co. (Alpine, California) whose beers (especially Duet, Nelson, and my favorite, Hoppy Birthday) always have just the right hoppy balance of green, citrusy, and fruity characteristics. A few years ago Owner and Brewmaster Pat McIlhenney hinted at one recipe design secret: Pat targets a hop oil ratio across beers. To determine his ideal target he started by brewing single hop beers, which "proved invaluable. Understanding the individual sensory characteristics helped when analyzing the hop oil profiles," he said. Pat wouldn't reveal his specific ratio, but considering Duet is equal parts Simcoe® and Amarillo® and Nelson is a blend of Nelson Sauvin and Southern Cross, both would have high amounts of both humulene and myrcene. As Pat suggested, "All of the hop oils are important, some in abundance some in absence." While this approach lays down a hoppy base across recipes, trace oils resident in the various hops provide unique character to each beer. Analyzing oil profiles is a great way to select an initial blend, but there is no substitute for brewing a batch and dialing in the recipe based on your sensory preferences.

Hop Oils

Big Four

Myrcene: Green, resinous. Hops: Amarillo®, Citra®, Motueka, Cascade
Humulene: Piney, woody. Hops: Hallertau, East Kent Goldings, Nelson Sauvin, Northdown
Farnesene: Floral Hops: Sterling, Saaz, Santium, Tettnang
Caryophyllene: Woody Hops: Vanguard, Perle, East Kent Goldings, Admiral

Others

B-Pinene: Woody-green, pine Hops: Centennial, Bravo, Ahtanum
Linalool: Floral, orange Hops: Ultra, Horizon, Liberty
Geraniol: Floral, sweet, rose Hops: Brewer's Gold, Centennial, Cluster

To estimate the percentage of each oil in your beer, calculate the relative weights of the hops, total oil content in each, breakdown of that oil, and timing of the additions. It is possible to compute these figures by hand, but I devised a spreadsheet to simplify the process. Luckily, my friend Scott Janish took what I had done about five steps further with the help of Hopunion to create a slick web-based hop oil calculator: http://scottjanish.com/hop-oils-calulator/. Input your hop bill and Scott's program will output a graph of hop oils and projected flavor/aroma descriptors based on average hop analysis.

Try analyzing a few favorite IPA recipes you've already brewed (or commercial clone recipes); see any trends? Maybe you have a favorite oil profile and just don't know it yet! Scott ran a correlation across 25 batches of his hoppy homebrew and discovered that, "Farnesene seems to always have a negative impact in how I rate a beer's aroma, flavor, and overall excitement when added to the dry hop."

While mathematical analysis of hop oil content is no replacement for sensory analysis, it can provide some assistance when substituting varieties, designing a hop bill, or evaluating a new variety. As homebrewers we need to take every advantage we can when dealing with hops, which is unfortunately the beer ingredient that is both the most variable, and the one we have the least control over! BYO

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[1] https://beersensoryscience.wordpress.com/tag/myrcene/
[2] http://www.scottjanish.com/hops-understanding-blends-oil-testing

A close look inside of a hop cone.

NEW HOP EVALUATION

BY DAWSON RASPUZZI

It's no longer a surprise to read a label of a new commercial beer release and find a hop variety you've never heard of before. Hop breeders are coming out with new varieties every year. It's an exciting time to be a brewer, but it's also hard to keep track of these breeds. Whether you are lucky enough to get your hands on an experimental hop, or just a variety you have never brewed with, evaluation is key.

Jeremy Marshall
Lagunitas Brewing Company (Petaluma, CA)

Brewers are such specific animals — often falling hard for a hop that makes another brewer yawn. Statistics and research aren't well developed at this time, the traditional bag of essential oils (e.g., myrcene, carophylene, geraniol, humulene epoxide, etc.) never seem to correspond to the actual merit of the hop. I will look at alpha acid, but never to assess bittering potential; rather, there does seem to be a relation with medium to medium-high alphas and good aroma potential; it makes sense because the soft resins contain all the brewing value — both essential oils and alpha (and beta).

When we get a new variety we talk a lot about the "bag whiff." It doesn't sound scientific but the key volatile components that Lagunitas is interested in are often detected best from a distance (due to sulphur thiols and such) so a bag whiff is always the place to start. Then move on into a direct hit (smell the hops directly) and then the standard rub that brewers love to do at hop harvest. Then we can take it further down the rungs into the vaporizer and/or infuser.

Obviously it makes sense to avoid testing a new hop (or any new ingredient) in a stout or darker beer. It also makes sense to avoid any other bold ingredients such as herbs or fruit but also consider loud grains like rye. Here is the rule I use: Test "gentle" hops such as noble German and Czech varieties (e.g. Hallertau and Saaz types) or spicy, earthy hops like Goldings derivatives in lagers and very low gravity pale ales. The nice thing about lagers is that the slow, cold fermentation will lock in your kettle hops very well. However an ale fermentation typically blasts off all the delicate kettle and whirlpool hop volatiles, thus dry hopping has always been associated with ales. Punchy American and Southern Hemisphere varieties go best with dry hopped pale ales and IPAs. I do not recommend imperial or high gravity styles when it comes to exploring new hops; the hop may get lost in the esters and fruity higher alcohols.

Considering that we often need to conduct a homebrew in order to keep up with the velocity at which new hops are coming at us, I would argue homebrewers are at an advantage to commercial brewers. Most young commercial craft brewers right now were homebrewers first and we often still homebrew, and this is the easiest way to keep our knowledge current.

I am always going back to certain hops finding that I still don't see the hype. In that regard, trust your first instinct as the correct one. However, when another brewer makes a great beer with a hop we evaluated and didn't like I get excited. Turns out the brewer has to be a snake charmer, and not every brewer can get the snake to dance. I know of a brewer near us getting great notes from the newer German varieties that we didn't get much from; conversely, a lot of brewers can't believe what we are able to get out of the less celebrated Australian varieties such as Vic Secret™ and Enigma™.

When we get a new variety we talk a lot about the "bag whiff." It doesn't sound scientific but the key volatile components that Lagunitas is interested in are often detected best from a distance (due to sulphur thiols and such) . . .

Brendan McGivney
Odell Brewing Company (Fort Collins, CO)

With new hops we start with an organoleptic evaluation either in the field or, ideally, after the hops have been picked and kilned. We rub the hops and investigate the different aromatic components present in the variety. During the rub we also evaluate moisture, cone integrity and any evidence of disease pressure. We also look at any available data for a new variety — typically we are more interested in the oil fractions than the alpha acid content.

We have a standard recipe for new hop evaluation on our 5-barrel pilot system. The malt bill is fairly light in color and flavor to allow the hops to shine through. We adjust for alpha in the kettle but we use a standard quantity of hops in the whirlpool and hopback and we end up in the 35–40 IBU range. When pellets are not available for new varieties we utilize a similar recipe that is more hopback intense. Then we run all of our pilot beers through our daily taste panel to determine the different attributes of a new hop before deciding if we will further experiment with the new variety.

Customers can often find our pilot brews in our taproom, but the only experimental hop beer available in package is our Wolf Picker Pale Ale, released in our winter variety pack. Each year we focus on new hop varieties layered over a consistent malt bill in this beer. This year we used HBC (Hop Breeding Company) #472, HBC #438 and a new public variety called Cashmere. We pilot brewed single hop beers with each of these varieties before coming up with the hop blend.

Believe it or not I still homebrew after 20+ years in the industry and I make sure to evaluate hops from the homebrew shop. I would suggest that homebrewers who are looking at a variety they have not used before (or any hops for that matter) go through the rub and sniff test before committing to a variety. Sure, it would be a shame to waste $3–$5 on an ounce if you encounter subpar hops, but you would have a good idea of the hop quality before brewing with it. If a variety smells like garlic and burnt rubber it is a good indication that you may find those flavors in your finished beer.

Tim Sciascia
Cellarmaker Brewing Co. (San Francisco, CA)

Hop purveyors typically do an aromatic evaluation of new hops, which have become more detailed and accurate over the years. I think you have to take these descriptions with a grain of salt, but they can get you closer to the qualities you're looking for faster. Then it's time to order some so you can evaluate the aroma yourself. Statistics of oil levels, kilning temperatures, harvest dates, etc. can aid in narrowing down the pool of candidates for a single hop cultivar, but personal sensory evaluation is the true test.

Typically for Cellarmaker, we are looking for pungent IPA hops so we'll use new hops in a base beer of very minimal malt flavor and use a neutral yeast strain that is going to stay out of the way of the hop. From there, dry hopping is going to translate the aroma most accurately. Of course we aren't always looking for aroma, but the best flavor. Large whirlpool additions of the new hop gives us the clearest presentation of that profile.

For many varieties, we can tell if we want to use a new hop right away by smelling a freshly opened bag. Sometimes however, we will revisit a bag that's been open for a few months and the hop has changed — miraculously, sometimes for the better. We are told that oxygen is bad for hops, and that's very true over a long period of time. But other reactions happen other than staling. I've seen an overly onion/garlic hop lose that aroma and become even more fruity over a few months exposed to air. We are considering opening bags of certain hops at delivery for use at a much later date.

