

Off-Flavors, Part III

This session covers faults related to hops and some aspects of aging.

Alpha Acids (Bitter)

Detected in: Flavor, Mouthfeel.

Described As: Hoppy bitterness. Some hop varieties produce a “clean” bitterness, while others produce a harsher, “coarser” bitterness. Extreme levels of hop bitterness can impart a drying, harsh resinous and/or tongue-coating mouthfeel.

Typical Origins: Hop additions during wort boil. Additions of hop extracts to wort or beer.

Typical Concentrations in Beer: 0-140+ mg/l, 0-100+ IBU, depending on style.

Perception Threshold: 5-7 mg/l, ~5 IBU.

Beer Flavor Wheel Number: 1200.

Discussion: Hop bitterness is imparted to beer by isomerization of humulones during wort boil, converting them to soluble iso-humulones. Alpha acid utilization rates (AKA “Kettle Utilization Rates” or KUR) are determined by original gravity of the wort, alpha acid percentage of the hops, freshness of hops & boil time, to a maximum of about 25-33%. Hop bitterness is measured in terms of International Bitterness Units (IBU) or just Bitterness Units (BU), although this also measures soft hop resins in the beer overstating actual alpha acid concentrations by 5-15%.

Iso-alpha-acids derived from hop resins. There are 6 different variants and they all differ in relative bitterness. Hop bitterness in beer is first detected at about 10 IBU. Thereafter, changes in hop bitterness can typically only be detected in changes of +/- 5 IBU. Conventionally, the maximum threshold for perception of hop bitterness is about 100 IBU, although some people might be able to detect higher levels of bitterness.

Despite IBU levels, the character of hop bitterness is somewhat subjective. Cohumulones are said to produce harsher, coarser bitterness than humulones, which are believed to impart a mellow, pleasanter bitterness. Perception of hop bitterness is also influenced by mineral additions, malt selection, alcoholic strength and other aspects of the finished beer.

Unlike bitterness from phenolic compounds, hop bitterness is generally described as being “cleaner” and much more pleasant, with much less lingering aftertaste.

Perception of hop bitterness is increased by the presence of high concentrations of sulfate and magnesium ions. Sulfate ions also aid in extracting alpha acids from hops. Excessive levels of these ions can impart an unpleasant bitterness and aftertaste on their own, however.

To Increase: Adjust bittering hops to suit your recipe. Increase boil time - a minimum of at least 1 hour to a maximum of 2 hours for maximum IBU extraction. Use hops with a higher alpha acid percentage. Use fresher hops. Keep hops fresh by storing them in cold conditions in vacuum-sealed, airtight packages. Decrease wort gravity. Add hop fractions (artificially extracted alpha acids). Add magnesium and sulfate-containing salts (e.g., “Burton salts” or gypsum - calcium sulfate) to mash or wort.

To Reduce: Adjust bittering hops to suit your recipe. Decrease boil time. Use hops with lower alpha acid content. Reduce sulfate or magnesium salt additions to mash water.

When Are Alpha Acid Notes Appropriate?: To some degree, hop bitterness is expected in virtually all beer styles, with the exception of American lagers, Scottish ales and lambics. Extremely high levels of hop bitterness are expected in American pale ales, American stout, Russian imperial stout, IPA and barleywines.

Relative Bitterness of iso-alpha-acids

Compound	Typical % in Beer	Bitterness Rank
Trans-isochohumulone	7	1 (least bitter)
Cis-isochohumulone	30	2
Trans-isohumulone	10	2
Cis-isohumulone	40	4 (most bitter)
Trans-isoadhumulone	3	?
Cis-isoadhumulone	10	?

Hoppy (Aroma and Flavor)

Detected In: Aroma, Flavor.

Described As: Black currant, citrusy (e.g., grapefruit, lemon, lime, orange, orange marmalade, tangerine), currant, earthy, floral (e.g., dried flowers, fresh flowers, geranium, lavender, orange blossom, rose) fruity, herbal (e.g., lemongrass, minty, rosemary, thyme), grassy, perfumy, piney (e.g., balsam, spruce, “rustic”), resinous, resinous, spicy, stone fruit (e.g., apricot, cherry, peach, plum), tropical fruit (e.g., guava, mango, papaya, passionfruit, pineapple), woody or woody. Some varieties can also produce Catty (q.v.) or onion-like notes. Excessive levels can produce grassy, leafy or vegetal notes (see Grassy). Aged hops can produce hay-like (see Grassy) or Isovaleric (q.v.) notes.

