

The Complete Beer Fault Guide v. 1.4

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Introduction

This guide is a summary of my research into sensory characteristics of beer. Information has been gleaned from a number of sources, notably George Fix's *Principles of Brewing Science*, 2nd edition, but also a variety of online and academic sources. Even so, it is a work in progress. Eventually, it will include complete information on every sensory descriptor listed on the Meilgaard Flavor Wheel, as well as other sensory descriptors discovered by fermentation scientists.

Sensory descriptors are listed in alphabetical order. Note that some descriptors don't necessarily agree with information published by the BJCP.

5.2TM

Detected In: Flavor, mouthfeel.

Described As: Baking soda, harsh, metallic, salty, rough.

Typical Origins: 5.2TM mash stabilizer.

Typical Concentrations in Beer: N/A.

Perception Threshold: unknown.

Beer Flavor Wheel Number: N/A.

Discussion: 5.2 is a proprietary blend of phosphate salts (mostly sodium phosphate) sold by Five Star Chemical which claims to reduce mash pH to 5.2 and buffer it at that level regardless of starting pH. Under certain conditions, notably when using highly alkaline water, or if you use excess amounts, it can affect flavor and mouthfeel.

Also see Alkaline and Salty.

When Are 5.2 Notes Appropriate?: Never.

2-Phenylethanol (Rose-like)

Detected In: Aroma, flavor.

Described As: Rose-like.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0161.

Discussion: See Esters.

Acetaldehyde

Detected In: Aroma, flavor.

Described As: Aldehydic, bready, bruised apples, cidery, fruity, grassy, green apple, green leaves, latex paint (AKA emulsion paint), raw apple skin, "rough." Sometimes mistaken for cellar-like, musty or sour notes, sweet apple esters and/or acetic sourness (and vice-versa).

Typical Origins: Yeast activity, Microbial contamination.

Typical Concentrations in Beer: 2-15 mg/l.

Perception Threshold: 5-20 mg/l. At 6-8 g/ml it is perceived as a "fruity" flavor. At higher levels it has a distinctive "green apple" aroma flavor and aroma.

Beer Flavor Wheel Number: 0150.

Discussion: Acetaldehyde is the most important aldehyde (carbonyl compound) in beer, although there are others. Acetaldehyde is found in all beer, although detectable levels are considered to be a defect in most beer styles.

* It is typically produced as a precursor to ethanol produced during fermentation: glucose is metabolized into pyruvic acid which is then converted to acetaldehyde and then to ethanol. During fermentation some acetaldehyde escapes from the yeast cell. During the final phases of fermentation, the yeast scavenges free acetaldehyde and finishes converting it.

* In young beer or fermenting wort, acetaldehyde levels range from 20-40 mg/l, decreasing to 8-10 mg/l in finished beer.

* Oxidation of finished beer might convert ethanol back into acetaldehyde. In this case, acetaldehyde is usually accompanied by other oxidation and/or age-related defects.

* The combination of bacterial action and oxidation can reduce acetaldehyde to acetic acid (vinegar) due to the chemical reaction of ethanol and acetaldehyde. In this case, acetaldehyde is usually accompanied by acetic acid and other contamination defects. This is indicative of infection by *Acetomonas*, *Gluconobacter* or *Zymomonas* species.

Some Aldehydes Found in Beer

Aldehyde	Descriptor	Detectable range
3-Methylbutanal	Unripe banana	0.01-0.3
Acetaldehyde	green apples	2-20 mg/l
Benzaldehyde	Bitter almonds, burnt almonds, cherries	0.035-3.5
Butyraldehyde	melon, varnish	0.03-0.2
Hexanal	Bitter, vinous	0.003-0.07
Trans-2-nonenal	Papery, cardboard	0.00001-0.002

Increased By: * Yeast management: Yeast strain (highly flocculent strains). Poor yeast health. Underpitching. Fermentation at temperature too cool for yeast. Vigorous fermentation. Incomplete/stuck fermentation. Removing yeast from wort prematurely (e.g., fining, filtering, crash cold conditioning). Insufficient conditioning time. Increasing fermentation pressure (whether atmospheric or liquid pressure - although this is mostly a problem for large breweries, not homebrewers). * Aeration of green beer during conditioning or packaging. * Bacterial infection by *Zymomonas* or *Acetobacter* species (but usually accompanied by other off-flavors in such cases, such as sulfur compounds or acetic acid, respectively).

* Acetaldehyde concentrations are increased by rapid fermentation, higher fermentation temperatures and increased yeast cell count, although these factors also promote reduction of acetaldehyde.

To Avoid or Control: * Proper Yeast Management: Proper fermentation temperature. Longer fermentation and/or conditioning times. Proper yeast health/quality. Proper yeast strain. Proper pitching rate (at least 0.5 quarts per 5 gal. for ale, more for lager and high gravity beers). "Diacetyl rest" at ~50 ° F for 1-3 days at end of lagering period. Increasing yeast concentration during conditioning period. (Also see VDK for more detailed discussion of diacetyl rests.) * Reduce head

pressure during fermentation and conditioning to allow acetaldehyde to blow off. * Avoiding aeration of green beer or fermenting wort. * Proper sanitation to avoid bacterial infection. * Proper packaging and storage. Oxygen introduced during packaging can oxidize alcohol back into acetaldehydes, especially when catalyzed by heat and light.

* Scavenging of acetaldehyde by yeast is increased by promoting vigorous late primary and secondary fermentation, by conditioning at warmer temperatures and increasing yeast cell count during late primary and secondary fermentation (i.e., by adding more yeast or by rousing existing yeast).

When Are Acetaldehyde Notes Appropriate?: For most styles of beer, detectable level of acetaldehyde is a fault. The exception is that Lite and Standard American Lagers may have very low levels of acetaldehyde. This is because Budweiser has very slight acetaldehyde notes, since Anheuser-Busch uses beechwood slats in their conditioning tanks to encourage the yeast to flocculate and settle prematurely, before it reduces all the acetaldehyde to ethanol.

Acetic (Sour)

Detected In: Aroma, flavor.

Described As: Acidic, cidery, lingering sourness, sharp sourness, sour, sour apples, tangy, tart, vinegary.

Typical Origins: Microbial contamination.

Typical Concentrations in Beer: 30-200 mg/l.

Perception Threshold: 130 mg/l.

Beer Flavor Wheel Number: 0910.

Discussion: Acetic acid is one of the more common sour (q.v.) tastes found in beer. It naturally occurs at low levels in all beers as a result of yeast activity during fermentation, although detectable levels are considered to be a defect in most beer styles.

* Acetic acid is volatile and has a relatively low perception threshold, so it can easily be detected in a beer's aroma as well as in its flavor.

* High levels of acetic acid are caused by oxidation of ethanol by bacteria; most commonly *Acetobacter* species which produce a white pellicle or film on top of the beer in the conditioning vessel. *Acetomonas* bacterial infection also produces high levels of acetic acid. These infections produce a slimy, ropy film on top of the beer. Both of these infections take time to develop and can only proceed in the presence of oxygen. *Zymomonas* bacteria (typically *Zymomonas mobilis*) also produce acetic acid, along with esters, acetaldehyde and sulfur dioxide. Yeasts of the *Kloeckera* and *Brettanomyces* families can also produce acetic acid, in conjunction with other distinctive off-flavors (e.g., leathery, sweaty). Infections by these organisms can occur in anaerobic conditions, usually at ale fermentation temperatures or higher.

Increased By: * Inoculation with bacteria or wild yeast. * Exposing green or packaged beer to air.

To Avoid or Control: * Proper yeast management: Choose appropriate yeast strain. Reduce percentage of adjunct sugars in the beer. Pitch correct amount of yeast (0.5 - 1.5 qt per 5 gallons) for optimum yeast health and to minimize lag time. * Practice proper sanitation. Thoroughly clean all cold-side equipment before sanitizing it. Don't use cold side equipment which can't be sanitized (e.g., wooden or scratched plastic utensils/containers). * Don't use the same equipment for regular

Judging Tip: Green Apples and Butter

Acetaldehyde and Diacetyl often appear together in the same beer. Both chemicals are produced during the lag phase of fermentation and both should be metabolized by the yeast in the late fermentation/dormancy phases. Green apple and butter aromas and flavors might arise in beers, especially lagers, where the yeast has precipitated or been filtered prematurely, or otherwise produced a lot of acetaldehyde and diacetyl initially and then didn't have the ability to clean it up later (e.g., weak or mutant yeast).

Lager brewers deal with these problems by giving their beer a "diacetyl rest" (which also deals with acetaldehyde) by warming it to ~50-55 °F for a few days before filtering or packaging. See VDK for more information.

and standard beers unless it can be completely sanitized; especially avoid using soft plastic items for both. * Don't expose green or packaged beer to air.

When Is Acetic Sourness Appropriate?: Low levels of acetic sourness are expected in Belgian sour ales (Flanders Red, Flanders Brown, Lambics).

Acetone

Detected In: Aroma, flavor, mouthfeel (as warming).

Described As: Nail polish remover, solvent. Solventy or harsh mouthfeel.

Typical Origins: Yeast activity, process faults.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0123

Discussion: See Solventy.

Acidic

Detected In: Aroma, flavor.

Described As: Pungent aroma, sharpness of taste, mineral acid.

Typical Origins: Bacterial contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0900

Discussion: See Acetic (Sour), Lactic (Sour) or Sour.

Alcoholic

Detected In: Aroma, flavor, mouthfeel (as warming).

Described As: The general effect of ethanol and higher alcohols.

Typical Origins: Yeast activity.

Typical Concentrations in Beer: ?

Beer Flavor Wheel Number: 0110

Discussion: See Ethanol, Fusel Alcohol and Solventy.

Alkaline (Bitter)

Detected In: Flavor, mouthfeel, aftertaste.

Described As: Biscuity, bitter, caustic, chalky, detergent-like, drying, harsh, line-cleaner, lye, mineral-like, salty, sodium bicarbonate, soapy. Excessive alkalinity might affect perception of hop bitterness and malt character before it becomes obvious on its own.

Typical Origins: Water, process/equipment faults, contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: 200 mg/l.

Beer Flavor Wheel Number: 1310.

Discussion: Alkalinity in beer is a direct result of excessively high pH (above 4.6). It is usually due to excessive residual alkalinity in brewing water or due to excessive additions of brewing salts which increase residual alkalinity (e.g., calcium carbonate or magnesium sulfate). Alkaline materials are typically used as brewhouse cleaners and sanitizers (e.g., soap, caustic cleansers). In the bar trade, they are also used to clean the lines of draught dispense systems. If not properly rinsed, they can impart harsh, unpleasant flavors and mouthfeels to beer.

Alkalinity increases the pH of beer, affecting perceptions and activity of many other flavor compounds.

An excessively alkaline (above ~ pH 5.6) mash, or excessively alkaline sparge water promotes the extraction of polyphenols (see Phenols) which cause astringency and chill haze. Excessively alkaline mash also interferes with enzyme action in the mash. Excessively alkaline wort interferes with hot break formation.

To Avoid or Control: * Properly treat water. Limit brewing salt additions, especially calcium and magnesium. * Adjust mash and sparge liquor to proper pH. * Use cleansers in the proper concentrations and rinse thoroughly after cleaning brewing or draft dispense equipment. * Adjust mash and sparge liquor to proper pH.

When Are Alkaline Notes Appropriate?: Never.

Almond (Oxidation, Malt)

Detected in: Aroma, flavor.

Described As: Benzaldehyde, bitter almond, marzipan, nutty. Also described as Brazil nuts, hazelnuts or other types of tree nuts. In some cases it can be reminiscent of Playdough™, plastic or cherries.

Typical Origins: Aging, specialty grains, yeast strain.

Typical Concentrations in Beer: 1-10 µg/l.

Perception Threshold: 1 mg/l.

Beer Flavor Wheel Number: 0224.

Discussion: An occasional off-flavor in beer which arises due to aging. Similar smelling and tasting compounds might arise due to use of brown or toasted malt. Nutty oxidative notes occur when melanoidins, alcohol and oxygen interact reducing volatile molecules such as esters and hop compounds. They often occur with other oxidative notes such as dark fruit or sherry-like aromas and flavors. These compounds might be reduced back into their original form by oxidizing alcohols into aldehydes. Almond aroma is mostly caused by benzaldehyde.

Some strains of yeast produce aldehydes other than acetaldehyde during the initial phases of fermentation, which can result in aromas which are reminiscent of nuts, Playdough™ or plastic.

Also see Catty, Leathery, Oxidation, Papery and Sherry-like.

Increased By: High oxygen levels during mashing and boiling (i.e., Hot Side Aeration - HSA). Carrying hot or cold break into fermenting beer; increasing the amount of fatty acids present in finished beer. Exposing green beer to air during transfer and/or packaging. Excessive air inside storage containers. Non-airtight storage containers. High temperature storage conditions (above ~ 55 °F).

“Yeast Management”

The saying that “Brewers make wort, yeast makes beer” is absolute truth. Proper yeast selection and treatment makes the difference between great beer and undrinkable swill. Here is a quick summary of common “yeast wrangling” problems homebrewers encounter:

* **Improper Fermentation Temperature.** This probably the single biggest homebrew fault (with infection ranking a close second). Ideally, fermentation occurs on the lower side of the recommended fermentation range for the yeast strain (although there are exceptions), with steady temperatures or a slight temperature rise as fermentation progresses. Temperature changes should occur gradually (no more than ~0.3 °F or ~0.15 °C per hour) to avoid shocking the yeast.

* **Improper yeast strain for style.** Some strains of yeast are notable for producing high levels of Acetaldehyde, Diacetyl, Esters, Fusel Alcohols and/or Phenols. Others are notable for not flocculating well (causing haze), not working well in high alcohol or high O.G. environments (resulting in poor attenuation) or not working well at higher or lower temperatures (poor attenuation or off-flavors and aromas).

* **Poor yeast nutrition.** Yeast needs Free Amino Nitrogen (FAN), vitamins and trace amounts of minerals such as calcium, copper, iron, phosphorus and zinc. Generally, all-malt worts supply these nutrients in the proper amounts, but poor yeast nutrition can be a problem in ciders, meads, or beers made using more than 20% adjunct sugars. Various yeast nutrients are available; add them as necessary, following the manufacturer’s directions.

* **Insufficient yeast.** The higher the O.G. of the wort, and the cooler the fermentation temperature, the more yeast are needed. Proper cell count is (0.75 to 1.5 million cells) x (ml of wort) x (°Plato of wort). Use the bottom end of the cell count range for ales the high end for lagers. To get the proper cell count, a brewer needs to make a starter, reuse fresh yeast slurry or pitch more yeast packs. As a rule proper cell count for a 5 gallon batch of table strength (5% ABV, 1.050 O.G.) is 1 quart of starter, 2 quarts for table-strength lagers and strong ales, and 4 quarts or more for strong lagers.

* **Improper wort aeration.** Yeast needs oxygen when it is first pitched in order to synthesize fatty acids and sterols, which are necessary for yeast reproduction. The proper level of dissolved oxygen is (1 ppm dissolved O₂) x (°Plato), to a maximum of 10 ppm. As a rule of thumb, for a 5 gallon batch, this means 10 minutes of vigorously shaking or stirring the wort, 1-2 minutes of aeration using compressed air, or no more than 30 seconds of aeration using compressed oxygen. Wort should be aerated after it is cooled to pitching temperature, but before the yeast is added.

* **Poor yeast health.** Old smack packs or old dry yeast sachets have reduced yeast cell counts, and might have other problems. At the very least, you will need to make a starter if you use old yeast.

Multiply by 4 and add 1.0 to convert °P to S.G. There are 3785 ml per gallon (multiply by 0.00026).

To Avoid or Control: Avoid hot side aeration (don’t splash or spray hot mash liquor or wort). Get good hot and cold break. Separate hot and cold break from wort. Don’t aerate beer after fermentation starts. Avoid splashing beer during transfer and packaging. Purge conditioning and storage vessels with carbon

dioxide before filling them. Don't underfill bottles or kegs. Minimize headspace in bottles (no more than 1-2" below the crown). Get a good seal on bottles and keg. Use anti-oxidant bottle caps and/or wax over caps. Avoid high temperature (90+° F) storage conditions. Keep beer cool (32-50 °F) for long-term storage. Don't age beer unless it can stand up to long-term storage.

When Are Almond (Nutty) Notes Appropriate?: Low levels of nutty notes are acceptable, even welcome, in malt-focused dark beers such as Munich dunkels, English milds, brown ales, and brown porters and American brown ales, as well as dunkelweizens, weizenbocks and old ales.

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. Of these, cohumulones are the most easily isomerized. 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 mellower, 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. While higher (more basic) pH conditions aid in the extraction of alpha acids, hop resins extracted at lower pH conditions (5.2 pH) is said to give a finer, more balanced bitterness.

In addition to providing bitterness, polyphenols and hop resins from hops adsorb to the hot break during boiling, helping

it to precipitate. Unfortunately, some isohumulones (isomerized alpha acids) are precipitated with the hot break rather than going into the beer.

To Increase: * Increase 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 hops with a higher cohumulone level. * 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. Boil hops at a higher pH. * Boil hops at a higher pressure and temperature; at 140-145 °C (285-293 °F) hops are isomerized in just 3-5 minutes. (But be careful, since alpha acids are quickly degraded if you boil at too high a temperature and pressure or you boil too long!)

To Reduce: * Reduce bittering hops to suit your recipe. * Decrease boil time. Use hops with lower alpha acid content. * Decrease boil time. * Reduce sulfate or magnesium salt additions to mash water. * Extract hops at lower pH. * Use hops with lower cohumulone levels.

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-isocohumulone	7	1 (least bitter)
Cis-isocohumulone	30	2
Trans-isohumulone	10	2
Cis-isohumulone	40	4 (most bitter)
Trans-isoadhumulone	3	?
Cis-isoadhumulone	10	?

Apple

Detected In: Aroma, flavor

Described As: Fresh, ripe apple.

Typical Origins: Yeast action.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0142

Discussion: See Esters.

Astringent

Detected In: Mouthfeel, Aftertaste.

Described As: Mouth puckering, puckery, tannin-like, tart

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1340

Discussion: See Phenols (Polyphenols), also see Cloudiness.

Autolyzed (Sulfury)

Detected In: Appearance, aroma, flavor.

Described As: Bitter, brothy, decaying/rotten yeast, Marmite™, meaty, muddy, soy sauce, Umami (q.v.),

Vegemite™, vitamin B, vitamins, “yeast bite.” Ammonia-like, burned rubber, burnt tires, dirty diaper, eraser, ripe cheese, rotten meat, rubber bands or rubbery at extreme concentrations. Autolysis in beer can contribute to Haze.

Typical Origins: Yeast, Aging.

Typical Concentrations in Beer: 0 mg/l for fresh beer, higher for aged beer.

Perception Threshold: Variable depending on beer style and exact chemical.

Beer Flavor Wheel Number: 0725, also see 0740 Yeasty.

Discussion: Autolysis occurs when yeast cells die, weeks or months after they’ve flocculated and dropped to the bottom of the fermenter or conditioning vessel. Enzymes within the cell rupture the cell walls, literally making it “spill its guts” into the surrounding liquid.

Chemically, autolysis allows amino acids, fatty acids, lipids, phosphorus compounds, vitamins (e.g., riboflavin - vitamin B2) and other compounds to get into the beer. Since the enzymes aren’t destroyed when the yeast cell is ruptured, they can degrade other chemicals in the beer, accelerating the process of aging. In particular, esterases break down esters, destroying fruity or floral aromas and flavors. Other cellular compounds (notably lipids) increase beer pH increasing perception of hop bitterness and possibly imparting slight alkaline notes. Proteolytic enzymes and lipids degrade beer foam proteins and increase carbohydrate (starch) and protein (“chill”) hazes.

Note that flocculated yeast takes a while to die. Freshly flocculated yeast (i.e., a few days to a few weeks old) are mostly dormant and have high levels of internal food reserves (glycogen and the disaccharide trehalose). In this state, “yeast cake” or “yeast slurry,” mostly consisting of healthy flocculated yeast can be reused to ferment another batch of beer. On the other hand, old or unhealthy yeast cells will quickly die and rupture. In aged wild beers, the products of yeast autolysis provide food for subsequent colonies of souring bacteria, such as *Acetobacter*, *Lactobacillus*, *Pediococcus*, as well as wild yeasts such as *Brettanomyces*.

Products such as Marmite™ and Vegemite™ are produced by intentionally inducing yeast autolysis by heating yeast. Their meaty, brothy character comes from glutamic acid (see Umami).

Also see Butyric, Caprylic, Dimethyl Sulfate, Isovaleric, Oxidation, Sulfury, Sulfidic, Sulfitic, Umami and Yeasty.

To Avoid or Control: * Rack beer off of yeast cake within 2-4 weeks after fermentation stops. * Limit yeast carried into finished beer. * Age beer properly. Beer with high levels of suspended yeast doesn’t age well. See Oxidation for further discussion. * Pitch fresh, healthy yeast - older or unhealthy yeast cells are more prone to autolyze when they flocculate. * Don’t stress yeast - unhealthy conditions cause the yeast to flocculate which is a precursor to autolysis. * Store cropped yeast in healthy conditions. * Avoid extreme warming or cooling of fermenting or conditioning wort - extreme temperature swings cause some yeast cells to autolyze. * Condition and store beer at cool temperatures. Higher temperatures speed the process of autolysis.

When Are Autolyzed Notes Appropriate?: Extremely low autolyzed notes, in the form of brothy, meaty or soy sauce notes are acceptable in strong, aged bottle-conditioned beers, especially dark beers such as old ales. Even in these beers, however, high or unpleasant autolyzed character is a fault.

Judging Tip: Easily Confused Flavors

Some flavors and aromas are easy to confuse until you get enough experience telling them apart.

Acetaldehyde vs. Sour: In some cases, especially in amber or dark beers where there is also some roast astringency and dark malt character, it can be difficult for novice judges to distinguish between acetaldehyde and low levels of lactic or acetic sourness. The tip off here is the aroma. Lactic acid won’t have much (or any) aroma, while acetic acid will have a distinct vinegary smell. Also, the combination of acetaldehyde and dark malt has a slightly different aftertaste than the combination of sourness plus dark malt.

Diacetyl vs. Sweet/Malty: In some beer styles (notably strong Scottish ale) it is easy to mistake diacetyl (from yeast strain or incomplete fermentation from sweet and malty notes produced by “kettle caramelization.” Diacetyl will have a simpler more buttery aroma and flavor and might be combined with distinctive mouth slickness. Kettle caramelization (actually melanoidin reactions due to extended boiling) produces complex, lightly toasted sugars and amino acids which can be sweeter, bitterer, roastier and more complex.

DMS vs. Vegetal: DMS and vegetal notes can be difficult to distinguish in dark beers, since dark malt plus DMS character can take on an aroma and flavor reminiscent of tomato juice.

Hops vs. Grain vs. Water Astringency: Dry finish or aftertaste can come from mineral-rich water, dark malt or high levels of hop bitterness. If used in excess, or if handled incorrectly, any or all of the three can also cause astringency. Determining which of the ingredients is responsible is tricky. Look for other faults which might help narrow the range of possible problems, like high levels of hop bitterness, chill haze or a lingering “mineral water” aftertaste.

Hops vs. Yeast: Some flavors and aromas are difficult to distinguish from yeast-derived esters or phenols which produce aromas or flavors. Learning to tell the difference is a matter of understanding the style you’re judging and knowing your ingredients. In some cases, you can make guesses. For example, some strains of Belgian ale yeast will produce tropical fruit notes, while some strains of hops produce distinct citrusy and piney notes. If you encounter a beer with both of those ingredients, you can safely bet that the pineapple aroma probably came from the yeast, while the grapefruit notes came from the hops.

Autolyzed notes, especially at high levels, are a fault in other styles of beer.

Baby Diaper

Discussion: See Indole.

Bakelite

Detected In: Aroma, flavor

Described As: Electrical fire, old electronics, old TV set, plastic.

Typical Origins: Process faults.

Beer Flavor Wheel Number: 0502.

Discussion: See Bromophenols or Chlorophenols.

Banana

Detected In: Aroma, flavor

Described As: Banana.

Typical Origins: Yeast action.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0143.

Discussion: See Esters (Isoamyl Acetate)

Barnyard

See Caprylic, Horsey, Indole, Isovaleric and Leathery.

Beany

Described As: Bean soup.

Detected In: Aroma, flavor.

Typical Origins: Bacterial contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0223.

Discussion: Vegetal.

Biscuity

See Malty or Roasted.

Bitter

Detected In: Taste, Mouthfeel, Aftertaste.

Described As: Iso-alpha-acids.

Typical Origins: Hops.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1200

Discussion: See Phenols (Flavanoids) and Alpha Acids.

Bitter Orange

See Citrusy.

Blackcurrant

Detected In: Aroma, flavor.

Described As: Blackcurrant fruit.

Typical Origins: Oxidation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0144. For Blackcurrant leaves use 0810 Catty.