For us, new hops will always be used in conjunction with other hops we know very well so the qualities it brings to the beer will be glaringly obvious.

Unfortunately, availability at the homebrew level is limited. What I'd look for is the best hop quality coming out of your local homebrew shops. Ask how they repackage the hops they sell. Vacuum sealing is a must and storage temperatures matter. BYO

HOP COMBINATIONS

BY JOSH WEIKERT

Paradoxically, recipe construction is at once an element of the brewing process that gets far too much attention — and also not enough. It gets too much attention in that too many brewers look at recipes as magic spells that, when properly constituted, will lead them to homebrewing nirvana. They tinker, tweak, and adjust. They debate, discuss, and argue. They develop rules of thumb on malt ratios and lists of secret ingredients. In so doing, they run the risk of overcomplicating the situation. Recipes don't need to be complicated. Recipes don't need to invent anything new to be great. Heck, to a great many brewers recipes aren't even the most important part of this whole phenomenon, what with the huge contributions made by process and the variations one gets from one brew system to another. Enough, already. Recipes are easy.

But then again, recipe construction is also neglected. Sure, the recipe "simpletons" have a good point: SMaSH recipes —single malt and single hop — can make a phenomenal beer. They're also correct that complex recipes don't automatically result in complex flavors. Where the puritans might be stifling their disciples, though, is in pushing the narrative that recipe construction is actually unimportant, which is taking the conclusion too far. Beer recipes bear thinking about, particularly when we talk about hops, because hops are one of the major ingredients that makes beer "beer." Sure, I know that gruit exists, but for practical purposes in the modern era, beer is closely identified with hops — if you doubt that, take a look at how many IPAs are on the market at the moment, and how craft brewers are experimenting with more hops and different techniques in all kinds of styles. In light of the hoppy trends, it's surprising that so many brewers approach hopping so casually, and that we have so little scientific data to guide us.

The goal of this article is to give you some good, basic advice (and a strong cautionary note) about hop combinations, in order to provide a jumping off point for your own hopping experimentation. I'll even provide some of my own recommendations. However, your mileage may vary, as they say — not only because of the vagaries of things like equipment geometry and water chemistry, but because, to be frank, we don't know enough to provide hard-and-fast rules here. And only you know what you like, because taste is so subjective. We'll be learning together.

Photo by Charles A. Parker/Images Plus

TWO'S COMPLICATED

As I said earlier, there's not a thing wrong with single hopping. As a frequent German lager brewer, in fact, a number of my beers are single hopped. The intrinsic advantage of single hopping is that you have a pretty clear sense of what you'll be getting out of your hops, as any number of guides and descriptions exist of hop varieties to help you predict it. The unavoidable disadvantage of using just one hop in a beer recipe, though, is that you're giving up on flavors that can't be produced by a single hop, and that's before we get into the idea that you're counting on a single hop from (likely) a single crop for all of your hop flavors, aromas, and bittering. Call me paranoid, but I'm a bit wary of putting all my hop cones in one basket, which is why I tend to eschew single hopping for hop schedules. I'm not special in this aspect — I think most homebrewers probably do the same. But how much attention are we paying to it?

The answer should be "a lot." Hops, as I'm sure many of you know, derive their flavor properties from aromatic oils. These oils include specific chemical compounds that can impart flavors of everything from grass to pineapples to sage. "So what?," you might ask. "Can't we just get a breakdown of which oils are found in which hop, and build our flavor profile from there?" No, theoretical discussion participant — I'm afraid we can't. See, it isn't just the presence or absence of the oils in question that determine the flavors available in the hop. It's their ratio of one to the other. It's how those low-level chemical interactions affect the flavor at the end of the process. And the bad news (was there

HOP COMBINATIONS

These are some combinations of hop varieties that have worked well for me over the years. This is by no means an exhaustive list, but it should provide some good starting points as you develop your own recipes and combinations!

THE EASY WAY OUT: PRE-BLENDS

These are the Cliffs Notes version of hop combinations, since they come pre-blended (think Falconers Flight®, Zythos, etc.)! As a general rule, you're usually safe combining hops from the same regional/national geographic areas, so while you may not be able to find an explicit "noble hop" blend, multiple varieties from German hop producers will likely make for decent hop combinations.

Glacier

EARTHY (BUT NOT DIRT-Y): FUGGLES AND GLACIER

Earthy can be a tough one because it can be mistaken for musty/dirty. Hops like Fuggles and Spalt have a great natural earthy flavor, and when you add in Glacier you double-down on it but also add a touch of melon that brightens the flavor enough to prevent someone from wondering whether you accidentally hit their glass with potting soil.

FLOWER POWER: HALLERTAU AND NORTHERN BREWER

If you're in the market for a great soft hop flavor or aroma, you can't really go wrong with Hallertau (almost any variety – I'm a Hersbrucker fan, myself) as a base. You'll get a pleasant base of floral/herbal notes. Layering Northern Brewer on top adds an aroma of dried bark and wildflowers that complements it perfectly – this hop combination drives my altbier.

Hallertau

Northern Brewer

PINEY: CHINOOK AND WAIMEA

This combination is so piney that it will make you think you walked into a house with a ton of fresh Balsam wreathes at the holidays. Pine is easy – but the New Zealand Waimea adds a softness and a scent of fresh pine resin that is just perfect. Chinook will also bring a lot of grapefruit to the table.

Chinook

Waimea

Czech Saaz

Tettnanger

HERBAL: SAAZ, STYRIAN GOLDINGS, AND TETTNANGER

You're tripling down on the "herbal" here, which is really in the service of a definite Saaz character. My first four attempts at Czech Pils failed because the Saaz (for whatever reason – water chemistry is my best guess) just didn't come through. As I started blending in other European hops with similar spicy flavors, it built up and rounded out the herbal/spicy notes to the point where only an idiot could miss it.

Citra®

Motueka

TROPICAL: CITRA® AND MOTUEKA

Citra® is a no-brainer here, but the Motueka is what ramps it up to "tropical mixed drink" status. Like a lot of "down under" hops (this one from New Zealand) it adds a bit of citrus, which in this case is a dose of lime that brightens up the sometimes-overly-sweet Citra® flavors.

SARSAPARILLA: AMARILLO®, LIBERTY, AND CRYSTAL

This was found by accident, and I can't even believe I'm writing this. This combination of hops went into my second beer, an American brown ale. Between the light chocolate notes in the beer and these hops, you end up with a flavor that is almost exactly the flavor of sarsaparilla: Floral, wintergreen, a touch of citrus, and (when paired with the malts) a light licorice/anise.

Amarillo®

Liberty

Crystal

GRASSY: MOSAIC® AND SORACHI ACE

While most will cheat and just dry hop to achieve a grassy flavor, there are hops that provide it. This combination comes from a friend who makes some incredible American pale ales that come across as refreshing as anything thanks to their grassy/lemony flavor, achieved with this combination in a 2:1 ratio (Mosaic® to Sorachi Ace). Keep in mind that Sorachi Ace will also provide some herbal/dill qualities, while Mosaic® has some tropical fruit and aromas.

Mosaic®

Images courtesy of YCH HOPS, www.ychhops.com

> Be creative: The pine and resin in Mt. Hood might be a good combination with the minty/woodsy flavor of Northern Brewer.

good news?) is that we brewers don't yet have a clear sense of the rules of hop oil interactions and their resulting flavors (although scientists are most definitely working on figuring it all out). The net result is that there's still quite a bit of trial and error involved in coming up with winning hop combinations, but with some luck I hope to get you moving in the right direction.

COMBINING HOPS

When coming up with a viable hop combination, first think of the flavors you want. Just because we can't provide a this-then-that combination guide doesn't mean that you shouldn't start with what these hops taste and smell like, so a good hop chart (like *Brew Your Own*'s at byo.com/resources/hops) is a great place to start. There are two general strategies here: Amplify or complement. In the "amplify" approach you're using hops with similar flavor profiles to create a more robust sense of that flavor, so if you're looking for big-time tropical fruit flavor you might pair El Dorado and Citra®. If you want herbal, you might pair Saaz and Perle. Doing this means that you're likely to improve your odds of getting a particular character in the finished beer, often along with some subtle secondary flavors that a single hop wouldn't impart. A single hop also might not come through for you, depending on the batch, and when a style requires a particular hop character it can be a good idea to hedge your bets. If you're thinking "complement," then you're looking for different flavors that pair well together. As you'll see in the combinations on the previous page, this can make for some strange bedfellows! But be creative: The pine and resin in Mt. Hood might be a good combination with the minty/woodsy flavor of Northern Brewer. The advantage here is that you can try to build flavors that you simply can't get out of a single hop.