Typical Origins: Hops.

Typical Concentrations in Beer: 0.05 - 3 mg/l.

Perception Threshold: Variable, usually ~0.15 mg/l for dry hops, 0.01 - 0.2 mg/l for kettle hops.

Beer Flavor Wheel Number: Varies. 0171 Kettle hops. 0172 Dry hops. 0173 Hop oils.

Discussion: Various essential oils found in hops impart distinctive hoppy aromas and flavors to beer. They are imparted to beer by adding hops during wort boiling, during wort cooling (e.g., by letting hops steep in cooling wort or by running hot wort through a hopback), or by dry-hopping finished beer.

The most volatile chemicals (usually the smallest molecules) are quickly driven off during wort boil and only survive in aroma hop and dry hop additions. The larger, less volatile molecules last longer and are responsible for hop flavor (apart from hop bitterness, which is due to isomerized alpha acids). Of the essential oils, the two most important families are:

A. Hydrocarbon-Based Oils: Monoterpenes & sesquiterpenes. They represent about 75% of essential oils. Within this group, the most important sub-groups are:

I. Monoterpenes.

a) *Humulene* has a delicate, refined flavor and oxidizes to produce spicy notes. “Noble” hops have high humulene levels.

b) *Myrcene* is more pungent, and is higher in U.S. hops. It oxidizes to produce citrusy or piney notes.

II. Sesquiterpenes: Farnesene & Caryophyllene. They oxidize to compounds with “grassy” aromas.

B. Oxygen-Bearing Oils: Also called essential alcohols, they represent about 25% of essential hop oils. Within this group, the two most important molecules are:

I. Linalool has a hoppy aroma.

II. Geraniol has a floral, perfumy aroma like geraniums, roses or cheap perfume. In some cases it can smell like fresh grass. *Typical Concentration in Beer:* 0 - 100 µg/l (depending on hop level and strain used). *Perception Threshold:* A third of the population have a threshold of about 18 µg/l. The remainder have thresholds around 350 µg/l. *Beer Flavor Wheel Number:* 0162.

C. Ketones.

To Increase: * Choose hop varieties which are high in essential oils (e.g., noble hops). * Increase amount of aroma, flavor and dry hop additions. * Add more hops late during the wort boil - no more than 30 minutes before knockout for aroma hops, no more than 5 minutes before knockout for flavor hops. * Dry hop finished beer before packaging, or in keg/cask. * Add hop essential oils.

To Reduce: * Reduce late hop additions. * Use fewer hops.

When is Hop Character Appropriate?: Hop aroma and flavor is a defining characteristic of Pilsners, English pale ales, American ales, IPA and Barleywine. Some level of hop aroma and flavor is expected in most other beer styles, with the exception of lite American lager, standard American lager, premium American lager, doppelbock eisbock, sour beers and old ale.

Isovaleric (Fatty Acid, Sulfur)

Detected in: Aroma, flavor.

Described As: Blue cheese, cheesy, old hops, rancid, stale. Less commonly described as goaty, putrid, stinky feet, or sweaty.

Typical Origins: Hops, aging, process faults.

Typical Concentrations in Beer: 0.2 - 1.5 mg/l.

Perception Threshold: 0.7-1 mg/l. While everyone can taste isovaleric acid, perception threshold levels can vary by several orders of magnitude.

Beer Flavor Wheel Number: 0613.

Discussion: Caused by oxidation of alpha acids in hops, usually during storage, which produces valeric, butyric and 2-methyl butyric acids. All of these produce distinctive “blue cheese” notes. Somewhat related to Caprylic (q.v.). Often accompanied by Grassy (q.v.) notes. The intensity of this characteristic decreases with time, both in aged hops and beer

made with aged hops. Cheesy notes can also be produced by bacterial infections.

To Avoid : * Use the freshest hops possible. Store hops in vacuum-sealed, oxygen-free containers at low temperatures (e.g., in your freezer). Don’t buy hops which haven’t been kept under refrigeration. Don’t buy hops which you suspect are old or have been improperly stored. Badly treated hop cones will often be papery and pale, with no residual greenness. Badly treated pellets or plugs will lose their greenness and might be brown or buff colored. In all cases, they will have significantly less aroma than they would if fresh. * Allow beer to age; cheesy notes will recede with time.