Discussion: See Esters and Oxidation.

Body

Detected In: Mouthfeel.

Described As: Thin body is described as characterless, easy-drinking, light, refreshing, thin, thin-bodied or watery. Full body is described as chewy, cloying, full, full, full-bodied, oily, satiating, silky, thick or viscous.

Typical Origins: Malt.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a

Beer Flavor Wheel Number: 1410.

Discussion: Fullness of body is determined by the level of dextrins, proteins and other non-fermentable materials in beer. In thin-bodied beers, the reduced viscosity of the liquid makes it seem more watery, while full-bodied beers are more viscous and seem fuller. Lack of suspended particles and body-forming compounds can also contribute to poor head retention and poor foam stability in thin-bodied beers. Likewise, high levels of those materials aid in foam formation and head retention in fuller beers.

Combination of thin body and high carbonation in beers which have been stored for a while, especially in beers which started out with fuller body and lower carbonation levels, is a classic sign of a bacterial or wild yeast infection by a species which consumes dextrins.

Increased by: Increase wort gravity. Reduce amount of adjunct sugars. Increase the percentage of starch- and/or protein-rich grains in grist (e.g., crystal malt, wheat, oats). Skip or shorten protein and/or beta-glucanase rest. Mash at higher temperatures (to produce less fermentable wort). Add non-fermentable sugars to wort (e.g., dextrin, lactose). Don't fine or filter beer. Observe proper sanitation (to avoid wild yeast or bacterial infection).

Decreased by: Low gravity wort. High percentage of fully fermentable adjunct sugars (e.g., corn sugar, honey). Highly fermentable wort. Long protein and/or beta-glucanase rest (to break down starches and proteins). Mashing at lower end of starch conversion range (produces more fermentable wort). Excessive yeast attenuation. Low medium-length protein levels. Low dextrin levels. Extreme filtration (which removes suspended protein, starch, hop & yeast particles). Wild yeast or bacterial infection by species which metabolize dextrins. Use of starch or protein conversion enzymes (e.g., amylase, papain).

When Is Thin or Full Body Appropriate?: Very thin body is appropriate in light American lager. Light body is expected in Standard American lager and Berlinerweisse. Light body is acceptable in dark American lager, ordinary bitter, best bitter, mild and lambics (unblended lambic, gueuze, fruit lambic).

Belgian dubbels should have medium-full body, while Belgian dark strong ales can range from medium-light to full body (higher for "abbey" style versions). Medium full to full body is expected in such as Munich dunkel, doppelbock. Scotch ale, Baltic porter, sweet stout, oatmeal stout, foreign extra stout, American stout, weizenbock and old ale. Full to very full body is expected in strong, very malty beers, such as eisbock, Russian imperial stout and barleywines.

Bread Crust

Detected In: Aroma, flavor, mouthfeel.

Described As: 2-Acetylpyridine, Charred toast.

Typical Origins: Malt.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0421.

Discussion: See Malt.

Judging Tip: Guess That Bug!

Beer spoilage organisms often produce distinctive “off” characteristics, allowing you to guess the likely culprit. Also, since they require conditions to grow, you can also guess where to look for the sanitation problem in the brewing process.

Organism	Aerobic?	Grows in:	Spoilage Traits
Acetobacter & Gluconobacter	Required	F, C, P	Acetic acid, acetaldehyde, white pellicle
Acetomonas	No	F, C, P	Acetic acid, ropey film
Brettanomyces	Yes	F, C, P	Acetic acid, caproic, horsey, sweaty, papery white flecks or pellicle, thin body
Enterobacter	Yes	W	Butyric, caproic, DMS (at high levels), hydrogen sulfide, indole, isovaleric, mercaptans, phenolic, sulfur dioxide
Enterobacter - Clostridium	Yes	W, P	Butyric acid
Enterobacter - E. Coli	Yes	W	Indole
Enterobacter - Obesumbacteria Proteus	Yes	W	Parsnip or fruity odor, acetic acid, diacetyl, dimethyl disulfide, DMS, fusel alcohols, phenols
Hafnia Protea	Yes	W, F	Diacetyl
Kloeckera Apiculata	No	F, C, P	Acetic acid, caproic, esters (citrus, floral, fruity) ethyl acetate
Lactobacillus	No	F, C, P	Lactic acid. Sometimes diacetyl & butadiene, thin body, high carbonation, silky texture. Slow, persistent gush when bottle is opened
Megasphaera	Required	C, P	Butyric & caproic acids, hydrogen sulfide, mercaptans
Mold	Required	W, F, C, P	Moldy, grayish or bluish flecks on surface, sometimes fuzzy
Pectinatus	Required	W, C, P	Acetic & propionic acids, hydrogen sulfide, mercaptans
Pediococcus	No	F, C, P	Lactic acid, diacetyl, butadiene, slimy transparent ropy pellicle
Selenomonas	Required	C, P	Acetic, lactic, & propionic acids
Wild yeasts	Usually	F, C, P	Esters (banana, black currant, pineapple, etc.), phenols (esp. clove-like, peaty, plastic & smoky), diacetyl, DMS, fusel alcohols, solventy esters, thin body, high carbonation, dusty or filmy pellicle
Zymomonas	Yes	C, P	Acetaldehyde, hydrogen sulfide, acetic acid, DMS, phenols, sulfur dioxide
Zymophilus	Required	F, C, P	Acetic & propionic acids

Notes: No = Grows slowly or does not grow in the presence of oxygen. Yes = Facultative anaerobe. Required = Obligate anaerobe. W = Wort, F = Fermentation, C = Conditioning, P = Packaging & Storage.

Brettanomyces

See Horsey, Leathery or Sour.

Bromophenol (Phenol)

Detected In: Aroma, flavor.

Described As: Bakelite, electrical fire, electronics, inky, museum-like, old electronics, old TV set.

Typical Origins: Process/Equipment faults, contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: 1.3 µg/l.

Beer Flavor Wheel Number: Not yet assigned (within 500 phenolic category).

Discussion: A rather unusual off-characteristic, caused by contamination of brewing ingredients or packaging materials with bromophenols (e.g., 2-bromophenol). These compounds are often found in recycled paper and cardboard, as well as fireproofing materials. Also see Chlorophenols, Iodoform, Phenol, Smoky, Spicy and Vanilla.

To Avoid: * Avoid contamination of brewing ingredients, wort and finished beer.

When Are Bromophenolic Notes Appropriate?: Never.

Burnt

Detected In: Aroma, flavor, mouthfeel.

Described As: Scorched aroma. Smoky, sharp acrid taste. Dry mouthfeel.

Typical Origins: Malt, process faults.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0420,

Discussion: See Malty.

Buttery

See Vicinal Diketones.

Butyric Acid (Fatty Acid, Sulfury)

Detected in: Aroma, flavor.

Described As: Baby sick, butyric acid, putrid, rancid/spoiled butter, rancid/spoiled milk, vomit.

Typical Origins: Microbial contamination, aging.

Typical Concentrations in Beer: 0.5-1.5 mg/l.

Perception Threshold: 2-3 mg/l.

Beer Flavor Wheel Number: 0614.

Discussion: Butyric and 2-methyl butyric acids are produced by bacterial infections, usually *Clostridium* spp., either during wort production or after packaging. Clostridium can also infect sugar syrups used in brewing, as well as sour mashes exposed to aerobic conditions. All butyric compounds produce distinct, pungent unpleasant rancid odors. Flavor and aroma

activity of butyric acid compounds is heavily dependent on pH - their flavors are more intense at lower pH levels.

To Avoid: * Practice good sanitation. * Make sure that sugar syrups aren't contaminated. * When sour mashing, make sure that mash is kept above ~90 °F and isn't exposed to outside air.

When Are Butyric Notes Appropriate?: Never.

Can Liner

Detected In: Aroma, flavor

Described As: Lacquer-like.

Typical Origins: Equipment problems, contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0122

Discussion: See Plastic.

Caprylic (Fatty Acids, Sulfury)

Detected in: Aroma, flavor.

Described As: Goaty, soapy, sweaty, tallowy, waxy, vegetable oil.

Typical Origins: Microbial contamination, aging.

Typical Concentrations in Beer: 2-8 mg/l.

Perception Threshold: 4-6 mg/l. Levels of 10+ mg/l produce goaty notes.

Beer Flavor Wheel Number: 0611.

Discussion: Capric, caproate and caprylic acids are short chain fatty acids believed to be by-products of yeast metabolism, produced during lipid synthesis by the yeast. They are released into wort either due to leakage through ethanol-damaged cell membranes or due to autolysis.

Flavor and aroma activity of caprylic, capric and caproate acid compounds are heavily dependent on pH - their flavors are more intense at lower pH levels.

To Avoid: * Good yeast management; proper aeration of wort, proper yeast health, to reduce levels of fatty acids. * Good hot and cold break to precipitate trub. * Minimize amount of cold break which gets into fermenter to reduce fatty acids. * Remove green beer from yeast cake after fermentation is complete (within 2-4 weeks). * Store beer in cool conditions.

When Are Caprylic Notes Appropriate?: In some light lager beers, very low levels of caprylic acids are acceptable. Higher levels are a fault in most beers, although detectable levels of caprylic compounds are acceptable in lambics.

Caprylic Acid

Detected In: Aroma, flavor.

Described As:

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0612

Discussion: See Caprylic.

Caramel

Detected In: Aroma, flavor

Described As: Burnt sugar, toffee-like.

Typical Origins: Malt, adjunct sugars.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0410

Discussion: See Malty or Sweet.

Carbolic

Detected In: Aroma, flavor

Described As: Phenol.

Typical Origins: Contamination, Process faults.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Judging Tip: "Review Sanitation"

If you judge long enough, eventually you'll get "**THE BEER FROM HELL**" with aromas reminiscent of feces, rotten eggs, burnt matches and/or rotten vegetables. These are caused by serious bacterial infections. More typically, you'll encounter *Lactobacillus* infections and wild yeast infections which produce have rubbery, plastic, smoky or clove-like notes. Rarely, you'll encounter *Pediococcus Damnosus*, which produces distinct "butter and vinegar" notes (due to diacetyl and acetic acid), or *Brettanomyces* infections (see Horsey).

All you can do in such cases is give the beer the best score you can assign with good conscience (remember 13 is the minimum "courtesy score") and tell the brewer their beer was infected. But, just writing some variant of "Review sanitation" isn't good feedback, you need to get more specific. Here are common causes of contamination:

- *Moldy equipment.* Plastic equipment, especially soft plastic, can pick up moldy flavors and aromas if put away wet or allowed to stand on wet, moldy surfaces. Solution: Buy new equipment, you'll never get the mold smell out.

- *Scratched Equipment.* Any scratch big enough to see can harbor bacteria and wild yeast. These can be carefully buffed or polished out of metal or hard plastic items. For soft plastic, it's generally easier to replace the item.

- *Soft plastic.* Bacteria can form spores or hide in scratches or pores in soft plastic materials, especially hoses and gaskets. Replace soft plastic items on a regularly basis - at least yearly, sooner, if you think they're the source of contamination.

- *Cracks, crannies and joints.* Anyplace there's a weld or joint in your system, there's a place where bugs can hide. Likewise, areas you can't see or get to easily can also harbor bugs. Pumps, heat exchangers, counterflow wort chillers and filters are common culprits when troubleshooting sanitation problems.

- *Bottles and carboys.* It's sometimes hard to get all the dirt out of bottles and carboys, and anything that isn't clean can't be sanitized properly. Bottles are cheap enough that you can afford to throw really filthy bottles into the recycle bin. Carboys need to be carefully washed to get all the crud out of them and then need to be sanitized thoroughly. Ideally, you should store them filled with a relatively mild sanitizer like Star-San™ or Iodophor™. If not, they should be thoroughly dried and then capped so that dust doesn't get inside.

- *Open Fermentation.* Sometimes it's hard to get a good seal on a fermentation bucket. While this isn't a problem initially, due to the overpressure produced by the CO2 escaping as the yeast ferments, once fermentation stops all kinds of evil critters can sneak into your beer. If you use an open fermentation system, unless you're trying to make lambics, you're just asking for trouble.

Beer Flavor Wheel Number: 0503
Discussion: See Phenol or Chlorophenol.

Carbonation

Detected In: Mouthfeel.
Described As: CO₂ content.
Typical Origins: Carbonation.
Typical Concentrations in Beer: ? mg/l.
Perception Threshold: ? mg/l.
Beer Flavor Wheel Number: 1360
Discussion: See Mouthfeel.

Cardboard

See Papery.

Catty (Hops, Oxidation)

Detected in: Aroma, flavor.
Described As: Black currant leaves, “litter box,” oxidized beer, ribes (a genus of flowering plants which includes black currants and gooseberries), tomato plants, tomato urine.
Typical Origins: Aging, hops, contamination of ingredients.

Typical Concentrations in Beer: 0 mg/l.
Perception Threshold: 15 ng/l.
Beer Flavor Wheel Number: 0810.

Discussion: p-Menthane-8-thiol-3-one and similar compounds are produced by some varieties of hops (e.g., Citra™, Strisselspalt). They can also arise during the early phases of beer oxidation. Rarely, catty note can occur when ingredients contaminated with p-Menthane-8-thiol-3-one precursors are used in brewing.

Also see Almond, Leathery, Oxidation, Papery and Sherry-like.

To Avoid: * Choose appropriate hop strain. * Use fresh clean malt and hops. * Avoid oxidizing wort or green beer (e.g., avoid hot side aeration, don't splash wort or beer during transfer or packaging). * Store beer at cool temperatures.

When Are Catty Notes Appropriate?: Beer made with certain strains of hops might naturally have catty notes. As a sign of oxidation, it is a defect in all styles of beer.

Celery

Detected in: Aroma, flavor.
Described As: Cooked vegetal, soapy, vegetal.
Typical Origins: Essential oils, contamination.
Typical Concentrations in Beer: n/a.
Perception Threshold: n/a.
Beer Flavor Wheel Number: n/a.

Discussion: Celery-like notes in beer are caused by essential oils found in old hops (see Citrusy or Hoppy), spices such as coriander (see Ham-like or Spicy), or produced by wort-spoiling coliform bacteria (also see DMS, Indole, Sulfury and Vegetal).

When Are Celery Notes Appropriate?: Never.

Characterless

Detected In: Aroma, flavor, mouthfeel.
Described As: Bland, empty, flavorless.
Typical Origins: Poor recipe design.
Typical Concentrations in Beer: ? mg/l.
Perception Threshold: ? mg/l.

Judging Tip: Medicinal or Plastic Notes

It's a common beginning brewer's mistake to just use tap water when making extract beer, rather than using dechlorinated or distilled water. As a result, their beers often have “Band-Aid™,” “Chloraseptic™,” “Listerine™,” medicinal, plastic or smoky notes due to chlorophenols. Another beginner's mistake is to use too much chlorine-based sanitizer, especially bleach. It's particularly difficult to properly rinse such solutions from soft rubber equipment, such as gaskets and hoses. The result is beer with the same chlorophenolic notes. A quick way to make yourself look like a Home-Brew Guru to a novice brewer is to tell them how to dechlorinate their water, or how to make a proper bleach water solution, even though the information is in every basic homebrewing book!

Beer Flavor Wheel Number: 1412.
Discussion: See Body, Bitterness, Esters, Malty.

Cheesy

Detected in: Aroma, flavor.
Described As: Dry, stale cheese, hydrolytic rancidity
Typical Origins: Hops, oxidation.
Typical Concentrations in Beer: n/a.
Perception Threshold: n/a.
Beer Flavor Wheel Number: 0612.
Discussion: See Butyric and Isovaleric Acid.

Chewy

See Body.

Chlorophenol (Phenol)

Detected in: Aroma, flavor, mouthfeel.
Described As: Adhesive tape, antiseptic, Band-Aid™, Chloraseptic™, disinfectant, “hospital-like,” medicinal, mouthwash, plastic, trichlorophenol (TCP), uncured lacquer. In high levels they might have an astringent, drying, numbing, prickly or puckering mouthfeel.

Typical Origins: Process/equipment faults, contamination.
Typical Concentrations in Beer: 0 mg/l.
Perception Threshold: 1-5 µg/l in water, 3-40 µg/l in beer.
Beer Flavor Wheel Number: 0504.

Discussion: Chlorophenols (e.g., 2,6-dichlorophenol) are a class of phenols (see Phenols); a large family of aromatic alcohols consisting of a benzene ring plus a hydroxyl group and side chains.

Chlorophenols are phenols with a chlorine side chain. They are formed from chemical reactions between alcohol and chlorine-based sanitizers, chlorine or chloramines used to treat water supplies, or water polluted with chlorine compounds.

Unlike esters or fusel alcohols, phenols are largely non-volatile and don't get converted into other compounds. This means that once they're in a beer, they tend to remain in it.

There is genetic variation in the ability to detect certain phenolic compounds and some people are completely insensitive to them. Also see Bromophenols, Iodoform, Phenol, Smoky, Spicy and Vanilla.

To Avoid: * Use chlorine-based cleaners and sanitizers in the proper concentrations; more isn't necessarily better * Thoroughly rinse brewing equipment and packaging to remove chlorine sanitizer. * Treat treated water to remove chlorine or chloramines. Filter through a carbon filter to remove chloramines and chlorine. Let tap water sit overnight to remove chlorine (won't work for chloramines). Add 1 Campden tablet (40 mg potassium metabisulfite) per 20 gallons of water to remove chloramines; let stand 15 minutes or boil. * Don't use polluted water (e.g., exposed to industrial pollutants).

When Are Chlorophenols Appropriate?: Never. Off-flavors and aromas from chlorophenols are always a fault in beer.

Chocolate

See Roasty

Cidery

Detected in: Aroma, flavor.

Described As: Apple, green apple.

Typical Origins: Adjunct sugars, yeast.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Beer made with a high proportion (20% or more) of sugar often has a cidery flavor and aroma, which is usually reinforced by thin body. Cidery character might be due to weak or incomplete fermentation caused by insufficient yeast nutrients, which results in higher levels of acetaldehyde.

To Avoid: * Reduce or eliminate the amount of simple sugar in the wort. * Add yeast nutrient.

When Is Cidery Character Appropriate?: Never.

Citrusy

Detected in: Aroma, flavor.

Described As: Citral, grapefruit, lemon, lemon zest, lime, orange, orange rind, orange marmalade, tangerine.

Typical Origins: Hops, fruit or spice additions, yeast.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: 0141.

Discussion: Citrusy notes in beer are caused by Esters and Phenols (q.v.). The more floral and fruity notes are usually produced by esters, while the spicy and herbal notes are typically caused by phenols. Hops, especially modern American, high-alpha acid varieties, contain essential oils, such as b-Selenene, a-Muurolene, Limonene, Limonene-10-ol, Citral, Nerol, l-Cadinene, D-Cadinene and oxidized Myrcene, which are also found in citrus fruits.

Some yeast strains can also produce citrusy notes, notably Belgian witbier yeast, which can produce orange-like notes.

Belgian witbier, is traditionally flavored with bitter (Curaçao) orange (*Citrus Aurantium*), which produces herbal, citrusy notes, reminiscent of chamomile. Some American interpretations of the style use sweet orange (AKA Valencia orange), which produces a familiar "orange peel" aroma like that found in Grand Marnier or Triple Sec liqueur, or orange flavoring. Likewise, specialty beers flavored with bitter orange or sweet orange might also have similar flavors and aromas.

Regular navel oranges don't have such strongly flavored peel, and have much thicker pith. This pith contributes bitterness, and possibly ham-like notes, but no orange aroma.

Finally, some herbs and spices can produce aromas and flavors which are reminiscent of orange or lemon, notably coriander and melissa (AKA lemon balm).

Also see Esters, Ham, Hoppy and Spicy.

To Avoid: * Change hop variety. * Reduce or eliminated flavor and aroma hop additions. * Change yeast strain. * Ferment at a lower temperature. * Don't add citrus, citrus peel, herbs or spices.

When Are Citrusy Appropriate?: Citrusy notes from hops are acceptable, even expected, in hoppy American ales. Bitter orange or sweet orange notes are expected in Belgian witbiers.

Clinging Bitterness

See Alpha Acids, Astringency, Metallic or Mineral.

Cloudiness

Detected in: Appearance.

Described As: Cloudy, foggy, hazy, opaque, turbid, yeasty.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Haze is caused by tiny particles suspended in beer. There are five types of haze:

1) **Biological Haze (AKA Bacterial or Yeast Haze):** Caused by suspended microorganisms.

2) **Oxidation Haze:** Haze formed when protein compounds in beer become oxidized. With sufficient aging, oxidation haze will eventually form in all beer.

3) **Pectin Haze:** Haze caused by suspended pectin (polysaccharide) from fruit. Only found in fruit beers.

4) **Protein Haze (AKA Chill or Tannin Haze):** Caused when high molecular-weight proteins (from malt) & polyphenols (from husks & hops) complex and begin to precipitate. It is especially noticeable when beer is chilled to 55 ° F or lower, since cooling accelerates the rate at which the particles bind together.

5) **Starch Haze (AKA Permanent Haze):** Caused by large molecular weight carbohydrates, including beta-glucans, suspended in beer.

To Avoid or Control Cloudiness

1) **Filtration:** 10-20 micron "trap filtration" removes most sediment & ice crystals. 3-5 micron filter removes dead yeast and most starch and hop particles, giving brilliant clarity. 1 micron filter removes yeast and chill haze particles. 0.65 - 0.5 micron filter removes most bacteria. 0.2 micron filter removes all bacteria.

2) **Cold Conditioning:** Extended cold-conditioning/lagering time can help yeast flocculate and allows protein or starch particles which come out of solution at lower temperatures to precipitate. Lagering is cold conditioning at ~32 °F for 2 or more weeks.

3) **Finings:** All finings require at least 50 mg/l calcium in water to work. Most work by electrostatically attracting suspended particles to the particles of fining material, forming larger particles which precipitate more quickly.

A) **Kettle/Copper Finings:** Help coagulate hot break, proteins responsible for protein/chill haze and flavor instability. All work by coagulating proteins. Typical kettle finings are: Irish moss (dried seaweed - *Chondrus Crispus* - at 50-150 mg/l), Protofloc™ (added at 30 mg/l), carrageen (a gum used in food production - derived from seaweed), and Whirlfloc™ (20-60

mg/l). All are added at the rate of approximately 1 tsp or tablet/5 gallons in the last 15 minutes of the wort boil.

B) Fermenter/Cold Side Finings: Either added to conditioning vessel near the end of conditioning period or added to the cask (for cask-conditioned ales). Used to remove yeast, protein, polyphenol or starch hazes. Fining are often packaged as powders and must be rehydrated using sterilized hot water. They take time to work - at least 25 hours.

Common yeast flocculants are isinglass (dried collagen obtained from the dried swim bladders of fish, historically sturgeon or cod, now various fish species from the South China Sea. Added at 1-3.5 mg/l at 42-55 °F), brewers' gelatin (added at 60-90 mg/l - not as effective as isinglass),

Polyclar™ or PVPP (tiny beads of polyvinyl pyrrolidone - plastic) is a polyphenol binder used to remove chill haze (6-10 g/5 gal).

Silica gel is a protein binder used to remove protein haze (usually added at 1-3.5 mg/l).

4) Other Methods: Depending on the type of haze and beer style, other methods might work:

A) Biological Haze: Yeast strain (some yeasts don't flocculate well). Increase conditioning time. Use proper sanitation to avoid bacterial or wild yeast infection. Fine using cold side finings (see above). Use protease enzymes such as papain.

B) Oxidation Haze: Avoid aeration of wort & beer, except after pitching yeast. Store beer at cool temp. (32 -55 °F).

C) Pectin Haze: Don't expose fruit or fresh fruit juice to temperatures above 170 °F. Add papain or pectinase enzyme as necessary.

D) Protein Haze:

- *Alter Grain Bill:* Use malt with lower protein content. Limit the use of protein-rich grains (e.g., wheat, rye, oats). Use adjunct grains to reduce overall protein content of grist.

- *Use a protein rest (113-131°F).*

- *Avoid Polyphenol/Tannin Extraction.* Don't over-crush grain to avoid getting polyphenol/tannin rich husk particles into wort. Don't over-sparge mash (i.e., pH above 5.8, S.G. below 1.008). Don't heat mash above 168 °F. Don't heat grains or tannin-rich fruits, herbs, spices or vegetables above 168 °F. Recirculate or vorlauf mash runoff until it runs clear to avoid carrying husk particles into copper.

- *Get a good hot break.* Boil wort for at least 1 hour at a rolling boil. Use hot-side finings (see above)

- *Get good separation of hot break from wort so trub isn't carried into the fermenter.* Commercial breweries sometimes use filtration or a hopback to achieve this.

- *Quickly cool wort to precipitate cold break.* Ideally, temperature should drop from boiling to below 100 °F within 30 minutes.

- *Get good separation of cold break so trub isn't carried into fermenter.* But, some cold break in the fermenter is necessary for yeast health.