When deciding on hops you should also consider the other flavors in the beer. If you're making a saison, you might think that you should be focusing on the herbal contributions of the hops — and you should. That doesn't mean that you can't add a bit of Cascade to help out in a beer that should also feature some orange notes, or Sorachi Ace for a touch of lemon. Use every ingredient in every way you can to get what you want — call it the "Law of Conservation of Ingredients." This can be done within the beer, but it can also be done in the context of food pairings: If you're making a beer to be served in a specific setting, you can try to build flavors that will pair well with other meal ingredients. For example, when my wife was making a cranberry beer to serve at Thanksgiving, she made sure to use a nice herbal set of hops, knowing that the cranberry and herbal flavors would be paired with turkey, and it rocked.

Finally, before you move on to my recommended pairings, a brief note on simplicity and parsimony in brewing: When in doubt, leave it out. Not forever, but at first. Single-hop beers give you the opportunity to see how a hop presents in a specific recipe on your equipment. Start with just one, and then in subsequent versions you can add in additional hops to see how the flavors change, but the only way to know for sure that you're getting the most out of your hops is to let your recipes evolve over time. Or you can ignore this advice and hope you get lucky, which worked out well for me as a relatively new brewer! There are lots of paths to the top of the mountain here.

TRY, THEN TRUST

There's an unavoidable level of trial and error in the process of finding the right hop combination: I regret that the knowledge base simply doesn't yet exist to be more definitive. That doesn't mean that you're flying completely blind, though. Try out my combinations. Build your own. Contact breweries that make the beers you like and ask them what they're using (imitation is the sincerest form of flattery, after all). But keep at it — the value of combining and pairing hops is every bit as great as pairing foods with beer, and other beer ingredients with each other. There's a whole world of flavors out there to play with, and it will likely be a very rare combination that makes a beer worse. Try out some combinations, take good sensory evaluation notes, and start finding your own blends! BYO

PRE-BOIL HOPPING

BY DAVE GREEN

Photos by Charles A. Parker/Images Plus

Breaking traditions has become a theme that both craft brewers and homebrewers alike strive for in their beers. One only needs to look at the US Brewers Association's definition of a craft brewer to see this: "The hallmark of craft beer and craft brewers is innovation. Craft brewers interpret historic styles with unique twists and develop new styles that have no precedent." I take that statement with a grain of salt since in my opinion many of these new and "innovative" techniques that brewers are using have roots in the past. Our forefathers had several millennia working on techniques and recipe development for the production of malted beverages. So to say something has no precedent, well I'll argue that more than likely, there is a precedent somewhere buried in the past.

During the dark ages of beer brewing post-World War II, when pale lagers came to dominate the global market, regional and sub-regional beer styles and generations of brewing knowledge were slowly and systematically snuffed out. Part of the renaissance of beer brewing over the past four decades has been in re-discovering these old practices. Germans, in particular, were relegated by law to brewing with a very limited range of ingredients to include in their beers. What evolved was a very technique-oriented brewing style where timing and ingenuity was required.

Two of those older techniques that fell by the wayside, first wort and mash hopping, have found new promise in modern brewing. First wort hopping is a hopping technique that was actually a very prominent form of hopping even one century ago in several brewing regions. Mash hopping is a less prominent technique that may have found a new place in the heart of our current brewing renaissance.

FIRST WORT HOPPING

As far as adjusting a brew day technique, it really doesn't get any easier than trying first wort hopping (FWH). While there is still some ambiguity that surrounds its overall affect on the finished beer, most brewers will either use it as a substitute for their bittering hop charge or their mid-boil hop charge. So why the ambiguity? Well it has been shown in tastings that first wort hopping can increase the perceived aroma of a beer when substituted for a traditional late hop addition to the kettle. Yet when a group of scientists tested the hop aroma components of FWH beers, they found that the aroma compounds were actually considerably lower in first wort hopped beers versus the same beer with that late hop addition. So let's delve into what first wort hopping is and indicate when you possibly should and should not use this technique.

First wort hopping if you are not familiar with it, is very simple. Add a portion or all of your late boil hop charge or bittering hops before the wort comes to a boil. It does not matter whether you are an all-grain or extract brewer. Generally as an all-grain brewer I do this about 3-5 minutes into the sparging process of the grain bed. When I'm using extracts, I generally wait until the wort has gotten up to about 180 °F (82 °C) before tossing the FWH into the kettle.

So what does FWH do for your beer? What repeated studies have shown from blind triangle taste tests is that it creates a softer, more rounded bitterness than adding your bittering hops to a rolling boil. There are two studies in particular that document this effect. The first is a fairly comprehensive study put out back in 1995 by a German group of researchers Preis, Nuremberg, Mitter & Steiner titled "The re-discovery of first wort hopping," published by Brauwelt International. The second study was performed by US homebrew guru Denny Conn, whose results roughly affirmed that of the German researchers and presented his findings at the 2008 AHA Conference.

The German researchers utilized two breweries to test first wort hopping versus a late hop addition. The taste tests from both breweries confirmed that there is a distinct difference between a beer with first wort hopped charge and bittering charge and beers brewed with a traditional bittering charge and late hop charge. Among those on the panel, 21 out of 23 tasters were able to recognize the taste discrepancy in a Pilsner. Of those 21

tasters who distinguished some difference between the two beers, 19 of them preferred the first wort hopped beer. That is enough to raise my eyebrows. Denny Conn's study, which was performed with two groups of BJCP judges and professional brewers, tested FWH beers versus a traditional bittering charge. What they found in a blind triangle test was that seven of the eighteen tasters were able to distinguish the first wort hopped beer; still significant but not quite as striking as the German study. The general consensus among those that could distinguish among the two beer types was that the first wort hopped beer offered a smoother bittering profile than the reference beer.

The other aspect that the two studies confirmed is that first wort hopping will increase your bittering units without increasing the perceived bitterness. The IBUs of a beer that has been first wort hopped achieve on average ~10% more hop utilization when analyzed against the same beer with a standard 60 minute hop addition. The Germans found in the first Pilsner with FWH 39.6 IBUs, compared to 37.9 IBUs for the reference beer. The second Pilsner was found to have 32.8 IBUs and the reference beer had 27.2 IBUs. Denny Conn's beers when analyzed had 24.8 IBUs for the FWH beer and 21.8 IBUs for the reference beer. The German study also showed that the iso-alpha acid concentration was quite a bit higher for the FWH beers. But again, taste tests revealed that the actual perception of the bitterness levels are slightly lower for the FWH beers. In other words, they had less bite.

So when is it advisable to utilize the FWH technique? Pretty much any beer you plan a bittering addition to mid-boil hop addition could be FWH'd. I do tend to use this technique when brewing beers that are more malt forward, or with well rounded styles such as continental lagers, roasted grain-focused beers, wheat beers and Scottish ales to name a few. Sometimes I will skip FWH and stick to a more traditional hopping schedule when I'm looking for more bite in the beer, such as with American IPAs, double IPAs, robust porters or imperial stouts. I've used FWH with all those styles as well with great results. I've also split my bittering hops so that half go in at first wort, and the second half go in with 60 minutes left in the boil. Another counter-indication for me is if I'm planning on boiling more than 75 minutes. I don't like to have my hops in contact with boiling wort for more than ~75 minutes for fear of polyphenols leaching into the wort from the hops. With that said, it has been reported that Pilsner-Urquell first wort hops their classic Pilsner and boils for 2 hours. Hard to argue with a classic like a Pilsner-Urquell.

So why does first wort hopping work? That is still not fully understood according to my research. All I can do is offer some theories as to why it provides a smoother bitterness. There are three primary alpha acids found in hops: humulone, cohumulone and adhumulone. Relatively, they are not that bitter, but when heated above about 175 °F (80 °C) they will isomerize (re-arrangement of the molecule) into iso-alpha form: iso-humulone, iso-cohumulone and iso-adhumulone respectively. At this point they are several times more bitter than their non-isomerized cousin. In the isomerization process each alpha acid is further divided into the cis and trans states. This is akin to left-handed vs. right-handed states; they are mirror images of each other, just flipped. Each of those forms acts slightly differently as well. Another factor that could play a key role here are hop glycosides which have been the focus of many discussions surrounding misunderstood components of hops. So why am I explaining all this? Well just to show that there is a lot going on in the bittering process. Add in beta acids plus oxidative reactions that are occurring on the various oil components and you can see that complex nature at a molecular level in your wort when hops are added.

The long and short of my hypothesis is that the isomerization reaction proceeds along slightly differently when hops are added off boil, 175–210 °F (80–99 °C). Maybe you get more cis-iso acids or vice versa. I don't have any empirical evidence for this theory, just anecdotal evidence when I've compared exclusively FWH beers to exclusively whirlpool hopped beers. We talk in similar terms when describing the bitterness of the beers hopped at off-boil temperatures, whether it is pre- or post-boil hopped. I have brewed both techniques on a cream ale, exclusively pre-boil FWH and exclusively post-boil whirlpool hopped beers and find the bittering qualities to match up fairly well. The whirlpool hopped beer had abundantly more hop nose and flavor, but the FWH beer had some hop aroma when compared to a standard American lager. My results are right in line with the German taste panel's findings, that FWH beers had slightly more hop aroma. The mystery deepens since this contradicts the German team's research when they performed gas chromatography on the resulting beers. What they found was that the FWH beers contained significantly less hop aroma compounds compared to the reference beers. The ultimate empirical answer to the mystery of why it works will have to await more scientific research. For now, I have to use my anecdotal evidence.