When Are Isovaleric Notes Appropriate?: Never. While “suranne” (literally, “superannuated”) hops are used in lambics, these should be aged for long enough that any cheesy notes are long gone.

Lightstruck (Sulfury)

Detected in: Aroma, Flavor.

Described As: Catty, farty, fecal, mercaptan, polecat, skunky, sulfury, sunstruck. Inaccurately described as methane or natural gas.

Typical Origins: Mishandling.

Typical Concentrations in Beer: 1-5 ng/l for beer kept in the dark. 0.01-1.5 µg/l for beer exposed to light.

Perception Threshold: 4 ng/l.

Beer Flavor Wheel Number: 0724.

Discussion: Lightstruck character is caused by a photochemical reaction where visible or ultraviolet light (wavelengths below 520 nm) makes riboflavin in the beer react with and break down hop-derived, sulfur-containing isohumulones (isomerized alpha acids). This liberates 3-methylbut-2-ene-1-thiol, a mercaptan, a compound detectable at just a few parts per billion, which is similar to the active ingredient in skunk musk. For this reason, mercaptans are added to natural gas (methane), which is naturally odorless, as a safety precaution. This leads some people to wrongly assume that household natural gas naturally smells like mercaptans.

The wavelengths of light responsible for triggering the lightstruck reaction are found in both sunlight and ordinary fluorescent lightbulbs. They readily penetrate all but dark brown “amber” glass, causing the contents to become “skunky” in as little as 30-120 seconds. Amber glass bottles allow about 5% of ultraviolet light (below 400 nm) to pass, while green glass allows about 80%. Between 400-520 nm (violet to green light), amber glass lets 5-30% of light pass (depending on frequency), while green glass allows 50-80% to pass. Clear glass and glass allows about 90% of all wavelengths to pass.

Some large commercial brewers avoid the problem of lightstruck beer in their signature products (e.g., Corona, Miller Highlife) by using a chemically modified form of isohulone which doesn’t react with riboflavins. This allows them to ship their beer in cheaper, more attractive green or clear bottles.

To Avoid: * Store beer (including fermenting beer) and hopped wort in containers which block light, ideally ones which are opaque. * Bottle beer in amber glass bottles. * Cover clear or green glass containers (including fermentors) which might be exposed to light. * Reduce the level of bittering hops (to reduce isohumulones, hence potential mercaptan precursors).

When is Lightstruck Character Appropriate?:

Lightstruck character is never appropriate. Sadly, it is so common in mishandled, badly-packaged, imported European and Mexican “green bottle” beers, especially light lagers, that many people believe that the beers were intentionally brewed that way!

Papery (Oxidation)

Detected In: Aroma, flavor.

Described As: Cardboard, dull, papery, shoe box, stale, wet cardboard. At low levels papery character can be taste or smell “like ball-point pen,” inky, musty, peppery or prickly. Less commonly, it is perceived as smelling like cucumbers, fat, honey, “library,” “old people,” orris root or soy sauce. In dark beers it might be detected as “tomato juice” notes.

Typical Origins: Aging, process faults.

Typical Concentrations in Beer: <50 ng/l in fresh beer, >0.2 µg/l in aged beer.

Perception Threshold: 50 - 100 ng/l.

Beer Flavor Wheel Number: 0820.

Discussion: Cardboard and papery notes are caused by long-chain aliphatic (non-aromatic) aldehydes (e.g., 2-nonenal). These are produced when lipid compounds naturally found in malt, which are liberated during mashing and wort boil, but initially bound to other molecules, undergo auto-oxidation.

The most notorious compound, 2-nonenal, is detectable at levels above 0.1 µg/l in water. It is responsible for cardboard or papery notes. Some people describe it as smelling like “library” (decaying paper) or “old people.” The latter sensation might be because 2-nonenol is present in human sweat and the human body produces more 2-nonenal as we age!

Obvious papery notes develop in the mid to late stages of aging, especially in light-colored, light-flavored, relatively weak (i.e., below 6% ABV) beers. At low levels, papery notes might be mistaken for one or more of the sensory descriptors listed above. As described for Oxidation, the time needed to develop papery notes depends mostly on how much oxygen is present in the beer and the temperature at which it is stored. Also see Almond, Leathery, Oxidation and Sherry-like.

To Avoid: As for Oxidation (see above).