- *Use cold side finings in the conditioning tank,* as described for Biological haze. Papain can break down proteins, but its action is indiscriminate and can affect body and head formation.

- *Increase cold conditioning time.*

- *Serve beer at temperatures above 55 ° F.*

E) Starch Haze:

- *Use high-quality malt* (lower beta-glucans).

- *Don't over-crush grains* to avoid getting starch particles into beer.

- *Use a beta-glucan rest during mashing* (110 °F for 15 min.).

- *Improve mashing technique.* Increase mashing time to insure complete starch conversion. Make sure that mash temperature is in the correct range for optimal starch conversion (~143-158 °F). Test for complete starch conversion before mashing out. Recirculate or vorlauf mash runoff until it runs clear (to avoid carrying starch particles into copper).

- *Some brewers use amylase enzyme* in the fermentation or conditioning tank, but this is problematic since amylase will eventually destroy all starches in your beer, not just beta-glucans.

When is Brilliant Clarity Expected?: Brilliant clarity is expected in: Light lagers, German pilsner, Bohemian pilsner, amber lagers, cream ale, blonde ale, Kölsch, northern German altbier, Düsseldorf altbier, Scottish ales.

When is Cloudiness Appropriate?: Whether haze is appropriate depends on the type of haze and the beer style:

* **Biological Haze:** Usually a fault, except in German wheat or rye beers served *mit hefe* (with the yeast roused). Slight biological haze is acceptable in straight (unblended) lambic).

* **Chill Haze:** Chill haze is acceptable in barleywines.

* **Oxidation Haze:** Never appropriate.

* **Pectin Haze:** Never appropriate.

* **Starch Haze:** Slight to extreme cloudiness due to suspended particles of wheat or rye are appropriate in American wheat or rye beers, German wheat and rye beers and Belgian witbier. Slight starch haze is acceptable in saison, bière de garde, straight (unblended) lambic and Belgian strong dark ale.

Clove

See Spicy.

Coconut

Detected In: Aroma, flavor.

Described As: Coconut, nutty, oaky, whiskey-like, whiskey lactone, wood-like.

Typical Origins: Wood-aging.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0222.

Discussion: Associated with wood-aged beers, especially those aged in oak casks. Whiskey lactone is a major flavor and aroma in some whiskeys and to a lesser extent in oak-aged beers and other distilled spirits.

While the exact origin of whiskey lactone is unknown, it is believed to come from the metabolism of malt-derived compounds by lactic acid bacteria (especially *Lactobacillus* spp.) during fermentation.

Coffee

See Roasty.

Control

Detected In: n/a.

Described As: n/a.

Typical Origins: n/a.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: 0000

Discussion: In every flight of doctored beers, there should be at least one fault-free undoctored beer. For tracking purposes, it is called the control and is sometimes given the tracking number of 0000.

Cooked Cabbage

See Sulfury.

Cooked Corn

See Dimethyl Sulfide (DMS).

Cooked Onion

Detected In: Aroma, flavor.

Described As: Dimethyl trisulfide, onion.

Discussion:

Typical Origins: Bacterial contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0736.

Discussion: See Onion or Vegetal.

Cooked Potato

See Methionol, Sulfury or Vegetal.

Cooked Tomato

Detected In: Aroma, flavor

Described As: Tomato juice (processed), tomato ketchup.

Typical Origins: Bacterial contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0733.

Discussion: See Vegetal.

Cooked Vegetable

Detected In: Aroma, flavor

Described As: Reminiscent of various sorts of vegetables, especially cruciform vegetables.

Typical Origins: Bacterial contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0730

Discussion: Mainly dialkyl sulfides, sulfurous-RSR, methyl thioacetate. See Onion or Vicinal Diketones (VDK).Vegetal.

Corn Grits

Detected In: Aroma, flavor.

Described As: Maize grits, adjunct.

Typical Origins: Grain adjuncts.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0312

Discussion: See DMS, Grainy or Malty.

Creamy

See Body, Head Formation and Retention or Silky.

Diacetyl

See Vicinal Diketones (VDK)

Diaper

See Indole.

Dimethyl Sulfide (DMS) (Sulfur)

Detected in: Aroma, flavor.

Described As: Cooked broccoli, cooked corn, cooked vegetable, corn, celery, cabbage, canned vegetables (e.g., canned asparagus), creamed corn, grainy, green beans, malty, olives, oysters, parsnips, sea vegetable, seaweed, sulfury, sweet corn, tomato juice, tomato sauce, vegetal, warty. Garlic or leeks (in pure form).

At high concentrations it can smell and taste like shellfish or water in which shrimp have been boiled. In pale beer it is usually detected as being corn-like. In darker beer, it can seem more tomato-like or vegetal.

Not to be confused with hydrogen sulfide (rotten egg) or sulfur dioxide (matches).

Typical Origins: Malt, microbial contamination.

Typical Concentrations in Beer: 10 - 150 µg/l.

Perception Threshold: 10 - 150 µg/l, 25-50 µg/l in beer.

Beer Flavor Wheel Number: 0732.

Discussion: Dimethyl sulfide (DMS) is a volatile sulfur-based organic compound derived from S-methyl methionine (SMM) which is an amino acid derivative synthesized when grain germinates during malting. No DMS is produced during germination, though.

SMM levels depend on barley strain and how the grain is malted; British pale ale malt has the lowest SMM levels, while Pils and 6-row lager malts have the highest levels (up to 8 times that of pale ale malt). Drying and kilning the malt at higher temperatures converts some SMM also drives off some DMS, so darker malts have less DMS than paler malts (e.g., the difference between Pils malt and Munich malt). Adjunct grains such as corn also contain high levels of SMM.

SMM is liberated into solution during mashing and is degraded into DMS during wort boiling. The chemical reaction is SMM > Dimethyl Sulfoxide (DMSO) > DMS. Fortunately, DMS is a volatile compound, so it can be driven off during a long, vigorous boil. Since DMS is produced at temperatures below boiling, slow cooling of the wort means that DMS is formed which isn't boiled away. Vigorous fermentation, especially open fermentation, also helps to drive off DMS.

Wild yeast or *Zymomonas* or *Proteus* bacteria may produce high enough DMS levels as to make beer undrinkable, but these also produce other off-flavors such as acetic acid, phenols and other sulfur compounds.

Increased by: * *Malt choice.* Pale, undermodified, continental malts have more SMM than darker, fully modified, UK varieties. SMM is also higher in malt with high moisture content (so store malt in a dry place). High levels of corn-based adjuncts in grist. * *Oversparging at low temperatures (below ~160 °F).* * *Weak or short wort boil* insufficient to drive off DMS. Get a full, rolling boil of at least 90 minutes. Get at least 8% evaporation when using pale lager malts. * *Slow wort cooling.* Don't let hot wort stand. Cool it immediately, as quickly as possible. * *Bacterial or wild yeast infection,* usually by *Obesumbacteria Proteus.* (This bacteria only grows during the lag phase of fermentation, when wort pH is at 4.4 or higher. It can be a problem if fermentation is sluggish or if the lag period is long - 24 hours or more.)

To Avoid or Reduce: * Use good-quality, properly-stored malt. Reduce levels of corn-based adjuncts. * *Keep sparge temperature near 168 °F. Don't collect wort below 1.008 S.G.*

* *Vigorous rolling wort boil.* Boil for at least 1-1.5 hours, depending on malts and beer style. Get at least 8% wort evaporation when using pale lager malts. * *Practice good sanitation* (i.e., Avoid cold side use of wooden or scratched plastic utensils/containers). * *Good yeast management.* Pitch sufficient yeast to minimize lag phase (at least 0.5-1 quarts per 5 gallons, more for high gravity beers and lagers). Minimize yeast shock - match starter gravity & temperature to that of wort.

When is DMS Appropriate?: Low levels are acceptable in light lagers, German pilsner, classic American pilsner, dark American lager, maibock and cream ale.

DMS

See Dimethyl Sulfate.

Dry-Hop Flavor

Detected In: Aroma, flavor.

Described As: Hop aroma.

Typical Origins: Dry hops added in tank or cask.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0172

Discussion: See Hoppy.

Drying

Detected In: Mouthfeel, Aftertaste.

Described As: Unsweet.

Typical Origins: Astringency, dark malt character, lack of residual sugars.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1341

Discussion: See Astringency, Body or Malty.

Earthy (Sulfury)

Detected in: Aroma, flavor.

Described As: Basement/cellar-like, compost, damp basement/cellar, damp soil, dank, earthy, freshly-dug soil, fusty, moldy, mushroom-like, musty, wet basement/cellar. Occasionally described as "beet-like."

Typical Origins: Microbial contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: 5 µg/l.

Beer Flavor Wheel Number: 0841.

Discussion: Defect in beer caused by using water contaminated by microorganisms or by contamination with chemicals produced by bacteria which live in cellars and other damp places. Closely related to Musty character (see Musty). The active ingredient is 2-ethyl fenchol and similar compounds. Also see Musty.

To Avoid: * Make sure that equipment, especially items made of plastic or wood, are dry (or filled with sanitizer) before storing them. * Don't leave plastic or wooden conditioning tanks in contact with damp, moldy surfaces (e.g., don't put plastic buckets directly on damp basement floors). * Reduce humidity in cellaring areas to discourage bacterial growth.

When is Earthy Character Appropriate?: Never. Although the BJCP guidelines allow that some commercial examples of

bière de garde might have a bit of musty character, this should be due to yeast strain, not due to actual contamination or "corked" notes.

Electrical Fire

See Bromophenol, Chlorophenol or Phenol.

Enteric

See Indole

Esters

Detected In: Aroma, flavor.

Described As: Bubblegum, butter, candy (e.g., Artificial fruit, bubblegum, Circus Peanuts, Froot Loops™, Juicy Fruit™ gum, pear drops, Trix™ cereal), cream, citrusy (e.g., lemon, lime, orange, tangerine), floral (e.g., feijoa, flowery, geranium, jasmine, lavender, perfumy, rose, ylang-ylang), herbal (e.g., pine, sage), honey, plant-like (e.g., "green," green banana, new-mown hay, parsnip, waxy), soft fruit (e.g., grape, raspberry, strawberry), spicy (e.g., aniseed, cinnamon, wintergreen, liniment), tree fruit (e.g., apple, apricot, cherry, peach, pear), tropical fruit (e.g., banana, canned pineapple, coconut, mango, papaya, passion fruit, pineapple, "tutti-frutti"), "sweet" (aroma only) and/or vinous (e.g., wine-like, rum, sherry). Bitter, solventy or glue-like in very high concentrations.

Typical Origins: Yeast.

Typical Concentrations in Beer: variable.

Perception Threshold: 5-15 µg/l.

Beer Flavor Wheel Number: Variable.

Discussion: In beer, esters are formed by the esterification of fatty acids by Ethanol, and also in small amounts by the esterification of Fusel Alcohols.

Ester precursors are produced as minor elements of yeast metabolism: Alcohol Acetyl Transferase (AAT) and Acetyl Coenzyme A (aCoA); aCoA is normally used for the synthesis of lipids, which the yeast cell needs to build cell membranes. Esters are formed under conditions when aCoA isn't needed for synthesizing cell components. So factors which promote yeast growth (e.g., high levels of aeration) lower ester production. Also see Solventy.

Esters are mostly produced during the main (fermentation) phase of primary fermentation, but can increase slowly during the late phases of fermentation and during secondary fermentation. During long secondary fermentation, the level of esters might double.

Acceptable thresholds for esters in bottom fermented beers are up to 60 mg/l. Top fermented beers can contain up to 80 mg/l of esters.

Type and character of esters produced depends on the exact chemical reaction. Perception thresholds vary depending on the exact molecule. While there are about 60 different esters found in beer, the most important are: ethyl acetate, isoamyl acetate, isobutyl acetate, -phenyl acetate, ethyl hexanoate, and ethyl caprylate.

* **Ethyl Acetate:** The most common ester in beer, most typically described as smelling like ripe apples, pears or pear drops. *Typical Concentration in Beer:* 5-30 mg/l. *Perception Threshold:* 25-30 mg/l. See Solventy/Solventy Esters for full discussion.

* **Ethyl Butyrate:** *Canned pineapple, mango, papaya, pineapple, tropical fruits.* One of a family of butyrate esters found in beer. Imparts a welcome fruity ester character to some

beer styles (e.g., Belgian ales), but can also be an indicator of poor sanitation, since it is formed from worts which have higher levels of butyric acid (see Butyric). *Typical concentration in beer:* 0.05-0.25 mg/l. *Perception Threshold:* 0.04-0.4 mg/l. *Beer flavor wheel number:* n/a.

Ethyl Caprylate (AKA Ethyl Octanoate): Floral, Fruity (apple, apricot, banana, pear, pineapple), soapy, sweet, vinous (brandy, wine-like), waxy. Present in all beers, although concentrations vary widely. Concentrations are higher in Belgian beers. *Typical Concentration in Beer:* ?. *Perception Threshold:* 0.01-1.5 mg/l. *Beer flavor wheel number:* n/a.

* **Ethyl Hexanoate (AKA Ethyl Caproate, Ethyl Pentanoate):** Aniseed, apple, banana, brandy, floral (roses), fruity, “green,” honey, pineapple, rum, sherry, strawberry, “sweet” (aroma), wine-like. Present in all beers, although concentrations vary widely. A defect at high concentrations. *Typical Concentration in Beer:* 0.07-0.5 mg/l. *Perception Threshold:* 0.15-0.25 mg/l. *Beer flavor wheel number:* 1032. Also see 0142 Apple

* **Isoamyl Acetate:** Banana, Circus Peanuts candy, pear, pear drops. Present in all beers, although concentrations vary widely. Part of the signature of German wheat and rye beers. *Typical Concentration in Beer:* 0.8-6.6 mg/l. *Perception Threshold:* 0.6-4.0 mg/l. *Beer flavor wheel number:* 0131.

* **Isobutyl Acetate:** Papaya, apple. Present in all beers, although concentrations vary widely. Concentrations are higher in Belgian beers. *Typical Concentration in Beer:* 0.1-0.3 mg/l. *Perception Threshold:* 0.4-1.6 mg/l. *Beer flavor wheel number:* n/a.

Also see Solventy.

Other Esters

Ester	Description	Threshold
Butyl acetate	Banana, sweet	0.04-0.4 mg/l
Ethyl caprate	Goaty	0.01-1.0
Ethyl caprylate	Apple, sweet, fruity	0.01-1.5
Ethyl dodecanoate	Soapy, estery	3.5
Ethyl lactate	Fruity, strawberry	250
Ethyl myristate	Vegetable oil	0.4
Isoamyl propionate	Aniseed, pineapple	0.015
Phenylethyl acetate	Apples, honey, roses	0.05-3.8

Increased by: * Yeast strain. * Improper Yeast Management: Wild yeast infection. Insufficient or excessive yeast growth. FAN/Amino Acid deficiency. Mineral (Zinc, Calcium, etc.) deficiency. Underpitching yeast. Low dissolved oxygen - low oxygen levels limits rate of yeast reproduction due to limited sterol in cells. Incorrect fermentation temperature for strain, especially high temperature fermentation. * Aeration of green beer during growth phase of fermentation. * High gravity wort (above 13-15 °P, 1.052-1.060 O.G.) - going from 10 °P to 20 °P (1.040-1.080 O.G.) results in fourfold ester production. * High ethanol concentration (>9%). Dehydration of yeast. Excessive trub. * Moving green beer or fermenting wort during fermentation or maturation. * Wild yeast infection. * High pressure, either due to hydrostatic pressure due to fermentation vessel design or high pressure due to CO2 buildup (this is mostly a problem for large commercial breweries).

Decreased by: * Overpitching yeast. * Proper Yeast Management: High dissolved oxygen. Adequate oxygen levels for wort strength. Increased lipids in wort - carrying over more cold break into fermenter. Correct fermentation temperature for

strain - especially fermenting at the cool end of the proper temperature range. * CO₂ buildup in fermenter. * Aging - esters are degraded by esterases produced by yeast; they are also volatile and will evaporate or degrade into other compounds over time.

To Avoid or Control: Choose appropriate yeast strain. Pitch correct amount of yeast (less for higher fusel levels, which translates into higher esters levels) at 0.5 to 1 quarts of yeast slurry per 5 gallons. Maintain proper fermentation temperature for strain (higher temperature means more fusel alcohols, meaning more esters). Match starter to wort gravity & temperature.

Adequately oxygenate wort after pitching yeast (O₂ is used by yeast to make unsaturated fatty acids, using up aCoA and increasing thickness of cell membranes, thus preventing ester formation). Don't aerate wort once fermentation starts. Proper separation of trub from wort. High-pressure fermentation decreases yeast growth, hence fusel precursors - it is used by some large lager breweries. Aging will decrease or eliminate esters (over the course of 1+ year).

When Are Esters Appropriate? Esters are expected low to medium concentrations in American ales and hybrid styles.

They can be present in low to high concentrations in Belgian, English & German Ales. Younger, fresher ales will have higher ester concentrations.

German wheat and rye beers are noted for isoamyl acetate (banana) esters.

Belgian ales often have for bubblegum, tutti-frutti, pineapple & “tropical fruit” notes.

Sugar: Amino Acid Ratio on flavor production by yeast

Compound	Flavor	Impact of C:N Ratio
DMS	sweet corn	Higher ratio = more DMS
Esters, e.g., iso-amyl acetate	Banana	higher ratio = more ester
Higher alcohols, e.g., methylbutanol	Solvent	Too low or high a ratio = more alcohol
VDK e.g., diacetyl	Butterscotch	Higher ratio = more VDK
Organic acid, e.g., citric	Sour	Higher ratio = lower pH through reduced buffering
Fatty acids, e.g., decanoic	Various	Higher ratio = less fatty acid.

Ethanol

Detected In: Appearance, Aroma, flavor, mouthfeel.

Described As: Alcoholic, spicy, peppery or vinous in aroma and flavor. Burning, numbing, prickly and/or warming in mouthfeel. Can also be detected as a prickliness, warming, pepperiness or pain in the nasal passages. High alcohol beer (above ~8% ABV) might have distinct alcoholic “legs” which become visible when the beer is swirled in the glass and then allowed to settle.

Typical Origins: Yeast.

Typical Concentrations in Beer: 25,000-50,000 mg/l.

Perception Threshold: 5,000-13,000 mg/l. (About 6% ABV in beer).

Beer Flavor Wheel Number: 0110.

Discussion: Yeast produces ethanol (along with carbon dioxide) as a major product of anaerobic respiration during

fermentation. Acetate and various fusel (“higher”) alcohols are produced as minor respiratory byproducts during the metabolism of amino acids. Ethanol, acetate and fusel alcohols can all react chemically with oxoacids to produce esters. Ethanol is detectable at 1.5-2% ABV. Also see Fusel Alcohol and Solventy.

Increased By: Yeast strain (beyond about 9% alcohol). High-gravity/highly-fermentable wort. Proper fermentation temperature for yeast strain. Higher fermentation temperatures. Longer fermentation times (if “feeding” a high-alcohol fermentation).

Decreased By: Improper choice of yeast strain. Poor yeast health/quality. Low fermentation temperatures. Prematurely removing yeast from fermenting wort (e.g., filtering or fining).

To Avoid or Control: Proper wort gravity. Proper level of fermentable sugars in wort. Proper yeast selection. Proper yeast health. Proper fermentation temperature for yeast strain.

When Are Alcoholic Notes Appropriate?: Low to medium-high levels of ethanol aroma, flavor and mouthfeel are desirable in any strong beer, specifically Bocks, Scotch Ale (Wee Heavy), Baltic Porter, Foreign Extra Stout, American Stout, Russian Imperial Stout, Weizenbock, Saison, Bière de Garde, Strong Belgian Ales and Strong Ales.

Very low ethanol notes are acceptable in Vienna Lager, Munich Dunkel, Cream Ale, American Wheat/Rye Beer, English Pale Ale, Irish Red Ale, American Pale Ale, American Amber Ale, American Brown Ale, Robust Porter, English IPA, American IPA and Belgian Pale Ale.

Detectable levels of alcohol are a fault in low-alcohol beers, specifically English Ordinary Bitter, Mild and Berlinerweisse.

Some Alcohols in Beer

Alcohol	Threshold	Character
Ethanol	14,000 mg/l	Alcoholic
Iso-Amylalcohol	50	Alcohol, bananas, vinous
Iso-Butanol	100	“
Phenylethanol	40-100	Roses, perfume
Propanol	600	“
Tryosol	200	Bitter

Ethyl Acetate

See Solventy

Ethyl Butyrate

See Esters

Ethyl Hexanoate

See Esters

Extract Twang

Beers made using stale or inferior malt extract can have a very distinct flavor, often described as “extract twang” or “extract tang.” Some of this flavor is due to associated process faults (e.g., not pitching enough yeast and not properly aerating the wort), some of it is due to the composition of the extract (Historically, many extracts which claimed to be “all malt” were actually partially made with sugar), and some of it is due to staleness.

See Acetaldehyde, Papery, Sherry-like, Solventy or Solventy-Stale.

Fat, Oil or Hydrocarbon

Detected In: Appearance, Aroma, flavor, mouthfeel.

Described As: Gasoline (petrol), Greasy, kerosene (paraffin), machine oil, mineral oil, oily, “rich,” solventy, vegetable oil, in aroma and flavor. In mouthfeel, fat or edible oils are described as being mouth-coating, oily or slick. Hydrocarbons are described as burning or solventy. In appearance, fat is detected as lack of head and poor head retention (oils quickly destroy head on beer) and possibly beads of oil on the beer’s surface.

Typical Origins: Contamination, additions of oily adjuncts.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: ?.

Beer Flavor Wheel Number: 0641 (Vegetable oil) 0642 (Mineral oil, gasoline, kerosene, machine oil)

Discussion: This category covers a variety of edible and inedible lipids (waxes, oils, sterols, etc.) and hydrocarbon compounds. They are all very rare in beer.

While fat is arguably one of the basic tastes (scientists are still debating over whether there are specific taste receptors for fat or fatty acids), detectably fatty substances (as opposed to fatty acids) don’t naturally occur in beer.

Oily or fatty substances in beer are associated with unusual adjuncts added to the beer (e.g., coconut, peanuts) or with accidental contamination of wort, beer or brewing equipment.

When evaluating beer, oil on glassware or on your lips can affect head formation and retention.

To Avoid: * Remove as much oil from oily ingredients to be added to beer as possible (e.g., repeatedly rinse with hot water). * Skim oil off top of wort kettle or primary fermentor. * Carefully clean and rinse brewery equipment. * Don’t use contaminated ingredients. * Only use food-grade plastics in brewing (some non-food-grade plastics have oily compounds on the surface). * Carefully clean and rinse bottles, kegs, casks and glassware. * Don’t eat oily foods when evaluating beer. * Don’t use lipstick, lip balm or similar products when evaluating beer.

When Are Fatty Notes Appropriate?: Never, except when dealing with specialty beers which include fatty adjunct materials. Contamination by non-edible fats, oils or hydrocarbon compounds is a serious defect.

Fatty Acid

Detected In: Aroma, flavor.

Described As:

Typical Origins: Contamination, additions of oily adjuncts.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0610

Discussion: See Butyric, Caprylic, Horsey, Esters, Isovaleric and Vicinal Diketones.

Fecal

See Indole.

Film or Flakes on Top of Beer

Detected In: Appearance, possibly Mouthfeel.

Described As: Flecks or a continuous film of material, either white and “papery” in appearance, or transparent and oily on the surface of the beer. The film might have a slimy or chunky mouthfeel

Typical Origins: Yeast activity, infection.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: A film on top of finished beer could be due to oils (see Fat, Oil or Hydrocarbon) if oily ingredients were added to beer (e.g., cocoa butter), or if brewing equipment or beer is contaminated with oils or fats. More typically, a film on top of the beer has a microbiological origin. In early phases of fermentation, or during bottle conditioning, yeast might form a pellicle (film) on the surface of the beer. When sanitation is poor and beer is exposed to the outside air, mold and aerobic bacteria can grow on the surface. This is seldom a problem with bottled beer, but can occur when beer is in the conditioning vessel or in a keg.

* Greenish or brownish flecks on the surface of the beer during initial fermentation, or during cask-conditioning, are due to hop particles or extracted hop resins and oils.

* A fine, dusty, slightly filmy, floury or oily pellicle on the surface is probably due to wild yeast, *Brettanomyces*, *Pediococcus* or *Acetobacter*. It can also be ordinary dust, although dust motes usually carry microflora along with them.

* A transparent film with a slimy, “ropy” texture is typically due to *Pediococcus* infection, although it can also be due to wild yeast.

* White flecks with the texture of burnt paper, or a thin, papery white pellicle is a sign of *Brettanomyces* infection (usually in conjunction with micoderma or other bacterial infection).

* Flecks of grayish or bluish material on the surface of the beer, sometimes with a fuzzy surface, are due to mold infection.

To Avoid: * Practice good sanitation. * Eliminate or remove oils or oily ingredients (see Fat, Oil or Hydrocarbon, above). * Carefully rack or filter dry-hopped beer, or beer with a film on it, during packaging.