MASH HOPPING

Mash hopping is a much different beast than FWHing. First off, it is for partial mash and all-grain brewers only. Second, iso-alpha acid conversion does not take place at an appreciable level at mash temperatures, so alpha acids do not undergo the isomerization reaction. The oils that are extracted from the hops will most all be driven off during the boil, so why would anyone give mash hopping a second look? Well there may actually be a reason to take a look down this worm hole for a very specific purpose.

Mash hopping is simply adding a hop charge to the mash. I have always used whole leaf hops when mash hopping since it will aid in grain bed filtration in a manner somewhat akin to adding rice hulls. Mix the hops in at the beginning of the mash and do not change anything else about the mash.

So if the alpha acids are not going to convert and say 98% of them are

left in the mash tun and the oils will be driven off in the boil, why use it? Well what if you're planning on boiling the mash and what if the only time you're going to boil on that given brew day is during the mash? Two fairly well documented mashing techniques may come to mind; decoction and turbid mashing when answering the first question. The second question is found again by looking at what was done in the past.

Traditionally brewers have always boiled their wort after lautering for a minimum of 60 minutes. If Pilsner malt is used, that boil time is generally increased to at least 90 minutes to offset the increased levels of S-methyl methionine (SMM) (the dimethyl sulfide/DMS pre-cursor molecule) found in this lightly kilned base malt. But in this brewing renaissance everything can be questioned and the requirement of boiling is one of them. A scan through the history books found brewers in the past who have tried this no-boil technique.

So let me explain the no-boil technique, then I can get into why mash hopping is perfect for this technique. I first learned about no-boil beers from reading Michael Tonsmeire's brewing blog *The Mad Fermentationist*. In a post from 2008 he talks about reading Eric Warner's book titled *German Wheat Beer*. Warner explains that traditionally a Berliner weisse beer had the wort go directly from the lauter tun to the coolship, bypassing the kettle and boil process entirely. Tonsmeire took this concept and decided to apply it to his next Berliner weisse. There is one glaring problem with this, however: Berliner weisse uses a lot of Pilsner malt. Wouldn't DMS be a huge problem with the finished beer? Well what Mr. Tonsmeire and the ensuing wave of no-boil experimenters found was that DMS doesn't seem to be a major problem with these beers. Does the bacteria possibly mask the low levels of DMS that would be found in a no-boil beer or could the lack of a boil somehow prevents DMS or could it be that the DMS is oxidized by the acids produced by the bacteria or simply scrubbed out during the fermentation process? Once again, I could not find anything but anecdotal evidence that supports that no-boil beers will result in beers without the cooked cabbage like aromas that are associated with DMS. Needless to say, more intensive studies into this matter could result in some conclusive evidence as to why this may be the case by measuring DMS levels in the finished wort of a no-boil beer and the DMS levels post-fermentation.

Now to turn this back into mash hopping, what has evolved is a no-boil beer where a brewer can get their very small quantities of iso-alpha acids desired for a beer like a Berliner weisse from a mash that has been hopped, then isomerization occurs during the ensuing decoction process — depending on how much mash you are looking to pull for the decoction. So for argument's sake you have added hops in the entire mash and decide to pull half of the mash for decoction, then for calculation purposes simply consider that half of the hops are being boiled for the duration of the decoction boiling. Or you can save some money on hops by simply adding the hops directly to the pulled decoction. With a beer like a no-boil Berliner weisse whole leaf hops will now perform two functions, assist in grain bed filtration and provide the low levels of iso-alpha acids. Where else could you use this technique? Lambic-styled beers, Gose and other sour beers seem like a good fit for mash hopping if boiling is not truly required in sour beers. BYO

SAVE YOUR HOPS FOR POST-BOIL ADDITIONS

BY BRAD SMITH

In 30 years of homebrewing, I've seen a wide variety of "hop" trends and fads. Boil hops, flavor hops, aroma hops, whirlpool hops, dry hopping, fermentation hopping, continuous hopping, mash hopping, hop infusions, hop extracts, and of course the newest designer IPAs.

Some, like mash hopping, died quickly, but others like boil, flavor, and aroma hop additions have persisted. Today, I'm going to make the case that late hop additions, including "flavor" hop additions — generally boiled 30 minutes or less — are not needed, and in fact short boil additions in general are not an efficient use of hops. They don't deliver high utilization or much in the way of aroma oils. Whirlpool and dry hopping are more effective.

Before we can discuss the merits of various hop techniques, let's define a few terms used throughout this article:

Photo by Charles A. Parker/Images Plus

BOIL ADDITIONS – These are longer boil time additions made at the beginning of the boil, with the primary purpose being to provide bitterness and also the characteristic flavor of the hop to the finished beer.

FLAVOR ADDITIONS – A term that describes medium-length boil additions, generally added between 15 and 40 minutes before the end of the boil.

FINISHING ADDITIONS – A boil addition added within the last 10 minutes of the boil, with the primary purpose being to add aroma to the beer.

STEEPED OR WHIRLPOOL ADDITIONS – This refers to hops added at flameout, after the boil has ended, and then steeped or circulated in a whirlpool for a period of time at hot temperature before the wort is chilled.

DRY HOPPING – This refers to hops added either during fermentation or after fermentation is complete.

Using the terminology above, I intend to demonstrate that both flavor and finishing additions are probably not needed, and you can more efficiently use your hops in the boil, steep/whirlpool, or dry hop phases.

A BIT OF HOMEBREWING HOP HISTORY

When I started brewing at home in 1987, very little was known about hops, bitterness, hop aroma oils, or the best way to maximize hop flavor. We certainly knew about boil additions, late boil additions (called flavor additions) and dry hopping, but even estimating something as simple as the number of International Bitterness Units (IBUs) was not done at the homebrew level. Glenn Tinseth's equation, which is now commonly used to do this, would not be published and widely used for another eight years!

Looking through my 1984 copy of *The Complete Joy of Home Brewing* by homebrewing legend Charlie Papazian, most of the recipes list the hops simply as "boiling" or "finishing" with no boil times. Boil hops were usually added for the full boil, while finishing hops were added the last 10 minutes of the boil. Also it is interesting to note that there is no distinction in the recipes between "finishing" hops added at the end of the boil and dry hops. "Finishing" hops could potentially be used in the boil or added in the fermenter.

The significantly revised *New Complete Joy of Home Brewing* published in 1991 adds the concept of home bitter-

ness units (HBU), which was simply the ounces of hops multiplied by the hop's alpha acid percentage. It was still quite inaccurate as we had no idea of the boil time, but it was a step forward. All hop additions were still simply "boil" or "finishing."

Not until the early '90s do we see boil times more widely listed as well as attempts at the homebrew level to estimate the bitterness level of hop additions in IBUs. We also see a distinct breakout of bittering additions (45–90 minutes), flavoring additions (20–40 minutes) and finishing hop additions (15 minutes or less), as well as dry hopping listed in early editions of John Palmer's classic *How to Brew*.

What is particularly interesting to me is his description of flavoring additions, made midway through the boil as "a compromise between isomerization of the alpha acids and evaporation of the aromatics is achieved to yield moderate bitterness and characteristic flavors." So mid-boil flavor hops are intended to retain some aromatics while still providing bitterness.

Further, Palmer states regarding finishing hops that "fewer of the aromatic oils are lost to evaporation and more hop aroma is retained." Finishing hops in the last 10 minutes are primarily done to preserve aromatics, and not to provide much bitterness.

As I'll demonstrate shortly, flavoring and finishing hops actually don't preserve aromatic hop oils very well and boiling your hops, even for a short time, will boil off a large portion of your aromatic hop oils.

HOP FLAVOR AND BITTERNESS FROM BOILING

Hops contain well over 500 flavor compounds, and many of those compounds transform during the brewing, fermentation, and aging process in interesting ways. Relatively few of these compounds make major flavor contributions to the finished beer, though hops also act as a preservative, contribute to head retention, and perform other roles important to beer stability.

To some degree, we are only just starting to understand many of these compounds and how they transform and evolve in beer. However, a better understanding of bittering agents as well as aromatic hop oils has been a major driver in the recent rise of India pale ales with their hop-forward finish.

The best understood compounds in hops are arguably alpha acids, which have been studied for many decades. Alpha acids are a class of compounds found in the resin glands of the flower of a hop cone and provide the primary source of bitterness in hops and finished beer. These compounds include humulone, adhumulone, cohumulone, posthumulone, and prehumulone.

When alpha acids are heated in a solution they go through a process called isomerization. Isomerized alpha acids are bitter to taste, and provide the characteristic hop bitterness in beer. Boiling hops for a longer period of time leads to more isomerization, and more bittering compounds in the finished beer.

It is important to note that isomerization continues to occur at temperatures below boiling, though the rate drops quickly with temperature. At 194 °F (90 °C) you get approximately half the isomerization you would get from an equivalent boil. At 158 °F (70 °C) you will only get about 10% the utilization you get from boiling. So whirlpool hops do add some bitterness to the finished beer.

Obviously boiling hops also preserves a large number of flavor compounds characteristic to a single hop variety. For example, I'm quite sensitive to the flavor profile of Northern Brewer hops and can pretty easily identify it in a finished beer. Others may find Mosaic®, Simcoe®, and other hops easy to identify in a finished IPA. Each hop has its own boil flavor profile that you can detect even in a beer where only boil additions are made.

AROMATIC HOP OILS

Most of the recent work in hops has been centered upon understanding and exploiting aromatic hop oils. Improved knowledge of these volatile but aromatic oils has been key to the recent India pale ale revolution. There are several dozen aromatic compounds that have been isolated in hops. The critical ones are called aromatic oils or essential oils and these are found in the lupulin glands on the stem of the hop cone. Aromatic oils in total only constitute 0.5% to 3% of the whole hop cone by weight.

By their nature, all of the major aromatic oils have low boiling points, which makes them volatile in air. This means they tend to disperse rapidly when exposed to air, and also are not terribly soluble in solution. The aroma you smell is in fact the volatile compounds coming out of solution, dispersing, and breaking down in the air. If these essential oils were not volatile, they would not provide much aroma. However, their volatility means that they don't survive boiling well and many also break down when exposed to oxygen in air.

Here are the "big four" aromatic hop oils:

• **Myrcene**: Myrcene is the dominant aromatic hop oil in most hop varieties. It has a distinctive "green hop aroma" described as green, fresh hops, balsamic, resinous, or piney. Other spices that contain myrcene include thyme and lemon grass. It has a large presence in many American Pacific Northwest hop varieties and is widely used in American pale ales, IPAs, and other American ales. In Cascade, a defining member of the US hop family, myrcene makes up 50–60% of the total hop oil content. Other US hops are similar: Amarillo® (70%), Citra® (65%), Crystal (40–60%), and Simcoe® (60–65%).

Myrcene is quite volatile and has low solubility, which means that it will boil off quickly, losing about $^{2}/_{3}$ of its oil content in 10 minutes of boiling. It boils at around 160 °F (71 °C). Its low boiling point and fact that it is prone to oxidation means that myrcene is best preserved in a dry hop addition and not as a boil or whirlpool addition where high temperatures and oxygen added for fermentation will degrade its profile.

• **Humulene**: Humulene is the oil that

the scientific name *Humulus Lupulus* for hops is derived from. Humulene provides earthy, spicy, and sometimes woody or herbal flavors that are familiar to many brewers from noble hop varieties. It has a strong herbal component and is used widely in the perfume industry. In some noble varieties it can reach concentrations as high as 40% of the essential hop oils.

While humulene has a higher boiling point, just below that of water, it is still quite volatile. As much as half of the humulene oil will be boiled away within 15 minutes. Because of the higher boiling point it will perform well as a whirlpool hop addition, where it benefits from the higher solubility at elevated temperatures, though it can also be used effectively during dry hopping.

• **Caryophellene**: Caryophellene is an important essential oil in English hops, though it usually makes up only a fraction of the content of myrcene and less than 20% of total oils. Caryophellene provides dry earthy, woody, and sometimes spicy overtones that are characteristic of many English varieties like East Kent Golding and Northdown. While it can make up as much as 20% of the hop oil content in hops like UK Golding, Apollo, or Bramling Cross, it may be only 11–14% of the oils in other English hops like Fuggle or Whitbread. Many noble and Pacific Northwest hops have very low caryophellene content in the 0–3% range. It is chemically linked to the clove plant, and also a major spicy flavor component in black pepper.

Caryophellene has low solubility and like humulene you can expect that over half of the oil content will evaporate within 17 minutes of boiling. You can get higher solubility in a hot whirlpool addition or by exposing it longer when dry hopping.

• **Farnesene**: Rounding out the top four major hop oils is farnesene, which typically makes up 1% or less of total hop oils, though it can run as high as 10–20% of total oils in select noble hop varieties. It has a woody, herbal, citrus aroma that is floral in character. Farnesene is most closely associated with noble varieties, though it is not present in most German varieties such as Hallertauer Mittelfrüh. It can be found in German Tettnanger, Czech Saaz, Sterling, and Styrian Goldings.

Because farnesene is both highly volatile and hydrophobic it will not be found in a finished beer unless the beer has been dry hopped. It simply will not survive boiling or even a whirlpool addition. It is also highly prone to oxidation, which means aeration before fermentation will ruin its flavor profile. When dry hopped it will provide a lovely floral aroma with hints of lavender that often is a welcome complement to noble hop varieties.

The astute reader may notice at this point that the "big four" hop oils are all volatile and not particularly soluble in beer, which means they won't do well as a "flavor" or even "finishing" boil hop addition. Farnesene is so fragile it can really only be preserved in dry hopping. Myrcene is also a better dry hop candidate due to its low boiling point and oxidation that could occur during aeration and early fermentation. Even humulene and caryophellene, which have higher boiling points, will evaporate roughly half of their oil content away in a 10–15 minute boil.

OTHER HOP OILS

While the four "major" hop oils detailed earlier make up the majority of hop oil content for most varieties, a quick look at other aromatic hop oils will show that they don't fare any better in the boil. This is due to the nature of aromatics. To generate aroma, a compound needs to be both volatile and have low solubility so you can smell it as it disperses out of solution and into air. If it was highly soluble and non-volatile it would stay in solution and have little to no aroma. For example, another hop oil is linalool, which is technically a tertiary alcohol of myrcene. It has a pleasant sweet, floral, lavender, orange aroma, which is why it is widely used in perfumes. Linalool is present in many Pacific Northwest varieties including Cascade, Centennial, Citra®, Amarillo®, Mt Hood, Nugget, and Willamette and can be quite pleasant in a finished beer.

Like myrcene, linalool has a low boiling point and as an alcohol is subject to distillation when boiling. Because of this it has a boil-off profile similar to myrcene, with over half of the oils lost in the first 10 minutes of the boil. Also like myrcene, linalool can be more effectively preserved by dry hopping than it in a whirlpool addition since whirlpool temperatures are often above its boiling point.

A final hop oil I'll cover is geraniol, which provides a floral, rose-like aro-

ma characteristic of geraniums. Geraniol, like linalool, is technically an alcohol and is a primary component in rose oil as well as citronella oil and is an effective mosquito repellent! Geraniol is present in many hop varieties including Aurora, Cascade, Citra®, Mosaic®, Centennial, Motueka, and Styrian Goldings. Geraniol is somewhat less volatile than linalool and takes about 20–25 minutes of boiling to reach half of its starting content.

If we explore additional aromatic hop oils like cis-rose oxide, citronellol, limonene, nerol, pinene, and others we will see a similar pattern. Aromatic hop oils, by their very nature, are both volatile and not very soluble, meaning they will boil off rapidly and are better used either in a whirlpool or dry hop addition depending on their boiling point, oxidation concerns, and their ability to survive active fermentation. The CO_2 produced during active fermentation does tend to take some aromatics with it.

TOWARD AN EFFICIENT USE OF HOPS

I started the article with a historic discussion of how homebrewers evolved from a simple system of boil and finishing hop additions into a more complex system of mash, boil, flavor, and finishing hops followed by whirlpool and dry hop additions in a quest to drive more hop flavor into our beer. Some even go so far as to advocate "continuous" hopping where hops are added every minute or so during the boil.

Along the way we've made great progress in estimating the bittering compounds that a given hop addition contributes to beer, though we now understand that the bulk of this comes from alpha acids that are isomerized either during the boil or in the hot phase of the whirlpool.

As I covered in the sections on major hop oils, in the last few years we've really started to understand the critical role that aromatic oils play in beer, particularly in hop-forward beers like an IPA. Aromatic hop oils, by their very nature, are volatile and have low solubility so if you want to efficiently preserve the hop oils you can't boil them. They are best used either in the whirlpool or in dry hopping.

Armed with this knowledge, if we examine a traditional "flavor" addition, which Palmer defined as 20–40 minutes of boil time, we can see that the flavor addition will boil off anywhere from 50%–95% of the major aromatic hop oils depending on the oil. For a volatile hop oil like myrcene, I estimate less than 4% of the starting myrcene level will remain after a 40-minute boil. In essence, it is little different than a boil addition.

Finishing hops, defined as those added the last 10 minutes of the boil, do fare somewhat better. A volatile oil like myrcene will see about $^2/_3$ of its oil boil away in 10 minutes. Something more robust like geraniol may only lose about $^1/_3$ of the oil in 10 minutes boiling.