When is a Film Appropriate in Finished Beer?: Never.

Discussion: See Body and Head Formation

Flat

Described As: Variable. Undercarbonated.

Typical Origins: Lack of carbonation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1361

Discussion: See Body and Head Formation and Retention.

Floral

Detected In: Aroma, flavor

Typical Origins: Damascenone, rose-like flower-like, fragrant.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0160

Discussion: See Esters and Solventy/Solventy Esters.

Fresh-Cut Grass

See Grassy.

Fruity

Detected In: Aroma, flavor

Described As: Specific fruits or mixtures of fruits.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0140

Discussion: See Esters.

Full Body

See Body.

Fusel Alcohols (AKA Fusel Oils, Higher Alcohols)

Detected In: Aroma, flavor, mouthfeel.

Described As: Alcoholic, “harsh,” solventy, spicy or vinous in flavor and aroma, sometimes reminiscent of cheap distilled liquors (e.g., cheap vodka or rum). Some fusel alcohols might have an initial sweetness, but a harsh aftertaste. Fusels are detected in mouthfeel as burning, harsh, hot, numbing or prickly sensations. Can also be detected as a prickliness, warming, pepperiness or pain in the nasal passages.

Typical Origins: Yeast.

Typical Concentrations in Beer: Variable, usually ~5-100 mg/l.

Perception Threshold: Variable, usually ~50-200 mg/l.

Beer Flavor Wheel Numbers: 0110, 0120.

Discussion: Various fusel (“higher”) alcohols are produced as minor respiratory byproducts by yeast during the metabolism of amino acids. Acetate and fusel alcohols can all react chemically with oxoacids to produce esters.

* Yeast can convert amino acids in the wort into higher alcohols by deamination (i.e., removing amine groups), decarboxylation and reduction.

* Metabolism or oxidation of hydroxy acids or ketoacids can form higher alcohols.

* Higher alcohols can be produced from sugars which are converted to acetate and then to higher alcohols.

* Acetate and fusel alcohols can all react chemically with oxoacids to produce esters. Oxidation of beer due to aging can convert fusel alcohols to esters.

In well-made beer fusels are usually present in sub-threshold concentrations. Distressed or wild yeast might metabolize fatty acids (carried into the wort as trub from the hot and cold break) as a source of oxygen and carbon, producing a greater fraction of long chain alcohols and raising fusels to detectable levels. Likewise, high gravity worts, high fermentation temperatures and high concentrations of alcohol also encourage yeast to produce higher alcohols.

In beer, even if it’s not harsh or unpleasant, strong alcoholic notes are usually due to elevated levels of higher alcohols. Pure ethanol has little aroma or flavor of its own and is mostly detected in mouthfeel. Fusel alcohol concentrations in top-fermented beers should not exceed 100 mg/l. Fusel alcohol concentrations in bottom-fermented beers should not exceed 60-90 mg/l.

Solventy notes can also be produced by very high levels of ethyl acetate and similar esters (see Esters).

While technically alcohols, Phenolic compounds are described in their own sections. Also see Ethanol and Solventy.

Alcohols in Beer

Alcohol	Flavor	Detectable range
2-phenylethanol	Roses, bitter, perfumed	8-35
4-vinyl guaiacol	Clove-like	0.05-0.55

Cis-3-hexen-1-ol	Fresh cut grass	0.025
Ethanol	Alcoholic, strong	<5,000 - 100,000 mg/l
Glycerol	Sweetish, viscous	1,300-2,000
Isoamyl alcohol	Vinous, banana, sweet	30-70
Isobutanol	Alcoholic	80-100
n-propanol	Alcoholic	~600
Phenol	Phenol	0.01-0.05
Propan-1-ol	Alcoholic	3-16
Tyrosol	Bitter	3-40

Increased By: * Increased fermentation temperature. * Pitching temperatures above 8 °C (46.4 °F). Wild yeast infection. * Poor Yeast Management; Underpitching. Mineral deficiency. Poor yeast health. Low dissolved oxygen in wort. Incorrect fermentation temperature for strain (too high or low - especially too high). Dehydration of yeast. Lack of Free Amino Nitrogen (FAN). Insufficient amino acids. Excessive aeration of wort (i.e., above 10 mg/l). * High gravity wort (above 13 °P, 1.052 O.G.). * Excessively high levels of amino acids in wort. * High ethanol concentration (>9%).* Wild yeast infection. * Movement of green beer (i.e., stirring or pumping, repeatedly topping up fermenting wort).

To Avoid or Control: * Proper fermentation temperature. * Cooler pitching and/or fermentation temperature. * Proper yeast health. Correct pitching rates for wort gravity and style. * Avoid oxygenating fermenting wort or green beer. * Proper sanitation to avoid wild yeast infection. * Avoid CO₂ buildup in fermentor. * Avoid over-modification during mashing, to avoid excessive levels of amino acids in wort. * Longer conditioning time - fusel alcohols break down over time, producing a “smoother” flavor. (This is the reason that makers of distilled beverages age their products, and why aged spirits are premium products.)

When Are Fusel Alcohol Notes Appropriate?: Detectable levels of higher alcohols are always a fault. They are likely to appear in strong beers, especially beers fermented at high temperatures (e.g., Belgian strong ales), but can also appear in poorly-made or inadequately aged eisbocks or strong ales.

Garbage

See Indole or Sulfury.

Garlic

Detected In: Aroma, flavor

Described As: Reminiscent of garlic, onions or similar vegetables.

Typical Origins: Infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0723.

Discussion: See Onion or Sulfury.

Gassy

Detected In: Mouthfeel.

Described As: Overcarbonated.

Typical Origins: Carbonation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1362.

Typical Origins: Carbonation.

Discussion: See Head Formation and Retention.

Geraniol

Detected In: Aroma, flavor

Described As: Geraniol, Rose-like, different from 0161. Taster should compare the pure chemicals.

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0162

Discussion: See Hoppy.

Goaty

See Caprylic, Horsey, Isovaleric and Leathery.

Grainy

Detected in: Aroma, flavor.

Described As: Cereal husks, Fresh wheat or barley, Grainy, Grapenuts™, “green,” “green malt,” “harsh,” husky, nutty, raw grain flavor.

Typical Origins: Process/equipment faults, Malt.

Typical Concentrations in Beer: <1 - 20 µg/l.

Perception Threshold: 10 µg/l.

Beer Flavor Wheel Number: 0310.

Discussion: Caused by compounds such as isobutyraldehyde which are naturally found in grain husks. As with Polyphenols (see Cloudiness and Phenols) these compounds are extracted from husks due to over-crushing, oversparging, sparging with hot or alkaline water, or excessively long mashes. Higher levels of isobutyraldehyde are found in freshly-made malt which hasn't had sufficient time to rest (2-8 weeks).

To Avoid: * Allow freshly-made malt to rest for sufficient time. * Don't overcrush grains. * Proper mashing and sparging technique. Keep wort and sparge pH in 5.2-5.6 range. Don't collect wort below 1.008 S.G. * Keep mash-out temperature at ~168 °F or less. * Don't mash for more than 2 hours. * Don't expose steeping grains or grain particles to temperatures above ~168 °F. * Don't boil grains or grain husks.

When Are Grainy Notes Appropriate?: Grainy notes at low levels are acceptable in malt-oriented lagers, especially light-colored lagers. They are inappropriate in ales.

Grapefruit

See Citrusy or Hoppy.

Grassy

Detected In: Aroma, flavor.

Described As: Alfalfa, crushed green leaves, fresh grass, grass clippings, green leaves, hay, hedge trimmings, leafy, new-mown hay, sagebrush.

Typical Origins: Aging, aldehydes.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: 15 mg/l.

Beer Flavor Wheel Number: 0231.

Discussion: Caused by various compounds, including the aldehydes hexanal (e.g., cis-3-hexenol), furfuryl octanoate, and heptanal, which are produced by the use of large quantities of hops (especially fresh, undried hops), oxidation of alcohols in the finished beer, and/or the deterioration of improperly stored malt or hops. Certain strains of hops also impart grassy flavors and aromas to beer.

To Avoid: * Don't use undried hops. * Don't use aged hops. * Properly store beer. * Avoid oxidation of wort or beer. * Use a long wort boil to eliminate grassy aromas and flavors (they are driven off by a long boil time).

When are Grassy Notes Appropriate?: Some strains of English and American hops produce grassy notes when used in large quantities, but such notes are only appropriate at low levels and only in highly hopped beers (e.g., IPA).

Ham

Detected In: Aroma, flavor.

Described As: Bacon, cooked ham. Can also be accompanied by bitter, celery-like or soapy notes.

Typical Origins: Herb or spice additions.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Ham-like aromas are occasionally found in homebrewed interpretations of Belgian witbier, or beers where similar ingredients have been added. These aromas can occur when common or aged coriander is substituted for fresh, Oriental coriander. When this happens, oxidized essential oils can also give rise to soapy or celery-like notes.

The chemicals which produce ham-like aromas are furans and, possibly, essential oils such as b-Selenene and Cadinenes.

To Avoid: * Reduce or eliminate herb or spice additions. * Use fresh oriental coriander.

When are Ham Notes Appropriate?: Never.

Harsh

See Astringency.

Haze

See Cloudiness.

Head Formation and Retention

Detected In: Appearance.

Described As: Low head formation is described as headless, flat, lifeless, low, minimal, poor, still, thin or weak. Low head retention or poor head retention is described as fast-fading, low persistence or short-lived.

High head formation is described as frothy, full, large or thick. High head retention is described as lingering, long-lasting, long-lived or persistent.

Whether high or low, foam can appear to have a creamy, dense, foamy, frothy, lacy, moussy, rocky or solid texture. These adjectives are more typically applied to beers with larger heads, since there is more head to observe!

Typical Origins: Yeast, Packaging.

Typical Concentrations in Beer: 1.5-4.0 volumes CO₂/liter depending on style. 2.0-2.5 is average.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a. (Carbonation: 1360. Overcarbonation: 1361, Undercarbonation: 1362).

Discussion: Head on beer is formed when pressurized gas, typically carbon dioxide, but sometimes nitrogen (CO₂ or N₂) comes out of solution & interacts with surface-active materials, which form a skin around the gas bubbles, keeping them from escaping into the air. As gas vents from the beer, the foam gradually collapses. More gas means more potential foam.

Smaller, more even bubbles produce a longer-lasting, more stable head.

Head-Forming Materials: Head forming materials in the beer are short- to medium-chain proteins and starches (dextrins) in the beer, along with appropriate levels of dissolved gas (carbon dioxide or nitrogen) in the beer and sufficient nucleation sites (due to suspended particles of material) to encourage bubble formation.

Head Retention: Head retention is due to the factors listed above, as well as alpha acids and larger starch and protein particles in the beer. Head retention is measured in terms of the time required for the head to collapse to half its initial height. It should last at least a minute for in well-made beers.

Head texture should be uniform and tight, leaving "lace" on the glass as the beer is consumed.

Foam positive substances: The main foam producers are medium-length proteins (10k - 60k molecular weight) and water-soluble gums (e.g., beta-glucans), but also isohumulones and dextrins. Unoxidized tannins and anthocyanogens play a minor role. Increasing viscosity also increases foaming, so beers with fuller body produce more foam. Nitrogen gas aids foam by forming smaller bubbles than CO₂. Higher temperature kilning promotes foam-forming materials in malt. Commercial brewers also use heading agents to promote head production and retention.

Foam detrimental substances: Oils, fats, waxes & alcohols are all detrimental to foam production. High levels of amino acids, low molecular weight polypeptides, oxidized tannins & anthocyanogens are also detrimental to foam.

Lack of Head Retention: Lack of head retention and/or formation is caused by a number of factors:

1) Presence of Oils: Oils in beer or on the inside of the glass reduces surface tension. This keeps bubbles from forming and breaks down bubbles faster.

2) Lack of proteins. Short-chain polypeptides (proteins) are needed for head formation, while medium length polypeptides are necessary for head stability.

3) Lack of carbonation. Low levels of dissolved carbon dioxide and/or low levels of pressure mean less carbon dioxide to form bubbles.

4) Lack of nucleation points. In order for bubbles to form, there must be places where bubbles can "attach" themselves. In beer, nucleation points can form on the inside of the glass or on suspended material. This is one of the reasons why hazy beers tend to form bigger heads than clear beers, especially those which have been highly filtered.

5) Lack of hops. Alpha acids from hops help bubbles to cling together which aids head stability. Suspended hop particles help bubbles form. This explains why hoppy beers, such as pilsners and IPA have bigger, frothier heads than similar beers with less hop bitterness.

6) Lack of dextrins and starches. Starches aid foam stability. This is the reason that beers with high levels of starches, such as wheat beers, form bigger heads.

7) High levels of fatty acids. Fatty acids (from wort trub) inhibit bubble formation and head stability.

8) High alcohol levels. High levels of ethanol and/or fusel alcohols reduce surface tension. This is why strong beers don't form as much head as weaker ones.

9) Age. Age reduces carbon dioxide levels and breaks down compounds which help form and retain head.

10) Large bubbles. Smaller bubbles produce greater head. Nitrogen served beer works on this principle.

11) Excessive agitation. Shaking up beer can make it “use up” foam-producing compounds.

To Improve Head Formation and Retention:

1) Clean. Properly clean brewery equipment & serving containers. Oils and fats kill head retention, as do dish and dishwashing soap. Use different cleaners and rinse thoroughly. Use proper beer glassware cleaning agent for your beer glasses.

2) Alter Grist. Use body & head enhancing malts with high dextrin & protein levels., e.g., Crystal, Carafoam™, wheat, oats. Reduce percentage of fermentable adjunct sugars. *Drawbacks:* Can interact with tannins to promote chill haze, suspended starch/protein particles reduce clarity. Risk of stuck mash when using malts with high levels of proteins or gums.

3) Alter mash schedule to enhance head-retaining proteins.

A) Avoid Beta-Glucan rest (110 °F) unless dealing with v. gummy mash (e.g., rye, oats).

B) Use a protein rest (122 - 140 °F for 20 minutes). Use a protein rest to increase polypeptide levels, especially when using undermodified malts. This promotes the formation of short and medium-chain proteins, thus promoting head forming compounds.

C) Avoid a long protein rest (1+ hour): This can break down proteins too much, which will negatively affect head formation.

D) High Temperature Mash. Mashing at 154-162 °F at 5.5 - 5.6 pH promotes Dextrin formation by favoring Alpha-Amylase action.

E) Reduce wort gravity to reduce alcohol levels. *Drawback:* Less booze in your beer, not appropriate for all styles.

4) More high alpha acid bittering hops. Increasing isohumulones increases head formation. *Drawback:* Increased hop bitterness.

5) Vigorous wort boil. Breaks down proteins into short and medium-length polypeptides.

6) Proper separation of cold break. Trub formed during cold break consists largely of fatty acids, which can impair head retention.

7) Pitch healthy yeast in sufficient amounts. Damaged or insufficient yeast can produce higher levels of amino acids, which can damage foam. Pitch at least 1 million cells x 1 °P x 1 ml wort (usually 1-1.2 gal. yeast starter/5 gallons of wort, more for lagers). Properly aerate wort immediately after pitching to avoid formation of fusel oils. Avoid fusel oils/higher alcohols by fermenting at lower temperatures for yeast strain.

8) Proper sanitation. Bacteria & wild yeast can metabolize dextrins & proteins, destroying compounds which aid head formation as well as increasing alcohol levels.

9) Don't filter excessively. Extremely fine filters can remove suspended yeast/starch particles, as well as dextrins and polypeptides, all of which aid foam formation and stability.

10) Don't use amylase or protease enzymes. Enzymes such as amylase and papain added to green beer indiscriminately attack dextrins and proteins, causing thinner body and poorer head retention.

11) Avoid oily additions to beer (e.g., meat, nuts, some fruits, spices, herbs & vegetables).

12) Proper packaging and serving. Get the proper carbonation level for the beer style. Don't agitate kegs to get CO₂ into solution., it breaks down foaming and stabilizing compounds. Some styles of beer are dispensed using nitrogen gas and special taps (“sparklers”) to produce smaller bubbles. Use proper glassware (smaller, properly-shaped glasses with etched nucleation points). Don't eat oily food or wear lip balm or lipstick when tasting beer.

13) Heading Agents. Most added at bottling time. Common types are iron salts, gums (e.g., xanthan, gum Arabic), alginates & medium molecular weight polypeptides, such as Pepsin - derived from pork. *Drawbacks:* All alter flavor & mouthfeel, making beer seem “softer.” Usually not necessary for all-malt beers, used for commercial high-adjunct lagers.

14) Nitrogen (N₂) or Mixed (CO₂/N₂) gas dispense. Produces finer, longer-lasting bubbles. *Drawbacks:* Removes CO₂ “prickle” or “bite” altering mouthfeel. Difficult for homebrewers to set up. Requires special equipment. Not appropriate for many styles.

15) Don't age beer. Head-forming proteins and gums can break down over time.

When Is Low/High Head Formation and/or Retention Appropriate?: High head *formation*, usually with lingering persistence, is expected in any beer with a high level of alpha acids, proteins and/or starches, specifically: Dortmunder export, German pilsner, Bohemian pilsner, Vienna Lager, Oktoberfest, Munich dunkel, schwarzbier, bock (except eisbock), American wheat or rye, Düsseldorf altbier, strong Scotch ale, Baltic porter, stouts, IPA, German wheat and rye beers, French and Belgian ales (except for some Belgian specialty ales), Berlinerweisse, Gueuze and Belgian strong ales.

Low head *retention* is appropriate for any thin-bodied and/or aged beer, specifically light American lager, standard American lager, premium American lager, dark American lager, eisbock, cream ale, Kölsch, Berlinerweisse and unblended lambic

Some beers, especially aged and high alcohol beers, might have poor head retention, even if they have strong initial head formation: strong Scotch ale, Russian imperial stout, Berlinerweisse and strong ales.

Cask-conditioned ales (e.g., English pale ales, mild, Scottish ales, Irish ale) might have low head formation and retention due to low carbonation levels rather than thin body.

High Fill Level

See Improper Fill Level.

Higher Alcohols

See Fusel Alcohols.

Honey

Detected In: Aroma, flavor

Described As: Floral honey, honey perfume, fruity, perfumy, stale honey, sweet.

Typical Origins:

Beer Flavor Wheel Number: 1001

Discussion: Honey-like aromas and flavors are caused by specialty malts, yeast character, actual honey additions or oxidation. Chemicals which can produce honey-like notes include 2, 3-pentanedione, ethyl hexanoate, ethyl phenylethyl acetate and phenylacetic acid. See Esters, Malty, Oxidation, Sherry-Like, Sweet and VDK for more information.

Hop Aroma

See Hoppy

Hop Oil Flavor

Detected In: Aroma, flavor

Described As: Citrusy, floral, herbal, piney, spicy.

Typical Origins: Hops.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0173

Discussion: Imparted by additions of flavor hops, aroma hops and/or distilled hop oils. See Hoppy.

Hop Bitterness

See Alpha Acids

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, marijuana - often described using the euphemism “dank” - minty, rosemary, thyme), grassy, perfumy, piney (e.g., balsam, cedar, pine needles, resinous, resinous, spruce, “rustic”), 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: Ketones are similar to alcohols and aldehydes, but they have a double-bonded oxygen molecule in the middle of the molecule. Hop-derived ketones can have floral, herbal or spicy notes.

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.

Horse (Fatty Acids, Sulfury)

Detected in: Aroma, flavor.

Described As: Barnyard, goaty, horse blanket, horse harness, horse stable, horse sweat, leathery, saddle, sweaty, wet dog, wet fur. Rarely described as bacon, Band-Aid™, burnt beans, burnt plastic, clove-like, creosote, plastic, rancid, rotting vegetation, spicy, smoky or woody.

Typical Origins: Microbial contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: ~420 µg/l.

Beer Flavor Wheel Number: n/a.

Discussion: Distinctive aromas and flavors produced by various species of *Brettanomyces* and *Dekkera* yeast, usually *B. Bruxellensis*, but also *B. Lambicus* and *B. Clausenii*. The active chemicals are primarily 4-ethyl phenol (4-EP) and 4-ethyl guaiacol (4-EG), but also isovaleric acid, guaiacol, 4-ethyl phenol, 2-phenyl ethanol, -damascenone, isoamyl alcohol, ethyl decanoate, cis-2-nonenal and trans-2-nonenal. On its own, 4-EP produces medicinal phenolic aromas and flavors, while 4-EG produces smoky, bacony or spicy notes. See Oxidation, Phenolic and Sour for more information.

Since *Brettanomyces* are slow-growing yeasts, Brett infection rarely appears by accident, and usually only shows up in aged beers. Brett infections are more likely in beer with higher pH, where oxygen is present in the beer and the beer temperature is warm (68 °F or above). Typically, Brett produces 4-EP to 4-EG at about an 8:1 ratio, but since humans are more sensitive to 4-EG, the flavors balance out.

To Avoid: Practice proper sanitation. In particular, use pure yeast cultures, make sure that your fermentation is healthy and complete, store your beer cool and protect it from oxidation.

When are Horsey Notes Acceptable?: Some degree of Brett character is expected in Lambics. Extremely low levels are permissible as a point of complexity in dry stout and old ales, but such character shouldn't be obvious.

Historically, until the 1950s, Brett strains were present in the yeast blends British brewers used to pitch their wort. So more or less prominent Brett character might be expected in historical recreations of aged English beers, such as 18th or 19th century "stale, vatted" porter, 19th and early 20th century English IPA, and 19th and early 20th century aged "Burton" ales (what the BJCP calls English Barleywine, as well as certain varieties of English Pale Ale and Old Ale).

Husky

Detected In: Aroma, flavor

Described As: Chaff, "glattwasser," husk-like.

Typical Origins: Malt.

Typical Concentrations in Beer: n/a? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0311.

Discussion: See Astringent and Grainy.

Hydrogen Sulfide (H₂S, Sulfury)

Detected In: Aroma, flavor

Described As: Rotten egg, drains

Typical Origins: Yeast, infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0721

Discussion: See Sulfidic.

Improper Fill Level

Detected In: Appearance (Bottle inspection).

Described As: Contents of the bottle are significantly above or below the nominal fill level.

Typical Origins: Improper packaging.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: When judging homebrew, judges should never deduct points for an unusually high or low fill level, nor should they assume that a high or low fill level is a sign that the beer is flawed.

In properly-filled 12 oz. bottle (i.e., filled with about 12 oz. of fluid) the fill level just reaches the bottle's neck, leaving 1-3" of empty space between the beer and the bottle cap. Likewise, larger bottles are designed so that when the bottle is properly filled the contents just reach the neck of the bottle.

Legally commercial beer must be packaged so that the consumer gets at least the volume of beer stated on the label. But, for reasons of cost, brewers don't want to give away free product by overfilling their bottles. So, the ideal fill level is one which is right at, or just above listed volume. To hide the fact that the neck of the bottle is empty, most beers have labels around the neck. Historically, the need for the space between the fill level and the cap was to keep the beer from touching the bottle cap, since the cap could rust and impart metallic off-flavors to the beer.

Fill levels for bottles of homebrew are much higher, sometimes 14 oz. or more in a 12 oz. bottle. This is because homebrewers want to fill as few bottles as necessary to bottle

their beer and because the filled bottle "looks right" if the fill level is at least halfway up the bottle's neck.

Homebrewers who force carbonate their beer and bottle using counterpressure bottle fillers often "cap on foam" by filling the bottle right up to the lip. This helps to reduce oxidation by eliminating headspace. Brewers who bottle condition their beers typically leave a bit more headspace.

While on its own a high or low bottle fill is harmless, it might be the origin of actual faults. An unusually low fill level (i.e., below the shoulder of the bottle) might result in problems with oxidation or low carbonation levels. An unusually high fill level might result in low carbonation levels, yeast-derived fermentation faults (if the beer was improperly bottle conditioned) or metallic off-flavors due to contact with the bottle cap.

When is a High or Low Fill Level Appropriate?: Any fill level is acceptable for homebrewed beer. A high or low fill level is inappropriate in commercial beer. Note that many commercial beers have a wrapper around the neck of the beer to hide the fact that the bottle fill doesn't go all the way up the neck of the bottle, and possibly to disguise uneven or slightly high fill levels.

Indole (Sulfur)

Detected in: Aroma, flavor.

Described As: Barnyard, coliform, enteric, fecal, pig-like, and a variety of much more descriptive, but less polite, terms. Some people perceive it as a floral (jasmine) aroma, especially at low levels.

Typical Origins: Contamination.

Typical Concentrations in Beer: < 5 µg/l.

Perception Threshold: 5-15 µg/l. About half the population is very sensitive to indole while the remainder is not.

Beer Flavor Wheel Number: n/a.