While flavor and finishing hops do provide bitterness and preserve some aroma, they are not an effective way to do either. Whether we lose $^1/_3$ of the geraniol or $^2/_3$ of the myrcene in 10 minutes, late boil hop additions are not an efficient way to preserve aromatic hop oils. Whirlpool and dry hopping are far more efficient ways to preserve these volatile hop oils in your finished beer.

GETTING THE MOST FROM YOUR HOPS

Flavor and finishing hop additions are both a compromise. They don't make the most efficient use of isomerization to produce bitterness we can get from a full boil hop addition, and they also do a pretty poor job of preserving volatile hop oils. So why not eliminate them?

Well that's exactly what I, along with many brewers, have done the last few years. We don't use any flavor or finishing hops and instead focus our precious hops into a single boil addition followed by a whirlpool and dry hop addition where appropriate. A long boil addition provides the bitterness in a very efficient way, leaving more hops to potentially be used in the whirlpool or dry hopping where we can maximize and preserve the delicate aromatic hop oils so treasured in styles like IPA.

As a side note, some recent research published by the American Society of Brewing Chemists (ASBCJ-2014-0116-01, Kiyoshi, Okatohme, et al.) has explored the effects of hop oil additions made during active fermentation. Particular oils that are alcohols like linalool and geraniol go through biotransformations during active fermentation (post-growth phase) that can enhance the geraniol content and aroma in the finished beer, often giving interesting fruity, flowery, pleasant aromas. Since many US hops are high in geraniol and linalool content, some craft breweries have been exploring dry hopping during active fermentation with good results. This is another thing to try along with whirlpool and dry hopping to add some great hop aroma to your next IPA.

In conclusion, my best advice is to drop the flavor and finishing hops. Go with a single bittering addition to reach your target IBU level, and then appropriate use of hops in the whirlpool or through dry hopping, depending on which hop oils you are trying to highlight. Also, you might want to consider dry hopping during active fermentation for a unique aromatic note in your next IPA. BYO

HOP STANDS

BY DAVE GREEN

While the buzz around hop stands mainly revolves around highly hopped beers, there is a lot more to this technique than just trying to crank your DIPA up to an 11. (I will be calling this technique whirlpool hopping, but keep in mind that homebrewers don't need to keep their wort constantly swirling in the kettle for this technique to work.)

Photos by Charles A. Parker/Images Plus

THE WHAT AND WHY

A hop stand is simply allowing the boiled wort an extended contact period with the flameout hops prior to chilling the wort. Pro brewers typically create a whirlpool either in their kettle or in a separate whirlpool vessel with the hot wort and the ensuing vortex creates a cone shaped pile in the center of the vessel made up of the unwanted trub and left over hop material. Whether on purpose or inadvertently, pro brewers were giving their flameout hops extended contact time with the wort. This allows the hops added at flameout a period to release their essential oils into the wort, while minimizing the vaporization of these essential oils. In essence, adding a kick of hop flavor and aroma while also adding what can best be described as a smooth bitterness. In short, whirlpool hopping can add significantly to the hop flavor and aroma of beer.

ESSENTIAL OILS

The essential oils found in hops are volatile and provide beer with the hop flavor and aroma hop aficionados enjoy. While there are hundreds of essential oil components, for practical purposes brewers tend to focus on 4-8 main essential oils that play vital roles in providing hop varietal characteristics. One important characteristic is the essential oil's flashpoint, or the temperature at which the essential oil is actively vaporizing to the point where it could ignite if sufficient vapors were present. At wort boiling temperatures, all hop essential oils have surpassed their flashpoints, so a vigorous boil will drive them off fairly quickly. The best way to think about the driving off process is in terms of half lives. The lower the flashpoint, the faster the oil vaporizes and the faster the half life. The longer the hops are boiled and the lower the flashpoint, the less the essential oil will impact the beer. In effect, whirlpool hopping removes the rolling boil (for the whirlpool hops), lowering the temperature of the wort and therefore reducing the vaporization rate of the essential oils, allowing the essential oils to really "soak in" to the wort. The specifics of the "soak in" process is still very much a gray area but the general idea is that essential oils will be retained in the beer longer and enhance the hop flavor and aroma of the finished beer.

ALPHA ACID ISOMERIZATION

Alpha acids will continue to isomerize after flameout until the temperature of the wort reaches about 175 °F (79 °C). Homebrewers trying to calculate a beer's IBUs will need to guesstimate how much isomerization is occurring. The closer the wort is to 212 °F (100 °C) the higher the alpha acid isomerization rate. To do this, we can look to professional brewers for some guidelines. Ultimately, however, the thermal capacity of a professional 60-bbl whirlpool vessel is quite different than 5 gallons (19 L) of homebrew, so the comparisons can only be rough guidelines at best.

Matt Brynildson of Firestone Walker Brewing Company says, "The fact that there is some isomerization (about 15% in whirlpool versus 35% in

the kettle) of alpha acid means that not only hop aroma and hop flavor can be achieved, but also some bittering." For Pelican Pub & Brewery's Kiwanda Cream Ale, brewmaster Darron Welch adds the beer's only hop addition at flameout. Welch gets about 25 IBUs from adding roughly 0.75 lbs./bbl (0.34 kg/bbl) of Mt. Hood hops at flameout then allowing a 30 minute whirlpool stage. This means that Darron is getting roughly 16% utilization on his 15 bbl system for a 1.049 specific gravity wort. As mentioned, in a homebrewers hop stand, the 5-gallon (19-L) kettle is going to cool much faster and therefore create lower utilization rates. Brad Smith, creator of the BeerSmith brewing calculator, gives this advice to homebrewers, "Something in the 10% range is not a bad estimate if hops are added near boiling and left in during the cool-down period." From my own experience with extended hop stands in 11-gallon (42-L) batches, a 10% utilization rate for whirlpool hops seems reasonable.

THE WHEN AND HOW

While hop forward beers can benefit from this technique, any beer where some hop nose is desired is also a good candidate. For low IBU beers, you can add no-boil hops or you can add a tiny bittering charge of hops to help break surface tension of the beer and then add all or the majority of the IBU contribution at knockout, with the 10–15% utilization in mind.

If your brewing system has a pump, you may opt to setup a tangential inlet for your kettle to allow the pump to perform the whirlpool for you. Keep in mind that you do not need a vigorous whirlpool; just a simple spinning of the wort. If you do not have a pump, a simple spoon or paddle will work to achieve the same results.

The second factor to consider is the length of your hop stand. There are no right or wrong answers, but anywhere from 10 minutes to 90 minutes — or even an overnight stand — can be employed. For most super-charged, hop-forward beers, my hop stands will run 45 to 60 minutes. For a mid-range hop profile like an American pale ale or a beer I am looking to get a significant IBU contribution from, I will usually shorten that stand to 30 minutes. If the beer is not to be hop forward nor do I need significant IBU from the hop stand, then 10–15 minute hop stand usually will suffices.

Three temperature profiles that seem to be popular among homebrewers are just off boil range 190–212 °F (88–100 °C), the sub-isomerization range 160–170 °F (71–77 °C), and a tepid hop stand range 140–150 °F (60–66 °C). The 190–212 °F (88–100 °C) range will allow essential oils with higher flashpoints an easier time to solubulize into the wort and also will allow some alpha acid isomerization to occur with the best estimates of between 5–15% utilization. Some homebrewers will keep their kettle burner on low to keep the temperature of the wort elevated above 200 °F (93 °C) during their extended hop stands which would better emulate the conditions in commercial whirlpools. A hop stand in the 160–170 °F (71–77 °C) range will basically shut down the alpha acid isomerization reaction and the lower temperatures will reduce the vaporization of the essential oils. Homebrewers can use their wort chillers to bring the wort down to this range before adding the knockout hops or they can add a second dose of knockout hops. The 140–150 °F (60–66 °C) range will once again reduce vaporization of the low flashpoint oils, but may take longer to get the same amount of essential oils extracted.

I have never had dimethyl sulfide (DMS) issues with any of the beers I have performed a hop stand on and have always left the lid on. If using a Pilsner malt or other DMS-prone, lightly-kilned base malt, you may want to increase your boil time to 90 minutes.

DRY HOP CONSIDERATIONS

Another factor to consider is how to handle dry hopping your hop-forward beers if you employ an extended hop stand. Rock Bottom Restaurant & Brewery performed an extensive study on hop stands and dry hopping under the guidance of the Portland, Oregon brewmaster at the time Van Havig, (now of Gigantic Brewing Co., Portland, Oregon). The study was published by the Master Brewers Association of the Americas Technical Quarterly and considered beers that were hopped in four different ways, short hop stand (50 minutes) and no dry hops, long hop stand (80 minutes) and no dry hops, no hop stand and just dry hops and finally half the hops in hop stand (80 minutes) and half the hops for dry hopping. Beers produced using exclusively hop stands and the beers produced using exclusively dry hops will both result in well-developed hop characteristics, but there were some nuances. The long hop stand developed more hop flavor and aroma than the short hop stand indicating that essential oils were still soaking into the wort after 50 minutes. The exclusively dry hopped beer received its best marks in the aroma department, higher than the hop stand beers, but scored lower for its hop flavor. The beers where only half of the hops were added for the hop stand and half were added for aroma ended up scoring high in both departments. Havig's study also showed that adding 1 lb./bbl (0.45 kg/bbl) Amarillo® dry hops produced the same amount of hop aroma as ½ lb./bbl (0.23 kg/bbl), indicating diminishing returns at higher dry hop rates.

So if you are just giving this technique a try, here is what I would suggest based on the study's findings. Take all the hops you plan to add for late addition hops and dry hops and cut them in half. Add half at knockout and the second half as a dry hop addition. Again, don't feel the need to go overboard with these additions.

If you are interested in using this technique in your brewhouse, I have included three recipes I have used with great success to craft some of the best beers that have graced my kegerator. I assumed 10% hop utilization rates for the hops added for the hop stand. My next test will be of an extended spice stand . . . if it works for hops, why not my next winter warmer? Happy Brewing! BYO

ADVANCED DRY HOPPING

BY DAVE GREEN

My most memorable beer I've ever brewed was my first attempt at a Pliny the Elder clone. I used the recipe from the September 2004 issue of Brew Your Own. I remember thinking the author must have made a mistake in the recipe; it called for a whopping 6.75 oz. (191 g) of dry hops. Before that beer, I had never added more than 1.5 oz. (43 g) of dry hops. But against my wallet's better judgment, I brewed the recipe as it stood. The resulting beer was true hop heaven.

So what is it about that beer that is so striking? To anyone that has tasted or brewed a beer like Pliny the Elder, it's the hop oils that knock your olfactory senses sideways. Nowadays I constantly strive to make my hop-forward beers better, more interesting, more complex. Thanks in a large part to groundbreaking work by Thomas Shellhammer, Nor'Wester Endowed Professor of Fermentation Science at Oregon State University and his former student Peter Wolfe, who now resides as brewing scientist at Anheuser-Busch InBev, our understanding of the extraction process has advanced that much more. Using some advanced dry hopping techniques, we can use this science at home to achieve hop bliss. But first, let's go over essential oils and other hop components that can affect your beer.

Photo courtesty of pFriem Family Brewers

Hop cannons shoot the pellets into the fermenter via CO_2.

IDENTIFYING THE PLAYERS

Extracting hop oils and other aroma components from hop cones is the driving force behind dry hopping beers. The exact number of different hop oils found in the lupulin glands of hops has been found to be nearly 500 unique forms. Those hundreds of hop oils can be split into three major classification groups: Hydrocarbons, oxygenated hydrocarbons and sulfur containing compounds. The hydrocarbon group makes up well over half of the hop oils by weight in a hop cone, and most hop-heads might know them as terpenes. Hop oils like myrecene, pinene, and humulene are just three examples of terpenes (hydrocarbons) that many folks versed in this subject would recognize. But don't let names fool you. For example, humulene has been shown to come in 17 distinguishable forms in a hop cone, each slightly different than the other (welcome to the wonderful world of organic chemistry).

Oxygenated hydrocarbons include the terpenoids. Terpenes and terpenoids have a very similar skeleton structure, but the terpenoids will include an oxygen group. Esters and alcohol groups fall into this category with familiar hop oils like linalool, geraniol and citronellol. This group will come into play later when discussing glycosides, so pay mind to this group. Finally there are the sulfur compounds such as thiols like 4mmP, a polarizing compound some beer drinkers liken to cat pee while others perceive as tropical fruit aromas. Many recent studies have shown that sulfur compounds may play a bigger role in the hop characteristics than thought previously, given the very low sensory threshold of many of these compounds. Even though they make up less than 1% of the hops oils, the ultimate weight they carry into the beer may be rather hefty.

Just outside of the hop oil world, but very relevant to this discussion, you'll find the glycosides. Glycosides are in fact a combination of a terpenoid (see earlier) with a sugar molecule (glucose). Peter Wolfe took the time to slowly explain how glycosides can play a prominent role in the aroma of beer. Glycosides are tied together with a "relatively" unstable bond (an ester

bond) between the glucose group and the terpenoid. In beer, this ester bond can hydrolyze (break apart) and release the terpenoid and the glucose to the solution. So if you can hydrolyze the glycoside, you increase the terpenoids in solution.

I emphasized the word relatively in quotes in the last paragraph for a reason: To highlight the term. This bond break won't happen by itself; it needs a push. That can happen via two pathways. The first is a spontaneous reaction based on the pH of the solution. The lower the pH, the faster the spontaneous hydrolysis reaction can occur. This is convenient since beer pH is much lower than wort pH and this spontaneous reaction won't occur until pH is down near 4.4. The pH of beer is generally 4–4.2. The lower the pH, the faster this hydrolysis reaction occurs. The second pathway has been shown to occur thanks to yeast.

Hydrocarbons are generally the most volatile of the hop oils while their oxygenated cousins are less so. Glycosides are not volatile at all. Many brewers will look to the hop oil's flash point to gauge the volatility of the hop oil. The higher the flash point, generally the less volatile the hop oil. Hop oils can generally be diminished in your beer by three means. First is heat; the volatile oils can be vaporized more easily the warmer the solution. This most often occurs while the wort is still boiling or just after boil. Second is by scrubbing and most often occurs in the fermenter. Most brewers refer to the scrubbing process either when volatile oils are pushed out of the fermenter with any CO_2 escape or when oils stick to yeast membrane and are effectively dragged out of solution as the yeast flocculate (settle). Finally, hop oils can degrade by age or by oxygen. This occurs most often in the racking or bottling process and subsequent aging of the beer.

Now to put these concepts into play. To help with the details I interviewed seven brewers: Vinnie Cilurzo, Owner/Brewmaster at Russian River Brewing Co. in Santa Rosa, California; Matt Brynildson, Brewmaster at Firestone Walker Brewing Co. in Paso Robles, California; Jamil Zainasheff, Owner/Brewer at Heretic Brewing Co. in Fairfield, California: Ashton Lewis, Master Brewer at Springfield Brewing Co. in Springfield, Missouri; Josh Pfriem, Owner/Brewmaster at Pfriem Family Brewers in Hood River, Oregon; John Kimmich, Owner/Head Brewer at The Alchemist in Waterbury, Vermont; and Jack Hendler, Co-Owner/Head Brewer at Jack's Abby Brewing in Framingham, Massachusetts.

KNOW THINE ENEMY —O_2

Every brewer and scientist I talked to had the same piece of advice to homebrewers: Focus on minimizing oxygen uptake post-fermentation. So let's talk about this one first since it is the first variable every brewer should worry about. John Kimmich has focused a lot of time and energy towards making sure that the dissolved oxygen (DO) of his beers is minimized. While it may not be the only reason his beer Heady Topper is currently ranked the #1 beer in the world by users on BeerAdvocate.com, it certainly helps. He recounted a story when a quality assurance person from his canning company came to test his beers one day. The tester needed to run back to his car since he thought his dissolved oxygen (DO) meter was broken. He had measured 1 part per billion (ppb) DO in The Alchemist's brite tank (a vessel that is somewhat akin to a homebrewer's bottling bucket). He had never seen numbers that low. While John's process may seem like a bit of sorcery, one thing that I do know is that John is adamantly opposed to filtering his beers. The yeast left in solution can act as a buffer against any oxygen uptake. This is one reason you may not want to filter your beers when brewing a hop-forward beer.

So how and when is oxygen going to be introduced into your beer after fermentation finishes? There are two principle ways so long as you are using proper brewing equipment and not aging for long periods of time. The first potential culprit for O_2 ingression is from racking. To help you solve the racking dilemma, homebrewers have four options: A bronze, silver, gold, and platinum option. The bronze option is for homebrewers who don't have CO_2 on hand. Rack as gently as possible and if possible, rack before the yeast has finished primary fermentation. This will allow a new blanket of CO_2 to develop after racking. The silver option is for brewers with access to CO_2 who can purge their receiving vessel with a shot of CO_2. One physical trait of CO_2 to keep is mind is that it is slightly heavier than air (N_2 and O_2) so it will settle on the bottom and help create a blanket as long as there isn't too much agitation. So you may not need to purge all oxygen, just enough to create a healthy blanket. Ashton Lewis isn't as convinced, saying that, "Small differences in temperature create convective currents that mix gases. It may be true that there may be a greater concentration of carbon dioxide at the bottom of the vessel, but there is still more than enough oxygen in most cases of simple blanketing to oxidize beer." So finally we get to the gold and platinum options, which keeps the system closed and basically impossible for oxygen to get introduced to the beer (see the sidebar at the very end of this article for details on closed system racking).