Discuss: While indole and similar compounds naturally occur at trivial levels in beer, due to the thermal decomposition of the amino acid tryptophan, "enteric" notes only appear in detectable levels as a result of coliform bacteria (*Escherichia Coli* spp.) infection. These bacteria metabolize tryptophan to produce a family of chemicals called indoles as well as DMS. Since coliform bacteria are naturally found in the guts of most animals, indole is one of the major components in the smell of feces.

In beer, detectable indole aroma is a sign of serious contamination by coliform bacteria, which can occur when fermentation is slow to start and the wort becomes infected. Coliform bacteria are present on dirty dishrags, dirty sponges and unclean food preparation surfaces, so this sort of contamination can occasionally occur when homebrewers brew in an unclean kitchen. It can also occur when brewing operations take place close to sources of coliform bacteria (e.g., animal pens, cat boxes, toilet facilities). Rarely, it might be due to use of adjunct sugar syrups which have been spoiled by *E. coli* infection.

Practically, unless you are brewing with foul water, pitch no yeast at all and don't bother to sanitize your brewing equipment (especially sponges and dish rags), you have nothing to fear from coliform bacteria. Even if you do get a coliform infection, *E. coli* are easily killed by alcohol, so once fermentation finally takes off, they die off quickly.

Lambic brewers attempting true wild fermentations might occasionally run into problems with *E. coli*, however, since

coliform bacteria are the first “wave” of microflora to colonize the wort during spontaneous fermentation. For this reason, “enteric” aroma and flavor is described as an “unfavorable” characteristic for lambics.

To Avoid: * Practice proper sanitation. In particular, sanitize food preparation surfaces, sinks and cleaning materials such as sponges and dishrags. * Don’t brew or ferment your beer near toilet facilities, animal pens or similar sources of contamination. * Don’t use contaminated ingredients, such as polluted water or spoiled sugar syrups.

When is “Enteric” Character Appropriate?: Never. One whiff and you’ll know why!

Iodoform (Phenol)

Detected in: Aroma, flavor.

Described As: bitter, hospital-like, Iodophor™, iodine, metallic, sweet.

Typical Origins: Contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0505.

Discussion: Iodoform is an organoiodine compound with the formula CHI₃. It has a distinct pungent aroma and a medicinal, sweetish taste. Despite the fact that it isn’t a phenol, the Meilgaard Beer Flavor Wheel classes it, and similar iodine-bearing organic chemicals, with the Phenol flavors. Iodoform notes in beer arise when iodine-based sanitizer isn’t properly rinsed from brewing equipment, or brewery equipment or packaging materials sanitized with “no rinse” iodine cleansers (e.g., Iodophor™) isn’t allowed to dry. Rarely, iodoform notes can arise in beer when wort samples used treated with iodine, used to test mash conversion, are returned to the mash. Also see Bromophenols, Chlorophenols, Phenol, Smoky, Spicy and Vanilla.

To Avoid: * Use iodine-based sanitizers in the proper concentrations - more isn’t better. Thoroughly rinse sanitizer from equipment or packaging, or allow “no rinse” sanitizers to thoroughly dry before using equipment. * Discard wort samples tested with iodine rather than returning them to the mash.

When Are Iodoform Notes Appropriate?: Never.

Isoamyl Acetate

Detected In: Aroma, flavor

Described As: Banana, peardrop.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0131

Discussion: See Esters.

Isovaleric Acid (Fatty Acid, Sulfur)

Detected in: Aroma, flavor.

Described As: Blue cheese, cheesy, hydrolytic rancidity, old hops, rancid, Rochefort cheese. Less commonly described as dirty laundry, dirty socks, goaty, putrid, stale cheese, 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.

Jam-Like

Detected In: Aroma, flavor

Described As: May be qualified by sub-classes of 0140 Fruity.

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1002

Discussion: See Esters and Sweet.

Kettle-Hop Flavor

Detected In: Aroma, flavor

Described As: Imparted by aroma hops boiled in the kettle.

Typical Origins: Hops.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0171

Discussion: See Bitter and Hoppy.

Lactic (Sour)

Detected in: Aroma (but only at extreme concentrations), flavor.

Described As: Citric, crisp sourness, lactic, lemony, refreshing, sour, sour cream, sour milk, tangy, tart, yogurt.

Typical Origins: Microbial contamination.

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

Perception Threshold: 0.04 mg/l.

Beer Flavor Wheel Number: 0920.

Discussion: Caused by infection by various forms of Gram-positive bacteria, most commonly *Lactobacillus*, but also *Pediococcus* (although lactic sourness is only obvious after diacetyl has been reduced), both of which are present in dust and saliva. Acidulated malt can also introduce lactic sourness without the need for bacterial infection. Likewise, lactic acid, normally used to reduce mash pH can be used to sour beer. Lactic acid is mostly non-volatile so it is odorless except in high concentrations. It has a crisp, clean, tart sourness reminiscent of yogurt.

Increased By: * To induce lactobacillus infection, brewers sometimes use a sour mash, where mash inoculated with *Lactobacillus Debruckii* is held in an anaerobic state at ~ 115 °F for 2-3 days. Lactobacilli are also sometimes added to beer during secondary fermentation. * Avoid oxygenation of mash during sour mashing. Don't let mash temp. fall below ~115 °F when sour mashing. * Cold-side storage containers and utensils used to produce sour beers must be kept separate from those used to produce regular beers if they can't be sterilized.

To Avoid: * Proper yeast management. Choose appropriate yeast strain. Reduce percentage of adjunct sugars in the beer. Pitch correct amount of yeast (0.5 - 1.5 qt per 5 gallons) for optimum yeast health and to minimize lag time. * Practice proper sanitation. Thoroughly clean all cold-side equipment before sanitizing it. Don't use cold side equipment which can't be sanitized (e.g., wooden or scratched plastic utensils/containers). Don't start a siphon by sucking it (lactobacillus is present in the human mouth). * Avoid oxygenation of green beer. * Perform mash out and sparge at ~168 °F, lauter at above 160 °F. * Limit or eliminate acidulated malt, sour mash or lactic acid additions.

When Is Lactic Sourness Appropriate?: Very low levels of lactic sourness are acceptable in dry stout. Medium to high levels of lactic sourness are expected in Berlinerweisse. Medium to high levels of lactic sourness and low levels of acetic sourness are expected in Belgian sour ales.

Leathery (Oxidation)

Detected in: Aroma, flavor, mouthfeel.

Described As: Hay-like, leathery, mouth-drying, powdery.

Typical Origins: Aging.

Typical Concentrations in Beer: 0 mg/l in fresh beer.

Perception Threshold: 10 µg/l.

Beer Flavor Wheel Number: 0830.

Discussion: An off-characteristic associated with the intermediate stages of aging in beer, often found in conjunction with Woody notes. Represented by the compound 6-Isobutylquinoline. Leathery compounds act synergistically with paper (q.v.) flavor to impart stale aroma and flavor. The precise origins of leathery stale notes are unknown. Also see Almond, Catty, Oxidation, Papery and Sherry-like.

Fermentation by *Brettanomyces* strains can also impart leathery notes to beer. See Caprylic and Horsey.

To Avoid: * Avoid aerating wort or beer. * Prevent oxygen from getting into beer packaging. Purge kegs or bottles with CO₂ before filling. Cap or seal packages carefully. Use oxygen barrier caps. * Store beer at cool temperatures. * Avoid temperature swings when aging beer.

When Are Leathery Oxidized Notes Appropriate?: Never.

Lemon

See Citrusy.

Licorice

Detected In: Aroma, flavor.

Described As: Anise, licorice.

Typical Origins: Malt, oxidation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0412

Discussion: See Malty and Oxidation, except possibly aged beers such as Old Ales where they are acceptable at very low levels.

Light Body

See Body.

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!

Low Fill Level

See Improper Fill Level.

Low Head Retention

See Head Formation and Retention.

Malty

Detected in: Aroma, flavor, mouthfeel (for dark malts).

Described As: Biscuity, bitter, bread crust, bread, burnt, burnt grains, chocolate, coffee, cooked grain, cookie-like, cookies, crackers, crusty, dough-like, doughy, espresso, flour-like, floury, Graham crackers, grainy, grassy, Malto-Meal™, nutty, roasted, toasted, toasty. Dark crystal malt can also produce “dark fruit” (e.g., black currants, cherries, plums) or “dried fruit” notes (e.g., dates, figs, prunes, raisins). Some crystal specialty malts will produce distinctive sweet notes, such as brown sugar, caramel, honey, molasses, toffee or treacle.

Typical Origins: Malt.

Typical Concentrations in Beer: Variable, depending on type and beer style.

Perception Threshold: Variable, depending on type and beer style. Some compounds can be detected in µg/l.

Beer Flavor Wheel Number: 0320.

Discussion: Drying, kilning and roasting malt produces a vast variety of aromas and flavors associated with Maillard reactions. Maillard reactions occur when reducing sugars react with amino acids at high temperatures, and moderately moist conditions, producing N-substituted glycosylamine and water. The unstable glycosylamine then undergoes Amadori rearrangement, forming ketosamines. These compounds react further, either forming water and reductones, nitrogenous polymers and melanoidins, or producing pyruvaldehyde and other short-chain hydrolytic fission products. Maillard reactions are different from caramelization which is the pyrolyzation of sugar under extremely high, dry heat.

Products formed by Maillard reactions are still poorly understood, but commonly include heterocyclic compounds such as acrylamides, pyridines (e.g., 2-acetylpyridine, 6-Acetyl-2,3,4,5-tetrahydropyridine - which give biscuity, cracker-like notes) and melanoidins (which give roasted or toasted foods their characteristic brown or black colors). Other products include furans, pyrazines, pyrroles and thiopenes.

Depending on the temperature and duration of drying, kilning and/or roasting malt might have flavors and aromas ranging from bread to burnt grain. In conjunction with sugars and dextrins in the beer, these compounds might also exhibit characteristics reminiscent of caramel, toffee, treacle, molasses and similar caramelized sugars - although the process of Maillard reactions is different from the process of caramelization. Beers that have been contaminated with caustic, or which are otherwise higher in pH than normal will have more pronounced pyridine and acrylamide notes.

When is Malty Character Appropriate?: Some degree of malt character is always expected in beer, although toasted and roasted notes associated with darker beers are considered to be faults in very pale beers. Likewise, in some brown beers (e.g., porters, brown ales) extremely dark roast notes are considered to be a fault, as is the absence of amber or brown malt notes.

Mealy

Detected In: Aroma, flavor

Described As: Flour-like, raw grain.

Typical Origins: Malt.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0313

Discussion: See Grainy or Malty.

Meaty

Detected In: Aroma, flavor

Described As: Brothy, cooked meat, meat extract, peptone, yeast broth.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0741

Discussion: See Autolyzed, Umami or Yeasty.

Melanoidin

See Malty or Roasty.

Melony

Detected In: Aroma, flavor.

Described As: Reminiscent of melons (cantaloupe, honeydew, watermelon, etc.) or melon rinds.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0145

Discussion: See Esters.

Mercaptan (Sulfury)

Detected in: Aroma, flavor.

Described As: Catty, drains, farty, fecal, leeks, polecat, rotten vegetables, skunky, sulfury, sunstruck. Inaccurately described as methane or natural gas.

Typical Origins: Yeast, microbial contamination.

Typical Concentrations in Beer: 0-0.5 µg/l.

Perception Threshold: 1 µg/l.

Beer Flavor Wheel Number: 0722.

Discussion: Caused by chemicals such as ethanethiol, methanethiol, methyl mercaptan, which are typically formed at low levels by some strains of yeast during fermentation. These compounds are produced in detectable quantities by infection by anaerobic bacteria such as *Pectinatus frisingensis*, *P. cerevisiophilus* and *Megasphaera Cerevisiae*, usually in conjunction with other sulfur-bearing compounds such as hydrogen sulfide or dimethyl sulfide. Mercaptans are also produced during yeast autolysis due to the decomposition of sulfur-bearing amino acids or peptides. Also see DMS, Hydrogen Sulfide and Lightstruck.

To Avoid: * Practice proper sanitation. * Remove beer from yeast cake soon after fermentation stops (i.e., within 2-4 weeks).

When are Mercaptans Appropriate?: Never, although extremely low sulfury notes are permissible in some varieties of beer fermented with sulfur-producing yeast strains.

Metallic

Detected in: Appearance, aroma, flavor, mouthfeel.

Described As: Aluminum foil, Bitter, blood-like, bloody, coin-like, coppery, ferrous sulfate, harsh, inky, iron, iron-like, rusty, rusty water, tingling, tin-like or tinny. Metallic ions can cause haze in beer and can affect foam quality.

Typical Origins: Contamination.

Typical Concentrations in Beer: <0.5 mg/l.

Perception Threshold: 1-1.5 mg/l.

Beer Flavor Wheel Number: 1330.

Discussion: While trace amounts of copper, manganese, iron and zinc are necessary for yeast health, detectable levels of metallic ions are rare in beer. When they arise, they are usually due to high levels of metallic ions in brewing liquor or due to ions leached from metallic brewing equipment or brewing supplies such as filter powders or syrups stored in steel cans. Metallic notes might also arise due to products of lipid oxidation, through processes which aren't fully understood. Metallic ions can also promote the formation of other staling compounds. High levels of some metallic ions can also be toxic to yeast.

There is some scientific controversy over whether metallic tastes are properly part of mouthfeel or flavor, and the exact neurological pathways involved in perceiving metallic sensations.

To Avoid: * Properly treat water to remove excess metallic ions. * Don't use fittings, containers or sealants which are likely to corrode (e.g., iron, mild steel, lead, solder, non-food-grade brazing compounds). * Properly passivate brass fittings used in the brewing process. * To avoid corrosion, don't leave caustic cleansers or sanitizers in prolonged contact with metal fittings, rinse thoroughly and allow equipment to air dry. * Only use stainless steel, food-grade plastic or glass containers to store fermenting wort or finished beer.

When are Metallic Notes Appropriate?: Never.

Methionol

Detected In: Aroma, flavor

Described As: Cooked potato.

Typical Origins: Infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 073?

Discussion: Caused by 3-Methylthiopropionaldehyde. See Sulfury or Vegetal.

Mineral

Detected in: Aroma (sulfate only), Flavor, mouthfeel.

Described As: Alkaline, bitter, chalky, dusty, drywall, eggs, plaster, sulfate, salty. High sulfate levels can impart a "clean" or "eggy" hydrogen sulfate aroma to beer. Some mineral ions, such as calcium or sulfate, can impart a harsh mouthfeel, by accentuating hop or alkaline bitterness.

Typical Origins: Water.

Typical Concentrations in Beer: Variable, depending on style. Typically no more than 200 ppm for calcium, carbonate/bicarbonate, and sulfate, no more than 50 ppm for magnesium, sodium and chloride.

Perception Threshold: Variable.

Beer Flavor Wheel Number: n/a.

Discussion: Mineral character can be imparted to beer by using brewing water which is high in certain non-metallic mineral salts, or by adding excess levels of brewing salts to beer. Sulfate aids isomeration of alpha acids, and increases perception of hop bitterness. In excessive levels it can produce a harsh, lingering hop bitterness. On its own, it can produce a detectable aroma. Chloride enhances perception of sweetness at low levels, but can seem bitter at higher levels. Calcium, carbonates and bicarbonates can seem chalky or plaster-like at high levels. Magnesium can seem bitter at high levels. At low levels, sodium, rather than seeming salty, can seem slightly powdery or minerally.

To Avoid: * Properly treat brewing water. * Don't use excessive amounts of brewing salts.

When are Mineral Notes Appropriate?: Very low levels of mineral notes might sometimes appear in pale ales and Dortmund export. Excessive, harsh or unpleasant mineral notes are always a fault.

Mineral Oil

Detected In: Aroma, flavor, mouthfeel.

Described As: Gasoline, kerosene, machine oil.

Typical Origins: Contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0642

Discussion: See Oily.

Molasses

Detected In: Aroma, flavor

Described As: Black treacle, treacly.

Typical Origins: Malt, sugar adjuncts.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0411

Discussion: See Malty and Sweet.

Moldy

Detected In: Aroma, flavor.

Described As: Cellar-like, leaf-mold, woody.

Typical Origins: Infection, Contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0840.

Discussion: See Musty.

Mouthcoating

Detected In: Mouthfeel (and aftertaste).

Described As: Creamy, unctuous.

Typical Origins: Malt, grain adjuncts, yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1320.

Discussion: See Body, Oily and Vicinal Diketones.

Musty

Detected in: Aroma, flavor.

Described As: Basement-like, cellar-like, cork taint, damp, damp basement/cellar, dank, dusty, earthy, fusty, moldy, mildew, mushroom-like, musty, wet basement/cellar. Occasionally described as "beet-like" or "corky" or as "old books" or "packaging materials."

Typical Origins: Contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: <10-25 ng/l.

Beer Flavor Wheel Number: 0842.

Discussion: Caused by 2,4,6-Trichloroanisole and other chloroanisoles produced by molds or fungus, as well as compounds such as geosmin. These chemicals are responsible for "cork taint" in wine, but are less commonly found in beer.

While black mold can grow in beer, typically these compounds get into beer because of mold which has grown on equipment which has been put away wet or which has been

stored in damp, moldy conditions. Mold can also grow on wooden barrels and corks, or can be introduced to beer if bottles are corked using improperly prepared corks. Moldy aromas can also migrate through soft plastic, contaminating hoses or buckets which are left standing on surfaces prone to mold growth (e.g., damp basement floors).

Rarely, musty notes can arise due to overpasteurization of beer or contact with improperly cleaned packaging materials.

In some cases, very low levels of Metallic character might be confused with Musty flavor.

To Eliminate: * Properly clean and sanitize equipment. Make sure that equipment, especially items made of plastic or wood, are dry (or filled with sanitizer) before storing them. * Don't leave plastic or wooden conditioning tanks in contact with damp, moldy surfaces (e.g., don't put plastic buckets directly on damp basement floors). * Reduce humidity in cellaring areas to discourage mold growth. * Don't transfer beer or wort in conditions where mold spore counts are likely to be high (e.g., damp basements or sheds, periods of prolonged damp weather outdoors). If you must transfer wort or beer under such conditions, minimize contact with air by using a pump or siphon and sealed vessels.

When is Moldy Character Appropriate?: Never. Although the BJCP guidelines allow that some commercial examples of bière de garde might have very low, musty "corked" notes, this should be due to yeast character rather than bad corks or bad storage conditions!

Nail Polish Remover

See Solventy

Nutty

Detected In: Aroma, flavor.

Described As: Aromas and flavors reminiscent of various types of nuts (e.g., almonds, Brazil-nuts, hazelnuts, walnuts), sherry-like, woody.

Typical Origins: Malt, oxidation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0220.

Discussion: See Almond, Malty or Roasty.

Oaky

See (Tannins).

Oily

Detected In: Aroma, appearance, flavor, mouthfeel.

Described As: Oily in appearance, reminiscent of various types of oils in aroma, flavor or mouthfeel.

Typical Origins: Malt, adjuncts, contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0640.

Discussion: See Body, Fat, Oil or Hydrocarbons, Silky or Vicinal Diketones.

Onion (Sulfur)

Judging Tip: Oxidation Can Be Subtle

While the BJCP exam only tests on cardboard and sherry notes associated with oxidation, when judging oxidation can be much more complex and difficult to recognize. Oxidation first manifests as a slight "dullness" in flavor and aroma, progressing to papery notes and finally possibly going to dark fruit or sherry after months of years of aging.

Slight oxidation can make the difference between a winning homebrew and an "also-ran," especially for beer styles which don't age well. Beers with lower ABV, lots of late hops, high levels of esters, and/or high levels of wheat, rye or oats are very vulnerable to the effects of oxidation. Hefeweizens and witbiers are notoriously unstable and are at their best within 2-4 weeks after they are packaged. Pilsners, and most table-strength ales, are at their best 2-8 weeks after they are packaged. Only beers of 6%+ ABV and amber or darker color (SRM 9+) benefit from extended aging.

Champion homebrewers time their brewing schedules so that their beers reach the judges in peak condition. For beers which advance to the 2nd Round of the National Homebrew Competition, many brewers rebrew their beers and submit bottles from the new batch to the second round.

Detected in: Aroma, flavor.

Described As: Cooked onion, garlic, onion.

Typical Origins: Grain, contamination.

Typical Concentrations in Beer: 0.05 - 0.3 µg/l.

Perception Threshold: 0.1 µg/l.

Beer Flavor Wheel Number: 0736.

Discussion: Onion, garlic or cooked onion notes in beer comes from mercaptans, such as Ethyl mercaptan and propyl mercaptan, as well as diethyl sulfide. These are produced from sulfur-bearing amino acids naturally found in malt during wort boiling. They are purged from beer during fermentation by yeast-derived CO₂. To a lesser extent, they are derived from hop oils during wort boiling or aging. Bacterial contamination can also produce onion or garlic notes, but usually along with much more prominent "rotten vegetable" or "rotten egg" notes.

To Eliminate: * Full, rolling open wort boil. * Vigorous fermentation. * Malt selection. * Practice good sanitation.

When is Onion Character Appropriate?: Detectable garlic or onion character is never appropriate, although at very low levels the chemicals responsible for those aromas and flavors contribute to the sulfury character acceptable in some pale lagers.

Orange

See Citrusy.

Oversweet

Detected In: Aroma, flavor.

Described As: Sickly sweet, cloying.

Typical Origins: Malt, adjunct sugars.

Beer Flavor Wheel Number: 1006

Discussion: See Sweet.

Oxidation

Detected In: Aroma, flavor, mouthfeel.

Described As: Dull, stale. At low levels oxidation can be taste or smell “like ball-point pen,” honey, inky, metallic, musty or nutty and might have a slight harsh, metallic, peppery mouthfeel. See discussion for further sensory characteristics associated with oxidation.

Typical Origins: Aging, process faults.

Typical Concentrations in Beer: Variable depending on exact chemical.

Perception Threshold: Variable depending on exact chemical.

Beer Flavor Wheel Number: Variable.

Discussion: Oxidation is the interaction of dissolved oxygen with other chemical compounds in beer, usually formyl carboxyl compounds. It is the major source of flavor instability during beer storage. Oxidation is increased by introducing air to wort or beer after fermentation has begun and by storing beer at high temperatures in non-airtight containers. There are many pathways which cause flavor instability in beer, some of which are discussed elsewhere; also see Almond, Catty, Leathery, Papery and Sherry-like.

Flavor instability is noted as a progressive drop in hop bitterness (the remaining bitterness can become harsher), hop flavor, hop aroma, and Esters. Changes in flavor or aroma due to flavor instability are more perceptible in blander beers than more full-flavored ones.

In early- to mid-stage oxidation, beer might develop “ribes” (blackcurrant leaf or tomato urine) and/or Leathery notes which fade with time. As the beer ages, it might also develop honey, bready or toffee-like flavors and a sweet or honey-like aroma. With time, the beer might develop distinct Papery or “tomato juice” (see Papery), and/or Almond, Isovaleric or Sherry-like notes (q.q.v.). The latter can sometimes be perceived as vinous or woody. Likewise, harsh or solventy higher alcohols might degrade to more pleasant Esters or Aldehydes, and the beer might develop Earthy, Metallic, straw-like (see Grassy) notes. Beer aged at 77 °F (25 °C) tends to develop caramel notes while at 86-99 °F (30-37 °C) it develops more papery notes.

Changes in flavor or aroma due to flavor instability are more perceptible in blander beers than more full-flavored ones.

The main factors in oxidation are levels of dissolved oxygen in the beer and temperature. Oxygen can be introduced into the beer at any stage during the brewing process, from mashing to conditioning. Except when aerating the wort to improve yeast performance (the yeast takes up the dissolved oxygen within a few hours), brewers should take every step possible to avoid aerating their brewing liquor, mash, wort or beer.

Commercial breweries take great pains to prevent oxygenation at all phases of production. During mashing, mash is “doughed in” in an oxygen free environment and, ideally, mash is pumped into the mash tun from below to minimize oxidation of the mash. Sparge liquor is deoxygenated and is pumped into the lauter tun under oxygen free conditions. Pumps and other equipment are checked to make sure that oxygen doesn’t get into the mash or wort during transfer. Wort boil, fermentation and conditioning also takes place in oxygen free environments. Modern packaging equipment means that modern commercial bottled beer has less than 0.1 ppm dissolved oxygen.

-Aeration of the sparge liquor during recirculation (AKA “hot side aeration”) is a major factor in oxidation of homebrewed beer. Splashing or aerating mash liquor, sparge

liquor, wort or beer during transfer or packaging are other sources of oxidation in homebrew.

Regardless of oxygen levels, rate of flavor change depends on temperature. Beer stored at 32-39 °F (0-4 °C) shows no oxidation even after many months of storage, while beer packaged under low oxygen conditions might show signs of aging after about 100 days at 68 °F (20 °C). Storage at higher temperatures results in a 2-3 fold increase in aging rate; beer might show signs of oxidation at 30 days if held at 86 °F (30 °C), while beer held at 140 °F (60 °C) will show signs of oxidation after just 1 day!

Pathways involved in synthesis of staling substances include:

* **Melanoidin-Catalyzed Oxidation of Higher Alcohols:** Alcohols in beer can be converted to their equivalent aldehydes through the catalysis of melanoidins.

* **Oxidation of Iso-alpha-acids:** Might be involved in staling of beer. Hop fractions less prone to staling.

* **Strecker Degradation of Amino Acids:** Reactions between amino acid and an alpha-dicarbonyl compound, such as the intermediates in browning reactions. The amino acid is converted into an aldehyde. Polyphenols may have a catalytic role.

* **Aldol Condensations:** Reactions between separate aldehydes or ketones is route through which (E)-2-nonenol might be produced by a reaction between an acetaldehyde and heptanal. Diverse other carbonyls might be generated in this way, with the amino acid proline as a catalyst.

* **Oxygenation of Unsaturated Fatty Acids:** Oxidative breakdown of lipids can cause sulfury or rancid notes in beer.

Antioxidants naturally found in beer, which block oxidation, include:

* **Polyphenols:** These compounds scavenge oxygen free radicals, superoxide and hydroxyl, inhibit lipoxygenase and act as chelating agents - sequestering metal ions such as iron and copper. Unfortunately, they also cause astringency and chill haze.

* **Melanoidins:** The compounds scavenge superoxide, peroxide & hydroxyl, but also promote formation of higher alcohols.

* **Sulfur dioxide:** SO₂ scavenges free radicals, but carbonyls bind with SO₂ in brewing process and SO₂ are lost in beer through unknown means (half is lost in 27 days at 104 °F - 40 °C - , 3 years at 32 °F - 0 °C). As SO₂ is lost carbonyl compounds are freed, resulting in flavor instability.

* **Yeast:** Yeast produces SO₂ and reduces carbonyl compounds to fusel alcohols.

* **Chelation:** Various chemicals in beer, such as amino acids, phytic acid and melanoidins, chelate metallic ions, preventing them from accelerating flavor instability.

* Sulfites (e.g., Potassium metabisulfite) added to beer immediately reduces carbonyl compounds, eliminating many “stale” characteristics. The problem is that sulfites contribute unwelcome sulfury notes to beer and are toxic to yeast, making it impossible to use them in cask or bottle-conditioned beer. In some cases, their use is also restricted or prohibited by law, making commercial brewers hesitant to use them.

To Avoid: * Avoid hot side aeration (don’t splash or spray hot mash liquor or wort). * Avoid splashing or spraying mashing in liquor, sparge liquor, wort or beer at all stages of the production process. * Get good hot and cold break to avoid carrying excess fatty acids into wort. Separate hot and cold break

from wort. * Don't aerate beer after fermentation starts. * Purge brewing, conditioning and storage vessels with carbon dioxide before filling them. * Proper packaging: Don't underfill bottles or kegs. Minimize headspace in bottles (no more than 1-2" below the crown). "Cap on foam" by immediately capping the bottle once it is filled. Get a good seal on bottles and kegs. Use anti-oxidant bottle caps and/or wax over caps. * Proper storage conditions: Avoid high temperature (90+° F) storage conditions. Keep beer cool (32-50 °F) for long-term storage - the cooler the better. * Don't age beer unless it can stand up to long-term storage.

When Is Oxidation Appropriate?: Whether oxidation is appropriate depends on the beer style and the flavors and aroma produced by oxidation: Dull, cardboard-like, inky, papery or rotten notes are never appropriate. Low to medium sherry-like notes are acceptable in weizenbock, Flanders brown ale, old ale and English barleywine. Aged examples of eisbock, Scotch ale, Baltic porter, foreign extra stout, Russian imperial stout, Dubbel, Belgian dark strong ale and American barleywine might also have slight dark fruit and vinous notes. Musty notes are acceptable in some cellared beer styles such as bière de garde.

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, soy sauce or stale bread crumbs. 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).

When Are Papery Notes Appropriate?: Never.

Parsnip

Detected In: Aroma, flavor.

Described As: Reminiscent of cooked parsnips.

Typical Origins: Infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0731

Discussion: See DMS, Sulfury or Vegetal.

Pear

Detected In: Aroma, flavor.

Described As: Reminiscent of pear or peardrop candies.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0146

Discussion: See Esters.

Peaty

Peat-smoked notes in beer are usually due to the use of peated distiller's malt, but low levels of peat character might be imparted to beer by certain yeast strains or use of water contaminated with bacteria, mold or decaying plant material. See Earthy, Phenols and Smoky.

Peppery

See Spicy.

Perfumy

Detected In: Aroma, flavor.

Described As: Reminiscent of perfume.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0163

Discussion: See Esters and Solventy Esters.

Phenolic

Detected In: Appearance, Aroma, flavor, mouthfeel.

Described As: Bitter, fruit skins, fruit pits, grape seeds, grape skins, husky, oaky, roasted, tannic, tea-like, vanilla or woody. Some have an astringent, drying, numbing, prickly, puckering or rough mouthfeel, sometimes detectable only in the aftertaste. Some spicy phenols can also be detected as a prickliness, warming, pepperiness or pain in the nasal passages. Polyphenols can combine with proteins in beer to form chill (protein) haze.

Typical Origins: Yeast, microbial contamination, process faults.

Typical Concentrations in Beer: 0.05-0.55 mg/l.

Perception Threshold: Variable depending on exact chemical; usually about 0.2 mg/l.

Beer Flavor Wheel Number: 0500.

Discussion: Phenols are an enormous family of aromatic alcohols consisting of a benzene ring plus a hydroxyl group and side chains. Technically, they are alcohols.

Unlike esters or fusel alcohols, phenols are largely non-volatile and don't get converted into other compounds. This means that once they're in a beer, they tend to remain in it.

There is genetic variation in the ability to detect certain phenolic compounds and some people are completely insensitive to them.

Common phenols found in beer are given below, along with their specific sensory characteristics and biochemical

origins. Also see Bromophenol, Chlorophenol, Iodoform, Smoky, Spicy and Vanilla.

* **Flavanoids (AKA Bioflavanoids, Flavanols):** This is a huge family of phenols with ketone-containing compounds which are naturally found in many plants. They have often little aroma, although they can be precursors to aroma compounds.

They produce flavors ranging from mildly to intensely bitter. Specific flavanoids relevant to brewing have aromas flavors reminiscent of chocolate, cocoa, coffee, earth, nuts and/or roasted or toasted foods. Some have an astringent, drying mouthfeel or aftertaste.

Flavanoids are present in grain husks, and the process of roasting or toasting malt oxidizes or pyrolyzes these compounds during Maillard reactions to produce the distinct flavors of biscuits, bread crusts, burnt grain bitterness, chocolate coffee, roasted grain or toast.

Flavanols are also present in many fruits, especially cherries, citrus and grapes.

* **Polyphenols (AKA Tannins):** These are phenols composed of two or more benzene rings. They have bitter, husky, oaky or vanilla-like aromas and flavors, also sometimes described as tasting like grape skins or grape seeds. Most also have an astringent, drying or puckering mouthfeel. They commonly occur in woody or husky plant materials.

Polyphenols in beer are mainly extracted from grain husks due to improper grain milling, mashing or sparging technique, but they can also be extracted from water left to stand in contact with decaying plant material, or from hops. Herbs, spices and fruits can also impart polyphenols.

Beer aged in contact with wood will also pick distinct oaky or woody notes from polyphenols. With time, these compounds will react with alcohol to produce vanillin, imparting the flavor and aroma of Vanilla (q.v.).

Beer left on the yeast cake for excessive amounts of time might also pick up polyphenols liberated during yeast autolysis.

Polyphenols can bind with suspended proteins in beer to form protein/chill haze.

They can also form oxidized fusel alcohols due to a reaction with aldehydes, if oxidized by hot-side aeration or poor storage conditions.

Over-attenuation and low dextrin levels (i.e., thin-body) can increase the perception of astringency.

To Avoid or Control: Methods of controlling phenols depend on the exact family of compounds:

* **Flavanoids (AKA Toasty, Roasty, Bitter):** *Causes:* Toasted or roasted malt additions. Fruit, spice or herb additions.

To reduce or avoid: Reduce or eliminate toasted or roasted malt additions. Reduce or eliminate fruit, spice or herb additions. Avoid scorching grains or wort.

* **Polyphenols (AKA Astringency):** Also see Cloudiness (Protein Haze). *Causes:* Malt, hops, fruit skins or seeds. *To reduce or avoid:*

- *Don't over-crush grain.*

- *Proper Mash/Sparge technique:* Avoid excessive sparging (stop runoff before it gets below 0.008 S.G.). Avoid collecting alkaline sparge (pH >5.8) liquor. Don't use highly alkaline or sulfated water. Don't let mash-out or sparge liquor temperature exceed ~168 °F.

- *Boil wort with a rolling boil for at least 1 hour* to promote hot break.

- *Get proper hot & cold break separation.*

- *Avoid excessive amounts of hops.* To get high IBU levels use a smaller amount of high alpha acid hops rather than a large quantity of low alpha acid hops. As a rule of thumb, use no more than 8 oz. of hops per 5 gallons of wort. Avoid excessively long boil times (>2 hours) when making beer with a large amount of hops.

- *Avoid Polyphenol Extraction:* Don't heat fruit or grains in water above ~168 °F. Limit time that beer spends in contact with dry hops, fruit (especially fruit stems and husks), herbs and spices (time can range from weeks to months depending on the exact material). For wood-aged beers, reduce exposure to wood and/or increase aging time. Don't leave beer on yeast cake for long periods of time (1 month or more) to avoid yeast autolysis.

- *Reduce Sulfate mineral additions.* Sulfate increases tannin extraction and accentuates polyphenol harshness and bitterness.

When Are Phenolic Notes Appropriate?: Whether phenolic notes are appropriate in a beer depends on the type of phenol:

* **Flavanoids:** Flavanoids which give bready, biscuity, crusty and/or toasty notes are expected in very low to high concentrations in almost all styles of amber or brown beer. Compounds which give burnt grain, chocolate, cocoa, coffee, roasted notes are expected in medium to high concentrations in most styles of dark beer, particularly porters and stouts.

* **Polyphenols:** Balanced low to strong polyphenol (woody, vanilla, oaky) character is expected in wood-aged beers. Subtle peat character is acceptable in Scotch Ale. Harsh or astringent notes are a fault in other styles of beer.

Pine

Detected In: Aroma, flavor.

Described As: Balsam, piney, resinous, "rustic", spruce, woody, woody.

Typical Origins: Hops, herb additions.

Typical Concentrations in Beer: variable.

Perception Threshold: variable.

Beer Flavor Wheel Number: 0210 (Resinous).

Discussion: Piney notes are typically caused by Esters and Phenol (q.v.) compounds found in hops, especially modern American varieties. Specific aroma and flavor compounds are hydrocarbon-based essential oils, which naturally occur in hops, such as a-humulene, a-Murolene, b-caryophyllene, b-pentene, b-Selenene, mitral, D-matinee Farnesene, Farnese, Geraniol, l-matinee, limonene, limonene-10-ol, myrcene Nerol, terminal. Not surprisingly, these compounds are also found in pine trees and other conifers.

Some specialty beers, notably holiday beers, spruce beers, and historical Scandinavian beers such as Finnish Sati and Swedish Gottlandstrikka, might have pine or spruce additions. The wort used to produce historical Scandinavian beers is traditionally filtered through a bed of young pine needles. Pine-flavored holiday beers typically use spruce or pine flavoring. These flavorings are very intense and can easily be overdone.

Note that traditional spruce beer, made with new spruce tips, doesn't produce piney notes. Instead, the flavor and aroma is much more herbal and citrusy. Older spruce tips can impart bitter and pine-like characteristics.

To Avoid: * Change hop variety. * Reduce or eliminate late hop additions. * Reduce or eliminate additions of pine or spruce flavoring. * Only use fresh spruce or pine tips (the soft, bright green tips which appear in the spring).

When Are Piney Notes Appropriate?: Subtle to moderate pine-like character is acceptable, even expected, in hoppy American ales. Subtle pine or spruce character can enhance holiday or historical specialty beers, but shouldn't be excessive.

Plastic

Detected In: Aroma, flavor.

Described As: Bitter, burning plastic, can-liner, chemical, lacquer, plastic, plasticizer, styrene.

Typical Origins: Microbial contamination, contamination.

Typical Concentrations in Beer: 0 mg/l.

Perception Threshold: 20 µg/l.

Beer Flavor Wheel Number: 0121 (Plastic), 0122 (Can-liner).

Discussion: Plastic notes are generally due to common plastics (e.g., styrene), lacquers (e.g., epoxy resin), or plasticizers (e.g., phthalates) introduced to beer due to contamination of brewing equipment or packaging materials. Phenolic notes reminiscent of plastics can also arise in beer due to wild yeast infections. Rarely, plastic notes can also arise in beer due to contaminated CO₂.

To Avoid: * Only use food grade plastic for brewing purposes or for dispensing beer. Non-food-grade plastic (e.g., trash can liners, trash cans, garden hoses) can leach plastic or plasticizers into beer. * Thoroughly clean and rinse new plastic equipment before using. Even food grade equipment might still have mold-release or plasticizer compounds on the inside. * Use only food grade plastic rated for high temperature use for hot side operations (e.g., mashing, transferring sparge liquor or wort). Standard plastic ice machine hoses aren't suitable. * Practice good sanitation to avoid wild yeast infection. * Avoid contamination of brewing equipment or ingredients with plastic materials or similar (e.g., epoxy resin, spray paint). * Use only food-grade carbon dioxide. * Only use tanks rated for food-grade CO₂. * Sample beer in glass containers, not disposable plastic cups. The latter sometimes retain residual amounts of plasticizer or mold-release compounds on the inside.

When Are Plastic Notes Appropriate?: Never.

Plastic Bandage

See Chlorophenols.

Playdough™

See Almond.

Potato

See Sulfury.

Powdery

Detected In: Aroma, flavor, mouthfeel.

Described As: Chalky, dusty cushions, irritating (with 0310 Grainy), mill room smell, minerally in flavor. Chalky, dusty, gritty, particulate, scratchy, silicate-like or siliceous in mouthfeel.

Typical Origins: Malt, hops, yeast, contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1350

Discussion: See Mouthfeel or Sediment.

Primings

Detected In: Aroma, flavor, mouthfeel.

Described As: Sweet, sugary, underattenuated.

Typical Origins: Sugar adjuncts.

Beer Flavor Wheel Number: 1004

Discussion: See Sweet.

Rancid

Detected In: Aroma, flavor.

Described As: Oxidative rancidity.

Typical Origins: Oxidation, contamination.

Beer Flavor Wheel Number: 0630

Discussion: See Oily or Oxidation.

Rancid Oil

Detected In: Aroma, flavor, mouthfeel.

Described As: Oxidative rancidity, reminiscent of rancid or stale vegetable oil.

Typical Origins: Oxidation, contamination.

Typical Concentrations in Beer: ? mg/l.

mg/l.

Beer Flavor Wheel Number: 0631

Discussion: See Oily or Oxidation.

Raisin

Detected In: Aroma, flavor

Described As: Black currants, Christmas pudding, dark fruit, dried cherries, dried fruit, figs, plums, Port wine, prunes, sherry, vinous, wine-like.

Typical Origins: Malt, yeast, oxidation.

Typical Concentrations in Beer: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Raisin-like aroma and flavor is due to Esters (q.v.) which arise due to the use of certain strains of yeast or the use of certain brands of crystal malt, notably DeWolf-Cosyns Special-B™. Raisin-like character can also develop due to age and oxidation, see Sherry.

When is Raisin Character Appropriate?: Raisin or dark fruit character is acceptable, even expected, in beers where Special-B malt is a standard part of the grain bill, notably Belgian Dubbel, Belgian Dark Strong Ales and Old Ales.

Raspberry

Detected In: Aroma, flavor.

Described As: Reminiscent of raspberry.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0147

Resinous

Detected In: Aroma, flavor.

Described As: Cedar, fresh sawdust, pine, pine needles, resin, spruce, terpenoid, woody.

0210

Discussion: See Hoppy, Pine or Spruce.

Ring In Bottle Neck

Detected In: Appearance (Bottle inspection).

Described As: A fine ring of brownish or whitish material just at the fill line in the neck of the bottle.

Typical Origins: Dry hopping, yeast, added ingredients, contamination.

Typical Concentrations in Beer: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: When judging homebrew, judges should never deduct points just because a beer has a ring around the neck, nor should they assume that the presence of a ring is an indication that the beer is flawed.

Some homebrewed beer might have a whitish or brownish “ring around the collar” just at the bottle fill line. This is a purely cosmetic fault.

A brownish or greenish ring of material is probably due to residual hop material or hop resins and oils. This is likely the case if the beer was dry hopped before being bottled. Other plant material, such as herbs or spices, can also leave a brownish or greenish ring.

A whitish ring is either due to yeast activity or due to the use of dry malt extract, especially if the beer is bottle-conditioned and was primed using dry malt extract. In some cases, though, it might be a sign of a bacterial or wild yeast infection, or added starchy or oily ingredients (e.g., coconut).

A clear, slimy ring might be due to added ingredients, but it could also be a sign of a wild yeast or bacterial infection. See Film on Top of Beer for more information.

When is a Ring In the Bottle Neck Appropriate?: A ring is always acceptable for homebrewed beer, but never acceptable for commercial beer. (Note that many commercial beers have a wrapper around the neck of the beer to hide the fact that the bottle fill doesn't go all the way up the neck of the bottle, and possibly to disguise the presence of a ring.)

Roast Barley

Detected In: Aroma, flavor, mouthfeel.

Described As: Reminiscent of chocolate, cocoa, coffee, espresso or mocha in flavor and aroma. Detectable as astringency in mouthfeel.

Typical Origins: Malt.0422

Discussion: See Malty.

Roasted

Detected in: Aroma, flavor.

Described As: Biscuity, bitter, bread crust, burnt, burnt grains, chocolate, coffee, crackers, crusty, espresso, Graham crackers, nutty, roasted, toasted, toasty.

Typical Origins: Malt.

Typical Concentrations in Beer: Variable, depending on type and beer style.

Perception Threshold: Variable, depending on type and beer style. Some compounds can be detected in µg/l.

Beer Flavor Wheel Number: n/a.

Discussion: The flavors and aromas of darker malts are actually a sub-class of Malty (q.v.) characteristics found in combination with various phenolic compounds (notably flavanoids and monophenols), which are produced when malt is kilned at high temperatures. Maillard reactions, which occur at higher kiln temperatures, produce a variety of compounds which give flavors ranging from biscuity or nutty to coffee-like or burnt. From lighter to darker malts, typical toasted or roasted flavor compounds are as follows:

Lightly Toasted Malts: Light to medium amber in color, producing flavors and aromas reminiscent of biscuits, crackers or Graham crackers.

Toasted Malts: Dark amber to light brown, producing characteristics reminiscent of bread crust, nutty or toasted.

Roasted Malts: Medium to dark brown, producing characteristics reminiscent of chocolate, coffee or espresso.

Black Malts: Dark brown to black, with a burnt or bitter flavor and aroma.

In conjunction with sugars and dextrins in the beer, these compounds might also exhibit characteristics reminiscent of caramel, toffee, treacle, molasses and similar caramelized sugars - although the process of Maillard reactions is different from the process of caramelization.

See Malty and Phenols for more detailed discussions.

When is Roasted Character Appropriate?: Some degree of toasty or roasted character is expected in amber, brown or black beers. Typically, some degree of lightly toasted or toasted malt character is expected in amber-colored beers, while darker toasted characteristics and subtle roasted notes (e.g., bread crust, nutty) are expected in brown beers. According to modern interpretations, porters are expected to have nutty and chocolatey notes (but very subtle or absent coffee or burnt character), while stouts are expected to have coffee-like and subtle, bitter, “burnt grain” character, possibly in addition to nutty and chocolatey notes. In most cases, toasted and roasted notes associated with darker beers are considered to be faults in lighter-colored beers.

Rose-like

See 2-Phenylethanol and Esters.

Rotten Vegetable

Detected In: Aroma, flavor.

Described As: Reminiscent of rotting vegetation.

Discussion: See DMS or Vegetal.

Rubbery

See Autolyzed, Plastic or Sulfur.

Salty

Detected in: Flavor.

Described As: Salty. Can be described as bitter, harsh, mineral-like or sour at low levels. At very low levels it can increase perceptions of sweetness.

Typical Origins: Water, process faults.

Typical Concentrations in Beer: <100 mg/l (typically 10-50 mg/l).

Perception Threshold: 200 - 500 mg/l.

Beer Flavor Wheel Number: 0150.

Discussion: The ability to detect saltiness is one of the basic tastes in humans. Saltiness in beer is due to excess sodium ions, usually due to excessive sodium chloride (table salt) additions rather than brewing with naturally salty water. Potassium chloride (a form of potash, also added to “lite” or dietetic salts) can also have a salty character. Salt is also found in trace amounts in malt, but this isn't a significant source of salt in beer.

At sub-threshold, sodium enhances the perception of sweetness in beer. Saltiness is detectable at 100-1,000 mg/l in water, although most people detect it at 100-500 mg/l. IN beer, it can be detected at 200 mg/l.

To Reduce or Avoid: Limit brewing salt additions, particularly sodium chloride. Don't use water treated by ion-substitution water softening systems. Commercial brewers who

use brine as a refrigerant might get salty notes in their beer as a result of a refrigerant leak.

When is Saltiness Appropriate?: Never for the styles listed in the BJCP style guidelines. Dortmunder export comes the closest to having detectable levels of salt since the profile for Dortmunder water has 60 ppm. Scottish beer styles come next, since Edinburgh has 55 ppm of sodium. Specialty beers, such as German gose, might have detectable levels of salt, but only at low to medium-low levels.

Satiating

Detected In: Aroma, flavor, mouthfeel.

Described As: Extra-full, filling.

Typical Origins: Malt, adjunct sugars.

Typical Concentrations in Beer: n/a.

Beer Flavor Wheel Number: 1413.

Discussion: See Body

Sediment

Detected In: Appearance (Bottle inspection).

Described As: Powdery material on the bottom of the bottle.

Typical Origins: Dry hopping, yeast, added ingredients, contamination.

Typical Concentrations in Beer: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: *When judging homebrew, judges should never deduct points just because a beer has sediment at the bottom of the bottle, nor should they assume that the presence of sediment is an indication that the beer is flawed. They should also refrain from deducting points from appearance if the beer was clear in the bottle, but was subsequently roused due to rough handling.*

Likewise, high levels of sediment can alter perceptions of aroma, appearance, flavor and mouthfeel. Judges should learn to pour carefully to avoid rousing sediment and should avoid sampling beer from the bottom of the bottle. This is especially important when only one bottle of beer has been entered in competition, and it must go on to a mini-Best of Show or Best of Show round.

Some homebrewed beer might have sediment at the bottom of the bottle. *By itself*, this is a purely cosmetic fault, as long as the layer of sediment is sufficiently thin that it is possible to carefully pour the contents of the bottle without rousing the sediment. Sediment might contribute to other faults in beer, however, such as off-flavors and aromas caused by autolyzed yeast.

Grayish tan sediment is usually due to yeast. Sediment of other colors is due to settling of fine particles of other materials, such as malt, hops, herbs or spices. Otherwise clear beer, which has been aged for a long period of time, might have a layer of sediment on the bottom of the bottle. As a rule of thumb, the more tightly compacted the sediment, the older the beer. In commercial beer, this is usually a sign that the beer is very old, and might have characteristics associated with extended aging. For homebrew, the presence of sediment isn't as good an indicator of age.

If a beer which should be cloudy is clear or hazy, but has a thick layer of sediment at the bottom, it is usually a sign that the beer has aged for a while. While this isn't a fault in itself, since the sediment can be roused back into suspension, but it might be a warning that the beer has deteriorated due to age.

For styles of beer where cloudiness is expected, such as witbier and unfiltered German wheat and rye beers, the presence of sediment can be a fault if the roused sediment has a gritty or sandy texture. This is usually a sign that trub from the bottom of the fermentation vessel was added to the beer. Cheap commercial hefeweizens are sometimes produced in this fashion.

When is Sediment Appropriate?: A thin layer of sediment is always acceptable for homebrewed beer. Bottle-conditioned commercial beer might also have a thin layer of sediment, especially if it has been aged. Sediment is never acceptable in commercial beer which has been filtered and force carbonated. Beer which is supposed to be hazy or cloudy, like witbier and hefeweizen, should not show signs of serious sedimentation, with the beer at the top of the bottle being noticeably clearer and a thick layer of powdery sediment at the bottom.

Sharp

See Acetic.

Sherry-Like (Oxidation)

Detected in: Aroma, flavor.

Described As: Dark fruit (e.g., fig, grape, plum, prune, raisin), dry sherry, honey, inky, nuts (e.g., almonds, hazelnuts, walnuts), musty, port wine, red wine, rotten fruit, sherry, vinous, wine, woody. The combination of dark malt, dark fruit, sherry and alcohol is sometimes perceived as being like a Christmas or plum pudding.