The second potential culprit is from any post-fermentation additions such as dry hops or coffee or cocoa nibs or anything else that brewers may add to their beer. Pro brewers have created some highly inventive devices to deliver their dry hops to their fermenters in an oxygen free system. You may have heard of a hop cannon or Sierra Nevada's hop torpedo, which are two such devices. Hop cannons will shoot the pellets into the fermenter via CO_2 (see photo at the top of this article). The hop torpedo is an inline recirculation system that passes the finished beer through the dry hops before returning the beer back to the fermenter. Peter Wolfe and Thomas Shellhammer both agreed that these devices were overkill on the homebrew scale. Homebrewers can get away with eliminating most oxygen from the dry hop process for less. Thomas Shellhammer's advice,

especially with whole cone hops is, ". . .to ensure the hops are free of residual oxygen before adding to the beer. Do this by vacuum packing them first; better yet, vacuum pack then gas flush them with nitrogen or carbon dioxide. Another approach is to submerge the hops in cold sterile water, then transfer the whole lot to the beer." Ashton Lewis adds that working with de-aerated water is a huge benefit if you can get it. Boiling the water will help de-aerate but won't remove all residual O_2. Peter Wolfe's suggested approach is slightly different. "I like to rack my beer onto the dry hops when there are still a few gravity points left to go until terminal gravity is reached," he said. The active yeast will help absorb some of the oxygen uptake that has occurred during transfer. And finally for those homebrewers who try to emulate the recirculation methods utilized by pro-brewers, Vinnie Cilurzo adds that you have to make sure you are not introducing any oxygen into the system. If you can have your beer read 1 ppb DO after racking and adding dry hops, you've mastered this enemy.

Photo courtesty of AB-InBev

Thomas Shellhammer and Peter Wolfe (pictured here) are credited with a lot of groundbreaking work to further our understanding of the dry hopping extraction process.

CHOOSING YOUR WEAPONS

The age old discussion is, "Which is better for dry hopping in your hop-forward beers, pellets or whole hops?" No matter which you choose, the most important aspect is that you are choosing aromatic hops that are pleasing to your olfactory senses. To put it simply, "The hops need to smell awesome in order to make awesome beer," says Matt Brynildson. Vinnie Cilurzo's advice is to, "Watch out for hops that have onion/garlic character. You will never be able to get rid of this from the hop." Some brewers prefer whole hops and some prefer pellets.

That said, tests run by Peter Wolfe and Thomas Shellhammer point to pellets holding a slight edge over the unprocessed form. What they found is that pellets actually contain less essential oils than whole cone hops most likely due to the pelletizing process. But oils from pellets are more easily extracted into beer during dry hopping leading to slightly more aroma than whole cone hops. Also the oils in pellets were extracted faster than whole cones. Pellets have better storage life and are easy to work with for dry hopping since they submerse themselves, break apart, and fall to the bottom so you can easily rack your beer off of them. A downside can be that some pellet producers have been known to expose the hops to high temperatures during the pelletizing process, destroying the hop's precious oils. Most pelletizers for the craft beer world have learned of this potential pitfall and have made adjustments to the process in order to keep pelletizing temperatures as low as possible.

If you are going to be using whole cone hops, you need to deal with two potential factors that could hurt the beer. First is to make sure that if O_2 is found in the cones, that you flush them with CO_2, nitrogen (N_2), or sterile water before adding the beer (see Thomas Shellhammer's earlier advice). Racking the beer on top of the flushed hops is then the preferred method once you have them flushed. The second factor is that whole cones float and you need a way to submerse them without adding oxygen. A sanitized bag that is weighted down with sanitized stainless washers or marbles can be used to make sure that the hops remain submerged. Whole cone hops could also be added before primary fermentation is finished and then gently pushed down with a sanitized paddle to completely submerse them.

Despite what research shows, it is all about what works best for your system. Some homebrewers prefer to work with whole hops while others prefer to work with pellets. Both can produce award-winning beers.

TIMING IS EVERYTHING

For a few years I have always tried to eliminate as much yeast as possible from suspension before adding my dry hops. That concept was introduced to me from a sound bite given by Vinnie Cilurzo. The reason was simple as stated earlier in this article: Yeast can strip hop oils from solution. So I would either rack my beer to secondary before adding dry hops or added dry hops only after adding a fining agent like Polyclar or Biofine. I have always been happy with the results, but when I started polling homebrewers a little while ago, there

was a lot of attention paid to adding dry hops while yeast was still active. The term biotransformation of hop oils kept coming up.

In my discussions with pro brewers, two of the seven brewers add their dry hops while yeast was still active. On the one side of the coin, Josh Pfriem states that, ". . .the constant nucleation from fermentation scrubs away some of the hop aromas that you are trying to achieve." Matt Brynildson, on the other hand, adds his hops during fermentation, and the hardware garnered for his hop-forward beers should make any brewer re-think their approach. Matt has three reasons for his method: "This is to take advantage of the active yeast for (1) dissolved oxygen protection (2) natural mixing which we believe helps in better extraction of wanted oils and (3) biotransformation of hop oil compounds." But he also warns of the potential pitfall of adding dry hops to an active fermentation. "The dreaded 'beer volcano' can happen easily resulting in beer loss . . ."

So what are biotransformations anyway? Once again I turned to Peter Wolfe to help dissect this term. He explained that when we talk about biotransformations on hop compounds we are talking about oil components that yeast have modified. An important aspect is that we are talking mainly about terpenoids and glycosides. Terpenes are rarely affected by biotransformations. Biotransformations of hop compounds in beer can occur in two forms. The first is fairly straightforward when one compound is transformed into another. An example of this would be the transformation of geraniol to ß-citronellol. The second biotransformation is the hydrolysis of the glycosides which was introduced earlier. Certain yeast strains have shown the ability to transform non-aromatic glycosides into aromatic terpenoids. Shellhammer and Wolfe found that certain aromatic terpenoids increased their concentration over time in the presence of yeast. This may be just one reason many people find bottle conditioned or unfiltered beer to be superior to filtered beer.

CREATE THE PERFECT ENVIRONMENT

So for how long, at what temperature and how much to dry hop your beer? Before I started research into this article, my idea to get ideal hop oil extraction was to dry hop for 10 days at 65 °F (18 °C). It had always treated me well. I received a lot of hop aroma when appropriate levels of hops were added. But in a polling of homebrewers, I realized that my 10-day duration was on the high end of the scale. Many homebrewers were going as short as three days. Of all the brewers I talked to, only Vinnie Cilurzo went more than five days with his dry hops. Research by Wolfe and Shellhammer confirm that hop extraction occurs rapidly. In fact in a recirculating system they found that most aroma compounds are extracted from pellet hops in a matter of hours. For pelletized dry hops added without recirculation, they found that full extraction occurred in one to two days while whole hops took closer to a week for full extraction.

The next variable to look at is temperature. Considering the rise of the IPL (India Pale Lager), the temperature of the beer and its effect on the oil extraction is something to keep in mind. So my first turn in this department was to Jack's Abby Brewing Brewmaster Jack Hendler whose lagers have made waves in the US craft beer scene. Surprising to me, the average time Jack dry hops is only three to four days. He does increase his temperature to 55 °F (13 °C) for adding hops, but adds that, "The cooler the temp, the less aroma you'll pull from the hops." If you do plan to try an IPL of your own, Jack has some further dry hopping suggestions. "You'll need to reevaluate dry hop addition quantities, because the dry hop aroma will be highlighted more than an ale. You may find a different or smaller quantity gets the aroma you're looking for," he said.

So how much dry hops should you add? Obviously that is completely dependent on what you are trying to achieve with your beer. But keep in mind that sometimes, more isn't always better. In my freshman year microeconomics course I learned about a basic principle, the law of diminishing returns. In the terms of dry hopping, the more you add, the less net gain you add with each additional increment. In fact you may find that you are detracting from a certain nuanced characteristic of the beer if you overwhelm it with another characteristic. Finding the right balance of hop oils of a varietal or a blend is key. If you've had Heady Topper before, you may be surprised to learn that John Kimmich dry hops with under 4 oz. (113 g) per 5 gallons (19 L).

IS LAYERING THE KEY?

Only two of the seven pro brewers I spoke to didn't add their dry hops in stages. One that was surprising was John Kimmich who adds all his dry hops in one big charge for his Imperial IPA. Jamil Zainasheff pointed out an important nuance to me: "The main reason is that we're dry hopping into cylindroconical fermenters. The bottom is a narrow cone, which means that when the hops drop to the bottom, it results in a smaller surface area." He said not to worry about layering in dry hops on a small scale. Peter Wolfe also weighed in on the topic saying especially if a homebrewer is using a flat bottomed fermenter, there is little reason to layer in your hops, the surface area to volume ratio is much greater on a homebrew scale.

There is one reason that homebrewers may want to layer in their dry hops. As stated earlier, Matt Brynildson adds dry hops while active fermentation is still ongoing. For some of his beers, he will add a first dry hop charge near the termination of active fermentation and a second addition after flocculation has occurred. He backs up his approach with the concept to, "Take advantage of both conditions (1) with yeast and (2) without yeast influence." So if you plan to add your first dry hop charge near the end of active fermentation, you may also want to take advantage of this two layered dry hop approach. Otherwise, if you are planning on waiting until most yeast has settled from the beer, then one stage dry hops are all you need. BYO