Typical Origins: Aging.

Typical Concentrations in Beer: ?.

Perception Threshold: ?.

Beer Flavor Wheel Number: n/a.

Discussion: Sherry notes emerge when melanoidins, alcohol and oxygen interact, reducing volatile molecules such as esters and hop compounds. They only form in strong (6+% ABV) dark-colored (20+ SRM) beers and often accompany a darkening of the beer. These compounds sometimes develop from compounds which are responsible for less pleasant flavors earlier in the oxidation process (e.g., inky, musty, rotten fruit) and are reminiscent of aged red wine, dark fruit (e.g., dates, figs, prunes, plums, raisins), dry sherry, honey, nuts (e.g., almonds, hazelnuts, walnuts) and/or port wine. These compounds might be reduced back into their original form by oxidizing alcohols into aldehydes. Also see Almond, Leathery, Oxidation and Papery.

To Avoid: * Avoid hot side aeration (don't splash or spray hot mash liquor or wort). * Get good hot and cold break to avoid carrying excess fatty acids into wort. Separate hot and cold break from wort. * Don't aerate beer after fermentation starts. Avoid splashing beer during transfer and packaging. Purge conditioning and storage vessels with carbon dioxide before filling them. Don't underfill bottles or kegs. Minimize headspace in bottles (no more than 1-2" below the crown). Get a good seal on bottles and keg. Use anti-oxidant bottle caps and/or wax over caps. * Avoid high temperature (90+° F) storage conditions. Keep beer cool (32-50 °F) for long-term storage - the cooler the better. * Don't age beer unless it can stand up to long-term storage.

When Are Sherry-Like Notes Appropriate?: Low to medium sherry-like notes are acceptable in weizenbock, Flanders brown ale, old ale and English barleywine. Aged examples of eisbock, Scotch ale, Baltic porter, foreign extra stout, Russian imperial stout, dubbel, Belgian dark strong ale

and American barleywine might also have slight dark fruit and vinous notes.

Sherry-like notes can arise in other strong, amber to dark beers, such as bock, doppelbock, robust porter, American stout or double IPA, but are considered to be a fault in those styles.

Shrimp-like

Detected In: Aroma, flavor.

Described As: Reminiscent of cooked shrimp or other seafood, or water in which seafood has been boiled.

Typical Origins: Infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0727.

Discussion: See DMS.

Silky

Detected in: Mouthfeel.

Described As: Smooth, creamy, milky, oily.

Typical Origins: Malt, carbon dioxide or nitrogen gas.

Typical Concentrations in Beer: n/a.

Perception Threshold: n/a.

Beer Flavor Wheel Number: n/a.

Discussion: Silkiness in beer can come from three sources, either high levels of proteins from grains such as wheat or oats, Oiliness from grains such as oats or dispensing the beer using nitrogen gas and special taps.

Protein-derived silkiness or creaminess in mouthfeel is caused by low to medium-weight peptides and polypeptides, which also improve Head Formation and Retention as well as perception of body.

Low levels of oils in beer can also increase the perception of silkiness. Typically, these are imparted to beer at very low levels by the use of malts or adjunct grains which have higher residual levels of oils. Odd adjunct ingredients in specialty beers, such as nuts or peanuts, might also impart natural oils. Also see Fat, Oil or Hydrocarbon.

Some varieties of beer (notably dry stouts, but virtually any variety of English, Scottish or Irish ale) are dispensed using nitrogen gas or a mixture of carbon dioxide and nitrogen (“beer gas”). The beer is further exposed to nitrogen gas by being passed through a special “sparkler” tap which aerates the beer as it is poured, making it foam.

When some or all of the carbon dioxide in the beer is replaced with nitrogen, the beer produces smaller, more densely packed bubbles. This gives the beer a thicker, rockier, more finely-beaded head with improved retention and a creamy texture. In addition to the creamy texture character carrying through into the overall mouthfeel, the lack of carbon dioxide “bite” and “sharpness” make the beer seem sweeter and maltier.

Some commercial canned beers incorporate a “widget” which is partially or completely filled with nitrogen gas. When the can is opened, the gas in the widget is released as the surrounding carbon dioxide pressure is reduced; giving the beer the characteristic nitrogen dispensed creamy head and mouthfeel.

Also see Body, Head Formation and Retention and Vicinal Diketones.

When are Silky Notes Appropriate?: Some degree of silky or creamy texture is expected in any beer with a high level of oils, suspended starch or protein, notably oatmeal stouts and wheat beers, although perception of silkiness might be balanced

Judging Tip: Lactobacillus Infections

Even though it is a slow-growing, anaerobic bacteria Lactobacillus infections are common in homebrewed beer. The most common source of lactobacillus bacteria is the human body. The human mouth is filled with lactobacillus bugs and they are also present on human skin. This means that any contact with human hair, skin or saliva might carry lactobacteria into the beer. Due to their high tolerance for acidic conditions, they might survive fermentation, souring the beer during conditioning or aging.

A common beginner’s mistake is to start siphon hoses by sucking on them. This is a sure way to contaminate your brew. Even if you gargle with pure ethanol, you’d need to do so for at least 15 minutes to properly sanitize your mouth! Use a starter siphon or a pump to transfer your wort or beer.

Another mistake is to put any part of your body into your wort or green beer. Quickly washing your hands, or squirting them with sanitizer and then rinsing, won’t sanitize your hands! To get your hands to “beer clean” levels, you must use the same techniques that surgeons use. Remove any rings. Then, scrub your hands and forearms for at least five minutes using warm water and surgical soap, scrubbing both the front and the back of your hands for two minutes and cleaning under your nails using a nail file. A simpler method is to just wear sanitized latex gloves.

In the fermentation vessel, a lactobacillus infection will usually produce a scum on the top of the conditioning beer. Bottles of beer with lactobacillus infections typically have thin body and produce a low, slow, seemingly endless gush of foam when opened. But, because lactic acid doesn’t volatilize well, there isn’t much acidic aroma.

By contrast, Acetobacter infection is extremely rare in homebrew; it’s a relatively slow-growing bug and it requires aerobic conditions to flourish. When it does occur it is usually noticeable in the conditioning vessel as a slimy, “ropy” scum on top of the beer, combined with a distinct vinegar aroma. Due to the anaerobic environment, it is extremely unusual for bottle-conditioned beer to develop serious Acetobacter infections.

by high levels of hop bitterness, carbonation or dark malts. Any beer dispensed using nitrogen gas or beer gas should also have some level of silky texture.

Skunky

See Lightstruck.

Smoky (Phenol)

Detected in: Aroma, flavor, mouthfeel.

Described As: Bacon, barbeque, barbeque sauce, bitter, burnt, campfire, charred, lox (smoked dried salmon) scorched, smoked, smoked bacon, smoked ham, smoked herring (kippers), smoked salmon, wood smoke.

Typical Origins: Malt, process faults, contamination.

Typical Concentrations in Beer: 10 - 400 µg/l.

Perception Threshold: 15 µg/l.

Beer Flavor Wheel Number: 0423.

Discussion: Smoky notes arise due to monophenols; simple phenols with a hydrocarbon side chain. In brewing they occur as minor compounds during pyrolysis (heating material in the absence of oxygen), such as scorching wort/mash or smoking

malt. These compounds are then extracted during mashing and wort boiling. They can also be deliberately introduced into beer by using smoked malt or by adding smoked, or smoke-flavored ingredients (e.g., smoke flavor). Occasionally, wild yeast infections will also produce smoky notes, but these are generally subtler than those produced by scorched wort or smoked malt. Very rarely, smoky notes might get into beer when brewing equipment has been exposed to smoke or has scorched material on the inside, and isn't properly cleaned out before being used. Also see Bromophenol, Chlorophenol, Phenol, Spicy and Vanilla.

To Avoid: * *Avoid Scorching Mash or Wort:* Avoid excess heat during mashing/wort boil. Use a "flame tamer" under direct-fired brewing equipment or used indirectly-heated equipment. Add malt extract at lower temperatures and make sure it is thoroughly dissolved before bringing the wort kettle to a boil. Stir vigorously after adding extract to wort kettle to avoid scorching. Avoid excessively long boil times. Use proper technique when decoction/step mashing. * *Proper sanitation* to avoid microbial contamination by wild yeast. * *Proper yeast health.* Pitch yeast at sufficient levels and at correct temperature for style. Oxygenate wort to proper level for wort gravity. * *Reduce or eliminate smoked malt or smoke flavoring.* Especially with smoke flavor, a little goes a very long way. * *Clean equipment thoroughly.* Make sure that scorched material is completely removed.

When are Smoky Notes Appropriate?: Unpleasant burnt or scorched notes are a fault in any style of beer. Balanced, roasted, smoky aromas and flavors, typically imparted by judicious use of smoked malt, are appropriate in smoked beer. Subtle smoky notes from restrained use of peat smoked malt are acceptable in Scotch Ale. Smoky notes are a fault in other styles of beer.

Soapy

Soapy flavors typically come from improper rinsing of brewery equipment or glassware. Witbier and spiced beer can sometimes have soapy notes which occur due to the use of old or inferior coriander seed. See Alkaline or Phenolic.

Sotolone

Detected In: Aroma, flavor.

Described As: Burnt sugar, caramel, curry, fenugreek, maple syrup.

Typical Origins: Adjunct spices or sugars.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 011?

Discussion: Sotolone is the chemical responsible for the aroma and flavor of maple syrup and fenugreek, as well as some of the aromas found in curry powder. See Phenols.

Solvent-like

Detected In: Aroma, flavor

Described As: RE chemical solvents

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0120

Described As: See Fusel Alcohol and Solventy Esters.

Solventy Esters

Detected In: Aroma, flavor, mouthfeel.

Described As: At lower levels, ethyl acetate can smell flowery, floral or like Juicy Fruit™ gum. At higher levels, it smells like acetone, estery, harsh, lacquer, model [airplane] glue, model paint, nail polish, nail polish remover, paint thinner or turpentine. At high levels, mouthfeel is described as burning, "hot," harsh, "peppery" or "prickly." Aroma might be irritating to the eyes, giving an "eye watering" sensation.

Typical Origins: Yeast.

Typical Concentrations in Beer: ?

Perception Threshold: 8-42 mg/l.

Beer Flavor Wheel Number: 0120 (Solvent-like), 1033 (Ethyl Acetate).

Discussion: Solventy esters occur when alcohols are reduced by oxygen. As such, they naturally occur in all beers. The most common solventy ester is ethyl acetate, which occurs when ethanol undergoes esterification. As with other esters (see Esters) ester production is increased when fermentation is vigorous (e.g., higher temperature fermentation) or when the yeast is stressed (e.g., insufficient yeast cell count or oxygen levels). Some strains of wild yeast can also produce high levels of solventy esters. Also see Esters, Fusel Alcohol, and Oxidation.

Increased by: Yeast strain. Wild yeast infection. Insufficient or excessive yeast growth. FAN/Amino Acid deficiency. Mineral (Zinc, Calcium, etc.) deficiency. Underpitching yeast. Low dissolved oxygen - low oxygen levels limits rate of yeast reproduction due to limited sterol in cells. Incorrect fermentation temperature for strain, especially high temperature fermentation. Aeration of green beer during growth phase of fermentation. High gravity wort (above 15 °P) - going from 10 °P to 20 °P results in fourfold ester production. High ethanol concentration (>9%). Dehydration of yeast. Excessive trub.

Decreased by: Overpitching yeast. High dissolved oxygen. Adequate oxygen levels for wort strength. Incorrect fermentation temperature for strain (e.g., high or low fermentation temperature). Increased lipids in wort - carrying over more cold break into fermenter. CO₂ buildup in fermenter. Aging - esters are degraded by esterases produced by yeast; they are also volatile and will evaporate or degrade into other compounds over time.

To Avoid or Control: Choose appropriate yeast strain. Pitch correct amount of yeast (less for higher fusel levels, which translates into higher esters levels) at 0.5 to 1 quarts of yeast slurry per 5 gallons. Maintain proper fermentation temperature for strain (higher temperature means more fusel alcohols, meaning more esters). Match starter to wort gravity & temperature.

Adequately oxygenate wort after pitching yeast (O₂ is used by yeast to make unsaturated fatty acids, using up aCoA and increasing thickness of cell membranes, thus preventing ester formation). Don't aerate wort once fermentation starts. Proper separation of trub from wort. High-pressure fermentation decreases yeast growth, hence fusel precursors - it is used by some large lager breweries. Aging will decrease or eliminate esters (over the course of 1+ year).

When Are Solventy Notes Appropriate? Never. Although very low levels might occur in otherwise well-made strong ales, such beers should be conditioned until the solventy notes recede. See notes for Esters for styles where lower levels of solventy esters, which give floral fruity notes, are appropriate.

Solventy-Stale

Detected in: Aroma, flavor.

Described As: Chemical, stale.

Typical Origins: Aging.

Typical Concentrations in Beer: 0 mg/l in fresh beer. Up to 200 ng/l in badly-aged beer.

Perception Threshold: ~6 ng/l.

Beer Flavor Wheel Number: n/a.

Discussion: Solventy-stale notes are due to furfural ethyl ether (FEE). Its precursor, furfural alcohol, is produced by Maillard reactions (see Malty) during malt kilning and during wort boiling. Over time, ethanol interacts with furfural alcohol to form FEE. Beer stored at room temperature can develop perceptible levels of FEE after just 1 month. Beer stored at room temperature for 6 months can have concentrations of FEE up to 200 ng/l. Beer held at high temperatures (100 °F) can develop detectable FEE levels in just days.

Furfural alcohol and FEE are found in higher concentrations in dark beers, especially dark ales. Lower pH, darker color and higher alcohol content enhance FEE formation, while sulfite inhibits it. Note that oxidation doesn't play a role in FEE production, so the usual steps to avoid oxygenation don't apply. Also see Leathery, Oxidation, Papery and Solventy/Solventy Esters.

To Avoid or Control: * Don't boil wort at high temperatures for long periods of time. * Store beer at cool temperatures (the colder the better, down to 32 °F). See Oxidation for details.

When Are Solventy-Stale Notes Appropriate? Never. Very low levels are acceptable in aged beers, especially strong, dark ales.

Sour

Detected in: Aroma, flavor, mouthfeel.

Described As: Acidic, cidery, citrusy (e.g., lemon, grapefruit), tart, sour, sour milk. At high levels sourness can have a burning, hot, peppery, prickly or tingling mouthfeel. Note that many acids are non-volatile and might not be detectable in aroma.

Typical Origins: Yeast, malt, Microbial contamination.

Typical Concentrations in Beer: 90–300 mg/l.

Perception Threshold: 170 mg/l.

Beer Flavor Wheel Number: 0900. Use with 0141 for citrus-sour.

Discussion: The ability to detect sourness is one of the basic tastes in humans, and most food and drink is acidic to some degree. Beer typically has pH 4.0-4.5; below this, sourness can become noticeable and possibly unpleasant. Beer pH indirectly influences the flavor activity of a number of other chemicals and can affect perception of flavors and aromas.

Sourness in beer is due to excessively low pH due to high levels of organic acids in the beer. Acidic compounds are perceptible at 300 mg/l or lower. Any sourness in beer is due to added acids (e.g., fruit or food-grade acids) or bacterial action.

The two most important acids found in beer are Acetic acid and Lactic acid. They are described in their own sections. Other forms of sourness in beer include:

* **Ascorbic Acid:** Mistakenly thought to be an anti-oxidant for beer, it is sometimes added at bottling. It can complex with yeast to produce ethyl acetate (see Solventy). It has a crisp, citrusy sourness.

* **Citric Acid:** Used to lower mash pH and also naturally present in citrus fruits. It can appear in beers made with extremely high levels of adjunct sugars or in fruit beers. It has a tart, lingering, citrusy sourness.

* **Naturally-Occurring Acids:** Yeasts naturally produce organic acids such as oxalic acid, pyruvic acid and succinic acid, which have the effect of lowering beer pH as compared to the pH of the unfermented wort. They have a crisp, tart sourness and are not particularly volatile, making them hard to detect in aroma. Fatty acids are carboxylic acids with an aliphilic (i.e., hydrocarbon) tail. They are essential for yeast nutrition while the wort is fermenting, but can contribute to flavor instability in finished beer. They tend to produce unpleasant and aromas flavors when oxidized - see Butyric, Caprylic, Isovaleric and Horey.

* **Malic Acid:** Used in wine and cider-making, it is naturally present in many fruits, especially apples. It can appear in beers made with extremely high levels of adjunct sugars or in fruit beers. It has a cidery, tart, fruit-like sourness.

* **Phosphoric Acid:** Used to lower mash pH and to wash yeast. Imparts a lingering sourness.

* **Roast Acidity:** Present in dark malts due to kilning at high temperatures. Roast acidity is typically used to adjust mash pH when brewing dark beers. Adjusting mash pH downwards by 0.2-0.4 pH, depending on amount of dark malt used and the buffering capacity of the water. Roast acidity can impart a subtle, dry sourness to dark beers.

* **Sulfuric Acid:** Commercial breweries sometimes use mineral acids to adjust mash pH or to treat water because of their low cost. Very rarely, homebrewers might contaminate their beer with mineral acid. Mineral acids have a sharp, pungent aroma and a harsh sour flavor. In high concentrations, they are both caustic and toxic.

* **Tartaric Acid:** Used in wine making. Imparts a lingering sourness.

Some Acids Found in Beer

Acid	Description	Detectable range
3-Methylbutyric	Sweaty	1.5
Acetic	Vinegar	30-2175 mg/l
Butyric	Buttery, cheesy	0.5-2.2
Caproic	Vegetable oil	8
Caprylic	Goaty	15
Hexanoic	Vegetable oil	1.0-5.0
Hexenoic	Dry leaves	0.01
Oxalic		2-20
Phenylacetic	Honey	2.5
Propionic	Milky, acidic	1-150
Succinic		16-140
Valeric	Sweaty	0.03-0.1

To Avoid: * Choose appropriate yeast strain. Reduce percentage of adjunct sugars in the beer. Pitch correct amount of yeast (0.5 - 1.5 qt per 5 gallons) for optimum yeast health and to minimize lag time. * Avoid overly vigorous (i.e., high temperature) fermentation to reduce levels of naturally-produced acids. * Practice proper sanitation to avoid infection. Thoroughly clean all cold-side equipment before sanitizing it. Don't use cold side equipment which can't be sanitized (e.g., wooden or scratched plastic utensils/containers). Don't start a siphon by sucking it (lactobacillus is present in the human mouth). Avoid oxygenation of green beer. Avoid oxygenation of mash during

sour mashing. Don't let mash temperature fall below 130 °F when sour mashing. Perform mash out and sparge at ~168 °F, lauter at above 160 °F. * Limit or eliminate acidulated malt, sour mash or lactic acid additions. Limit quantities of acidic fruits.

When Is Sourness Appropriate?: Very low levels of lactic sourness are acceptable in dry stout. Medium to high levels of lactic sourness are expected in Berlinerweisse. Medium to high levels of lactic sourness and low levels of acetic sourness are expected in Belgian sour ales. Some fruit sourness is acceptable in fruit beers.

Sour Milk

See Butyric, Caprylic, Isovaleric, Lactic and Sour.

Spicy (Phenol)

Detected in: Aroma, flavor, mouthfeel.

Described As: Allspice, bitter, cinnamon, clove oil, clove-like, eugenol, ginger, herbal, medicinal, peppery, plastic, roasted, smoky, spicy. Some spices can be detected in mouthfeel as astringent, burning (e.g., black pepper, capsicum), numbing (e.g., wintergreen), peppery or prickling sensations.

Typical Origins: Yeast, microbial contamination, aging.

Typical Concentrations in Beer: 10-30 µg/l in normal beers > 40 µg/l in problem or specialty beers.

Perception Threshold: 40 µg/l.

Beer Flavor Wheel Number: 0111. See also 1003 Vanilla

Discussion: Spicy notes in beer are generally due to complex aromatic alcohols, a class of phenols with a multi-carbon and/or ester side chain. They are produced as minor metabolic products during yeast fermentation by the decarboxylation of phenolic acids via enzymes, especially by "Phenolic Off-Flavor Producing" (POF+) strains (e.g., Belgian and Hefeweizen strains, wild yeasts), and to a lesser extent by *Acetobacter* bacteria. They are also found naturally in herbs and spices.

Phenolic compounds produced by brewers' yeast usually include clove-like, spicy or peppery notes. Wild yeasts or bacteria can produce bitter, medicinal, plastic, roasted or smoky notes in addition to more pleasant spicy notes. Oxidation might also produce phenolic bitterness, especially in the form of eugenol (clove-like) spiciness.

Unlike other phenolic compounds, many complex aromatic alcohols are volatile, or easily degraded during storage, and will decrease as the beer is aged. Common complex aromatic alcohols as listed below. Also see Bromophenol, Chlorophenol, Phenol, Smoky and Vanilla.

* **4-Vinyl Guaiacol:** The most commonly produced phenolic compound, formed by phenolic off-flavor producing strains of brewers' yeast, especially German hefeweizen yeasts. It is formed during fermentation from its precursor, ferulic acid. It has a clove-like flavor and aroma. It is detectable at 40 ppb in water, 20 - 100 ppb in beer.

* **Capsicum:** Found naturally in chili peppers. Responsible for chili-pepper "heat" due to capsicum acting on the trigeminal nerve. Capsicum strength is rated in Scoville Heat Units" (SHU), ranging from 0 (bell peppers) to 16 million (pure capsicum). By comparison, pepper spray has about 5 million SHU and Tabasco sauce has 500-8,000 SHU.

* **Eugenol:** Found naturally in cloves (it's the active ingredient in clove oil), but also basil, bay, cinnamon and nutmeg. It can sometimes occur as an oxidation product as beer ages, especially in strong beers (ABV >7%).

To Control: **Causes:** Yeast strain (e.g., Belgian or hefeweizen yeast). Yeast mutation. Wild yeast infection, usually by *Saccharomyces Diastaticus* (medicinal, plastic, smoky notes). Underpitching. High temperature fermentation (above ~68 °F). Aging - oxygenation of beer might produce eugenol.

* **To increase 4-vinyl Guaiacol:** Use a ferulic acid rest during mashing (15 min. at 110 °F, at pH < 5.7). This liberates ferulic acid, the precursor to 4-vinyl guaiacol, which slightly aids in the production of clove flavor. Don't repitch hefeweizen yeast (4-vinyl guaiacol production is highest in the first generation). Underpitch hefeweizen yeast. Ferment German wheat and rye beers at 62 °F.

* **To Reduce or Avoid:** * *Proper yeast management.* Proper yeast strain. Avoid high-temperature (i.e., above ~68 °F) fermentation. Good sanitation procedures to avoid wild yeast infection. Don't repitch yeasts for more than 5-10 generations from the original culture to avoid yeast mutation. Don't reculture weak, old or mutated yeast. * Reduce or eliminate herb or spice additions. * Age beer properly - see Oxidation for details.

When Are Spicy Notes Appropriate?: Low to medium spicy and/or clove-like phenolic notes are expected in German wheat and rye beers, French and Belgian ales and Belgian strong ales. Balanced herb and/or spice notes are expected in spiced or herbal beers.

Spruce

See Pine.

Stale

Detected In: Aroma, flavor, mouthfeel.

Described As: Old beer, overaged, overpasteurized.

Typical Origins: Oxidation

Beer Flavor Wheel Number: 0800

Discussion: See Nutty, Oxidation, Papery and Solventy Stale.

Star Anise

Detected In: Aroma, flavor.

Described As: Reminiscent of star anise.

Typical Origins: Spice additions.

Beer Flavor Wheel Number: 011?

Discussion: The primary aroma compound in star anise is 1-p-Methoxyphenyl-2-propanone. See Spicy.

Straw-like

Detected In: Aroma, flavor.

Described As: Hay-like.

Typical Origins: Hops.

Beer Flavor Wheel Number: 0232

Discussion: See Grassy.

Strawberry

Detected In: Aroma, flavor.

Described As: Reminiscent of strawberries.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0148

Discussion: See Esters.

Sulfur

Detected in: Aroma, flavor.

Described As: Autolyzed, brothy, burnt match, cooked cabbage, cooked vegetable, garlic, mineral-like, matches, onions, putrid, rotten eggs, rotting vegetation, rubber, shellfish, shrimp, vitamins, sulfury, sulfitic, vitamin B, yeasty.

Typical Origins: Yeast, microbial contamination, aging.

Typical Concentrations in Beer: Variable.

Perception Threshold: Variable.

Beer Flavor Wheel Number: 0700.

Discussion: These are various sulfury or sulfitic compounds which originate from sulfur-bearing amino acids (e.g., cysteine and methionine).

Possible origins include malt type (especially pilsner malt), yeast strain, yeast autolysis, bacterial spoilage, water contamination, or high levels of sulfate ions in water treated with gypsum (calcium sulfate) or Epsom salts (magnesium sulfate). They can also arise due to overuse of sulfur-based antioxidants or antibacterial agents, such as potassium metabisulfite. While rare in beer, these flavors are common in over-sulfited ciders, meads and wines. Also see DMS, Sulfidic and Sulfitic.

To Avoid: * Proper yeast management. Choose an appropriate yeast strain. Rack beer from yeast within 2-4 weeks after fermentation stops. * Proper mashing and wort boiling technique. Get a full, rolling, open boil of at least 1 hour, especially when working with Pilsner malt. (see DMS for more ideas). * Practice good sanitation to avoid bacterial infection. * Avoid excessive sulfate additions. * Don't add sulfites to beer.

When are Sulfury Notes Appropriate?: Very low levels of "clean," mineral-like sulfury aroma and/or flavor are acceptable in Dortmunder export, German pilsner, Bohemian pilsner, Schwarzbier, Kölsch, Northern German altbier, Düsseldorf altbier, English ESB/pale ale (but not ordinary or best bitter) and IPA. Other sulfury flavors and aromas are faults.

Some Sulfur-Containing Compounds Found In Beer

Compound	Descriptor	Detectable range
3-methyl-2-butene-1-thiol	Lightstruck, skunk	0.000004-0.3
Diethyl sulfide	Burnt rubber, cooked vegetables, garlic	0.001-0.01
Dimethyl disulfide	Rotting vegetables	0.0075
Dimethyl sulfide	Black currant, cooked vegetable, cooked corn, sweet corn, tomato plants, tomato juice	0.01-0.2
Dimethyl trisulfide	Onion, rotting vegetables	0.00001
Ethyl mercaptan	Egg, garlic, onion, rotting leek, rotting vegetables	0.001-0.02
Hydrogen sulfide	Rotten egg	0.001-0.02 mg/l
Methionol	Cooked potatoes, mashed potatoes	<0.05
Methionyl acetate	Mushrooms	0.013-0.03
Methyl mercaptan	Rotting vegetables	0.00015
Methyl	Cooked cabbage	0.05

thioacetate		
Propyl mercaptan	Onion	0.0005
Sulfur dioxide	Burnt matches	25

Sulfidic (Hydrogen Sulfide) (Sulfur)

Detected in: Aroma, flavor.

Described As: Eggs, drains, fresh beer, putrid, sewer, sewer gas, sulfidic, rotten eggs.

Typical Origins: Yeast, microbial contamination, aging.

Typical Concentrations in Beer: 0.001 - 0.2 mg/l.

Perception Threshold: 4-5 µg/l.

Beer Flavor Wheel Number: 0721.

Discussion: Hydrogen sulfide (H₂S) is mostly produced by yeast during fermentation, and sometimes during maturation, by mechanisms which are still poorly understood. Yeast strain plays a major role; lager yeasts produce much more H₂S than ale yeasts. There is more than one pathway involved. It might be formed due to breakdown of amino acids such as cysteine, or peptides such as glutathione, or by the reduction of inorganic sulfur compounds such as sulfate and sulfite.

A small amount of H₂S is formed during wort boil from sulfur compounds found naturally in malt. More H₂S is produced in the presence of copper ions.

During fermentation, most of the H₂S is scrubbed out of solution by carbon dioxide, but some might remain in the finished beer.

Low concentrations give beer a desirable "fresh beer" character, but high concentrations of H₂S are a defect. Bacterial infections (by *Zymomonas*, *Pectinatus* or *Megasphaera* species), can also produce large amounts of hydrogen sulfide, often in conjunction with other "off" flavors. H₂S can also be released by dead yeast during autolysis, often in conjunction with other "off" characteristics. Finally, sulfite preservatives in cask finings might also release H₂S.

Extensive contact between beer and aluminum can also cause reactions which lease hydrogen sulfide.

To Control or Avoid: * Avoid excessive sulfite or sulfate additions. * Choose proper yeast strain for style. * Practice proper yeast management. Pitch sufficient yeast for wort gravity. Oxygenate wort properly. Make sure that yeast get sufficient nutrient (e.g., zinc) - limit sugar adjuncts and/or add yeast nutrient. Ferment at proper temperature for yeast to get a vigorous fermentation - warmer fermentation helps scrub H₂S out of the beer. Make sure that fermentation products are ventilated (i.e., airlock or blow-off tube, keep back pressure of fermentation tanks low). Don't reuse yeast beyond 5-10 generations to avoid mutation. * Condition beer for a sufficiently long time to get H₂S out of green beer. * Rack beer off of yeast within 2-4 weeks after fermentation ends. * Practice good sanitation to avoid bacterial infection. * Don't use cask finings preserved with H₂S, or use them in moderation. * Don't use aluminum for cold-side equipment.

When Are Hydrogen Sulfide Notes Appropriate?: At very low levels, sulfury notes from yeast are acceptable in some light lagers. Sub-threshold notes might be acceptable in pale, hoppy English ales. Noticeable hydrogen sulfide notes are a defect in all beer styles.

Sulfitic (Sulfur Dioxide) (Sulfur)

Detected in: Aroma, flavor.

Described As: Biting, burning matches, burnt rubber, choking, mothballs, sodium sulfite, sharp, striking match, sulfur dioxide, sulfurous.

Typical Origins: Yeast, process faults.

Typical Concentrations in Beer: <10 mg/l.

Perception Threshold: 7-20 mg/l.

Beer Flavor Wheel Number: 0710.

Discussion: Normally, yeast produces small levels (10 mg/l or less) of sulfur dioxide (SO₂) during fermentation. Higher levels are associated with added sulfites (e.g., potassium metabisulfite) used as anti-microbial, anti-oxidant and preservative.

Sulfites block staling in beer by interacting with acetaldehydes and carbonyl compounds, temporarily masking their distinctive flavors and aromas. As beer ages, however, sulfites form sulfur dioxide, adding distinctive “off”-characteristics to the beer along with the usual staling compounds.

High levels of sulfites (>10 mg/l) are toxic to yeast and bacteria. Levels of more than ~200-250 mg/l are toxic to people, but, fortunately, at that level, sulfite character is so strong as to be unpalatable. People with asthma are sometimes hypersensitive to sulfites, so U.S. and European law requires alcoholic beverages with more than 10 ppm of sulfites to be labeled with the warning: “Contains Sulfites.”

Note: When spiking beer samples with sulfite, make sure that none of your tasters are sensitive to sulfites and that they have no history of asthma.

To Avoid: * Avoid excessive sulfite (e.g., potassium metabisulfite) additions. * Choose proper yeast strain for style - some strains produce more SO₂ than others. * Avoid aerating mash, wort or beer, except when aerating wort prior to pitching yeast. This makes sulfite additions unnecessary. * Get a vigorous fermentation to scrub SO₂ out of beer. Ales seldom have SO₂ problems because their fermentation is more vigorous than lagers. * Condition beer for a sufficiently long time to get SO₂ out of green beer.

When Are Sulfite Notes Appropriate?: Never.

Sweaty

See Butyric, Caprylic, Horsey and Isovaleric.

Sweet

Detected in: Aroma, flavor, mouthfeel.

Described As: Cloying, honey-like, jam-like, jammy, malty, oversweet, primings, sickly sweet, sticky, Sucralose, sugary, syrupy, underattenuated, worty. Specialty sugars or specialty crystal/caramel malts might give sweet aromas and flavors reminiscent of candy, caramel, honey, maple syrup, molasses, toffee or treacle. Technically, sweetness is only detectable in flavor, but esters and VDK compounds commonly associated with sugars and sugary mixtures (i.e., honey) can give the illusion of sweetness in the aroma. High levels of sweetness can increase perception of body in mouthfeel, since they increase beer viscosity.

Typical Origins: Malt, adjuncts.

Typical Concentrations in Beer: ~20-30 mg/l.

Perception Threshold: ?

Beer Flavor Wheel Number: 0100.

Discussion: Sweetness is one of the basic human senses. Sweetness in beer is caused by the presence of “reducing” sugars such as simple sugars (e.g., monosaccharides) and short chain

polysaccharides (e.g., dextrans). Since simple sugars such as glucose, sucrose, fructose, maltose and maltotriose are fermented by yeast, non-fermentable sugars, such as lactose, are sometimes used to impart sweetness in brewing. Alternately, the brewer might mash at the high end of starch conversion temperatures (~153-158 °F) to promote dextrin formation in the mash. Sweet beer might be pasteurized or filtered to remove the yeast and then force carbonated at packaging.

The Plato scale corresponds to grams of sucrose per 100 milligrams of water. Degrees Plato (°P) roughly corresponds to S.G. at (1-S.G.)/4. In a finished beer attenuated to 1.008 to 1.010, this works out to 20-30 mg/l.

Unintentional sweetness and poor attenuation in beer is likely due to poor yeast health which resulted in a slow or stuck fermentation. Common causes of slow/stuck fermentation are low FAN levels, low levels of dissolved oxygen in the wort, high gravity worts or high levels of alcohol. Premature flocculation due to shocks to the yeast (e.g., sudden temperature swings) might also result in underattenuation.

To Increase: * Mash at a higher temperature (150-156 °F). * Add non-fermentable sugars (e.g., dextrin, lactose). * Increase wort gravity. * Remove the yeast from partially fermenting wort (e.g., filtering, fining). * Pasteurize or filter beer to remove yeast and add sugar at packaging.

To Decrease: * Practice good yeast management. Choose proper strain for style and wort gravity. Pitch sufficient yeast for wort gravity. Provide sufficient yeast nutrient. Oxygenate wort before pitching yeast. Avoid shocking the yeast. * Mash at lower temperatures (143-149 °F). * Reduce wort gravity. * Reduce or eliminate non-fermentable sugars. * Use more fully-fermentable sugars (e.g., corn sugar, sugar, honey syrup), typically up to about 10-20% of grist. This has the effect of thinning body, however, and might introduce “cidery” notes. * Rouse yeast in beer, while avoiding oxidation, to restart fermentation. * Pitch more yeast (of a higher attenuating or less flocculent strain).

When is sweetness appropriate?: Some degree of sweetness is expected in most beer styles, especially very strong, malty beers. Non-fermentable sugar is sometimes added to beers such as Southern English brown ale and sweet stout to deliberately increase sweetness. Excessive levels of sweetness are considered to be a fault in most beer styles, especially strong, malty beers such as doppelbocks and Belgian strong ales.

Relative Sweetness of Sugars

Sugar	Relative Sweetness
Glucose	0.7-0.8
Maltose	0.3-0.5
Fructose	1.1-1.2
Sucrose	1.0

Syrupy

Detected In: Aroma, flavor, mouthfeel.

Described As: Reminiscent of lightly caramelized (golden) sugar syrup.

Typical Origins: Malt, sugar adjuncts.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1005

Discussion: See Sweet.

Tarry

Detected In: Aroma, flavor.

Described As: Pine tar, pitch, resin, turpentine.

Typical Origins: Equipment faults, contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0501

Discussion: This off-characteristic can arise due to improper use of pitch to waterproof brewing equipment and beer storage containers. Given the ubiquitous use of stainless steel or food-grade plastic brewing equipment, this is a very rare problem, although it was once a problem when some beer barrels were lined with brewers pitch. If improperly heated, it can apparently impart resinous or turpentine-like notes to the beer. Also see Pine or Solventy.

Thick

Detected In: Taste, Mouthfeel.

Described As: "Épais" (French for thick), Viscous.

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1414

Discussion: See Body.

Toasty

See Malty or Roasty.

Toffee

See Diacetyl, Malty and Sweet.

Tomatoes, Tomato Plant

See DMS or Vegetal.

Umami

Detected in: Aroma, flavor, mouthfeel.

Described As: Brothy, glutamate, meaty, savory, soy sauce.

Mouthfeel can be described as hard-to-describe "tongue-coating" effect, which might affect perception of body.

Typical Origins: Yeast, adjuncts.

Typical Concentrations in Beer: ?.

Perception Threshold: ?.

Beer Flavor Wheel Number: n/a.

Discussion: Umami represents the taste of the amino acid L-glutamate and 5'-ribonucleotides such as guanosine monophosphate (GMP) and inosine monophosphate (IMP). Unlike other basic tastes, it was only identified recently (the flavor receptors for it were only identified in 2000) and its effects on flavor are subtle. Generally, rather than adding any flavor on its own, it balances tastes and rounds out flavors. Umami is found in aged meats, oily fish, milk, aged cheese (e.g., parmesan), fermented soy products (e.g., soy sauce) and vegetables such as tomatoes and seaweed.

To Control or Avoid: In beer, umami levels are low and are primarily contributed by yeast, especially autolyzed yeast. To avoid umami notes, don't let the beer sit on the yeast cake for more than a few weeks and store beer cold to slow yeast autolysis. To increase umami notes, do the opposite.

When Are Umami Notes Appropriate?: Aged bottle-conditioned beers might have a slight umami character due to yeast autolysis, generally detectable as "soy sauce" notes. High

levels are generally inappropriate, especially in young, fresh beer.

Vanilla (Phenol)

Detected in: Aroma, flavor.

Described As: Cream soda, custard-like, custard powder, ice cream, vanilla.

Typical Origins: Malt, aging, adjuncts, microbial contamination.

Typical Concentrations in Beer: 10-80 µg/l.

Perception Threshold: 40 µg/l.

Beer Flavor Wheel Number: 1003.

Discussion: Vanillin, the active ingredient in vanilla, is formed by the breakdown of lignins, naturally found in plant cell walls, when exposed to alcohol and oxygen. It is formed in some beers, particularly those high in phenols (e.g., tannins) during aging.

Vanilla is also produced during fermentation by strains of yeast ((POF+ strains) which produce phenolic off-flavors, from its precursor, ferulic acid. In such cases, it is usually accompanied by a similar molecule 4-vinyl guaiacol (see Spicy).

In a few cases, vanilla notes might occur as part of a wild yeast infection. Some wild yeasts produce phenolic flavor compounds which are degraded to form vanillin.

To Control or Avoid: * Avoid getting tannins and spicy phenols into beer. Practice good milling and mashing practice to avoid tannin extraction from malt. See Phenols for more suggestions. * Practice good sanitation to avoid wild yeast infection. * Limit contact with wood (both amount of wood used and time spent in contact) when wood-aging beer. * Proper choice of yeast strain - some yeasts produce vanilla-like notes.

When Are Vanilla Notes Appropriate?: Typically beer has trivial amounts of vanillins, so it is considered a fault in most beer styles. Some degree of vanilla character is welcome in wood-aged beers and German wheat and rye beers. Vanilla flavor and aroma might occur in spiced specialty beers.

Vegetable Oil

Detected In: Aroma, appearance, flavor, mouthfeel

Described As: Actual vegetable oil, or reminiscent of vegetable oil.

Typical Origins: Contamination.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0641

Discussion: See Oily or Rancid Oil.

Vicinal Diketones (AKA Diacetyl, VDK) (Fatty Acid)

Detected In: Aroma, flavor, mouthfeel.

Described As: Butter, buttered popcorn, buttery, buttermilk, butterscotch (at higher levels), honey, milky, movie/theater popcorn, toffee, vanilla. Oily, slick or creamy mouthfeel. Can give illusion of fuller body.

Typical Origins: Yeast, microbial contamination.

Typical Concentrations in Beer: 8-600 µg/l.

Perception Threshold: 10-40 µg/l. The ability to detect diacetyl is higher in light-flavored, low-alcohol beers, lower in more full-flavored beers. The ability to sense diacetyl is also genetic. Some people are sensitive to it down to 10 µg/l, others are insensitive to it. The typical threshold is 20-40 µg/l.

Beer Flavor Wheel Number: 0620.

Discussion: Vicinal diketones (VDK) consist of diacetyl & pentanedione. Since they are virtually indistinguishable by typical chemical tests, they are grouped together. Both are natural byproducts of fermentation, formed from minor metabolic products produced during the initial stages of yeast growth and fermentation, which leak out of the yeast cells into the beer. The highest concentrations are found in the initial stages of fermentation, during the reabsorbed by yeast in final phases of fermentation and are metabolized to relatively flavorless diol compounds.

High temperature fermentation both produces higher levels of VDK, but does an even better job of reducing them as long as the yeast remains active until the end of fermentation.

Bacterial infections, notably *Pediococcus* and *Lactobacillus*, can produce VDK in high concentrations, usually in conjunction with numerous other off-flavors and aromas as well. This is a common problem in infected (dirty) draught beer lines.

* **Diacetyl:** Produced during fermentation as a byproduct of valine synthesis when yeast produces α -acetolactate, which escapes the cell and is spontaneously decarboxylated into diacetyl. The yeast then absorbs the diacetyl, and reduces the ketone groups to form acetoin and then 2,3-butanediol. Healthy yeast has about 10 times the ability to absorb diacetyl as to produce it.

Diacetyl is typically detectable at 0.5 to 0.15 mg/l, although the ability to taste diacetyl is genetic. Some people can taste diacetyl down to 0.2 mg/l, while others are insensitive to it! It is described as tasting like artificial butter, butter, butterscotch, toffee or vanilla.

* **Pentanedione:** 2, 3-pentanedione is produced during fermentation as a byproduct of isoleucine synthesis when yeast produces α -ketobutyrate, which escapes the cell and is spontaneously decarboxylated into 2, 3-pentanedione. The yeast then absorbs the 2, 3-pentanedione and reduces the ketone groups to form relatively flavorless compounds.

Compared to diacetyl, pentanedione is much less important, since the perception threshold is 10 times higher than that of diacetyl and most yeast strains produce far less pentanedione than diacetyl. It is detectable at 0.90 mg/l. It is detectable in aroma and flavor as honey or honey-like perfume.

Some Vicinal Diketones and reduced derivatives in beer

Material	Description	Detectable range
2, 3-hexanedione	Strawberry	<0.01
2, 3-pentanedione	Honey	0.1-0.15
3-hydroxy-2-pentanone		0.05-0.07
Acetoin	Fruity, moldy, woody	1-10
Diacetyl	Butterscotch	0.01-0.4 mg/l

Increased By: * Yeast strain selection - some produce more VDKs, especially those which flocculate well and those which produce respiratory-deficient mutants.

* Improper yeast management. Insufficient or excessive yeast growth. Yeast mutation. Reusing yeast collected too early in previous fermentation cycle. Poor yeast health (e.g., Mineral deficiency, overpitching, low dissolved oxygen, high gravity wort, >9% ethanol concentration, delayed yeast collection,

insufficient cooling of fermentor cone, incomplete mixing in fermentor, excessively high or low pH). FAN/Amino Acid deficiency, especially insufficient levels of valine in wort (needed for diacetyl reduction). Underpitching yeast. Aeration of green beer after yeast growth phase. Slow/weak fermentation. Incomplete mixing in fermentor. Dehydration of yeast. Incorrect fermentation temperature for strain, especially low temperature fermentation. Swings in fermentation temperature. Insufficient fermentation time. Prematurely removing yeast from the wort (e.g., filtering, fining, reducing fermentation temperature).

* Improper Sanitation. Wild yeast infection (bacterial contamination can produce high levels of 2, 3- pentanedione). *Pediococcus Damnosus* infection produces large amounts of diacetyl, which isn't reduced with time. *Lactobacillus* infection during storage.

* Configuration & size of fermenting vessels can affect VDK production - but only for large commercial tanks where there is high pressure at the bottom of the tank.

* VDK precursors are increased by yeast strain, higher oxygen levels and higher yeast pitching levels, but the latter two factors also help yeast reduce VDK in the final stages of fermentation.

* Conversion of VDK precursors to VDK is increased by drop in pH (optimal at 4.2-4.4 pH), high levels of oxygen and temperature increases, especially during the fermentation stage of primary fermentation. These factors also help yeast reduce VDK, however.

Decreased By: * CO₂ buildup in fermentor. * Keep adjuncts low (<40%) or add yeast nutrient. * Use good quality malt extract (with good nitrogen and amino acid composition). * Good yeast management. Aerate wort well after pitching yeast. Use yeast starter (at least 0.5 quart per 5 gallons for ale, more for lager and high gravity beers). Use optimum fermentation temperature for yeast strain (not too cold). Use good quality moderately flocculating yeast, which is not susceptible to mutation or contaminated by wild yeast. Allow fermentation/diacetyl reduction to finish before racking off, lowering temperature or adding finings. Sufficiently age beer on yeast (rouse yeast if necessary, while avoiding aeration). Minimize aeration during transfer. * Use good sanitization practices to avoid bacterial infection.

* Yeast will naturally reduce VDK as fermentation progresses, so healthy, vigorous yeast activity during primary fermentation (down to about 90% of terminal gravity) will reduce most diacetyl.

* The yeast's ability to remove diacetyl drops during secondary fermentation (i.e., lagering). It is increased by a "diacetyl rest." Typically, this consists of increasing the temperature of lagering beer to ~50-55 °F for 1-3 days at end of lagering period. In some cases, however, more or less extreme rests might be required. Diacetyl uptake by yeast is slightly increased at 6 °C (43 °F) to a maximum activity at 20 °C (68 °F) for up to 34 days (maximum VDK reduction occurs at 3-4 days with very little additional reduction after about 16-24 days).

* Higher yeast concentrations and increased contact between yeast and fermenting beer (i.e., adding new yeast or rousing existing yeast into suspension) also increase yeast's natural ability to reduce VDK.

When Are VDKs Appropriate?: Low levels of diacetyl are acceptable in Bohemian Pilsner, English Pale Ales, Scottish Ales, English Brown Ales, Brown Porters, Robust Porters, Sweet Stouts, Oatmeal Stouts, Foreign/Extra Stouts, English IPA

and Strong Ales. They are a fault in other styles of beer, especially most lagers.

Low (sub-threshold) levels of diacetyl can give the illusion of richness or body in any beer style, although this is undesirable in thin-bodied beers.

Vinegar

See Acetic and Sour.

Vinous

Detected In: Aroma, flavor, mouthfeel (as warming)

Described As: Alcoholic, fusel alcohols, solventy, wine-like.

Typical Origins: Yeast.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0112

Discussion: See Ethanol, Esters, Raisin and Sherry-like.

Walnut

Detected In: Aroma, flavor.

Described As: Reminiscent of fresh walnuts.

Typical Origins: Malt, oxidation.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0221

Discussion: See Almond, Malty, Nutty and Oxidized.

Warming

Detected In: Mouthfeel (as Warming), Aftertaste.

Described As: Alcoholic warmth, burning, harshness, heat, prickliness, solventy warmth.

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1370. See also 0110 Alcoholic and 0111 Spicy.

Discussion: See Ethanol, Fusel Alcohols, Solventy Esters and Spicy.

Watery

Detected In: Mouthfeel.

Described As: Thin, seemingly diluted.

Typical Origins: Recipe, yeast, infection.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 1411

Discussion: See Body.

Winey

See Ethanol, Esters, Raisin and Sherry-like.

Woody

Detected In: Aroma, flavor

Described As: Seasoned wood (uncut)

Typical Origins:

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0211

Discussion: See Hoppy or Phenols (Tannins).

Worty

Detected In: Aroma, flavor.

Described As: Fresh wort.

Typical Origins: Malt.

Typical Concentrations in Beer: ? mg/l.

Perception Threshold: ? mg/l.

Beer Flavor Wheel Number: 0330. Use with other terms to describe infected wort, e.g. 0731 Parsnip

Discussion: See Grainy, Malty or Sweet.

Yeast Bite

See Autolyzed, Umami or Yeasty.

Yeasty (Sulfur)

Detected In: Aroma, flavor, mouthfeel.

Described As: Flavor of fresh bread, fresh yeast, heated thiamine, umami. Suspended yeast particles in beer can increase perception of body and can impart a creamy or smooth texture to beer.

Typical Origins: Yeast, process faults.

Typical Concentrations in Beer: ?.

Perception Threshold: ?.

Beer Flavor Wheel Number: 0740 (see also 0725 Autolyzed).

Discussion: Living yeast cells can give beer a distinct flavor and aroma, which is different from the aromas and flavors of autolyzed yeast. All cask- or bottle-conditioned beer will have some yeast in it, but yeast levels are likely to be very low unless the yeast is a non-flocculent strain or the sedimented yeast cake at the bottom of the package is roused.

High levels of yeast generally indicate insufficient conditioning time or rough transfer of raw or packaged beer which disturbed the yeast on the bottom of the vessel. Also see Autolyzed and Umami.

To Avoid or Control: * Proper yeast strain selection - some yeast strains flocculate and sediment better than others. * Sufficient conditioning time to allow yeast to settle. * Use of fermentor finings to encourage yeast to flocculate and precipitate. * Filter beer. If this is done, however, the beer must be force carbonated or have fresh yeast or fermenting wort pitched at packaging time. * Carefully transfer beer from conditioning vessel to packaging (i.e., bottling bucket, keg) to avoid rousing yeast cake.

When Are Yeasty Notes Appropriate?: Yeast notes are expected in unfiltered, turbid beers such as American wheat and rye beers, German hefeweizen, dunkelweizen and roggenbier and Belgian witbier. They are generally considered a fault in other beer styles. They are definitely a fault in beers where brilliant clarity or long conditioning time is the norm.

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