# BICEP #3

This session covers malt and malting, DMS, nutty and smoky off flavors and light and amber hybrid beers.

## Key to Abbreviations and Text

**Bolded Text (except for headers) is important information which you should know for the exam.**

*Italic Text is "just for fun" and won't be covered on any of the exams.*

***** This material might appear on the Online Qualifier Exam.

† This material might appear on the Tasting Exam.

‡ This material will be (or might be) tested on the Written Proficiency Exam.

## Part 1: Malting‡

**Why Malt?: Because malt is made from sprouted grains, it contains useful enzymes, such as amylase and protease, which the brewer can exploit during mashing. In particular, malting creates amylase enzymes which are necessary to convert amylose (starch) into simple sugars (e.g., glucose, maltose) which the yeast can digest during fermentation.** *It is possible to make fermented beverages from unmalted grain, but these require the brewer to use an outside source of amylase. Sake brewers add Koji enzymes, which contain amylase, to a "mash" of boiled rice. Brewers of indigenous tropical "beers" use amylase enzymes found in human saliva to convert starchy porridge into simple sugars. It is also possible to "mash" unmalted grains by adding commercially available amylase enzyme.*

Chemically, the malting process does the following:

* Converts large insoluble starch chains into water-soluble starches.

* Activates proteolytic enzymes responsible for protein conversion and degradation.

* Activates diastatic enzymes responsible for starch conversion.

**1. Alpha Amylase** - the major starch debranching enzyme. It breaks 1-6 links in alpha glucans, breaking branched starches into short-chain starches (dextrins).

**2. Beta Amylase:** The major starch reduction enzyme. It produces maltose by cleaving 1-4 links near reducing ends of starches.

* Germination phase of malting breaks down cell walls. This produces **cytase enzyme complex** (hemicellulases, beta-glucanases) which clears a path for other enzymes in endosperm so degradation can proceed more quickly.

**About Grains:** Grains are seeds, and all seeds have similar parts. While it isn't necessary to go too deeply into plant biology to understand malting, it is helpful if you know the basics about how a seed sprouts. A seed is similar to an egg, containing an embryo as well as the proteins and starches necessary to sustain the embryo until it can gain food on its own. For the outermost to innermost layers, a seed consists of the Hull, the Aleurone Layer and the Endosperm, with the Embryo stuck onto one end of the Endosperm.

Seeds begin to germinate when they absorb enough water in order for enzymes to interact with other molecules within the seed. At that point, the embryo "wakes up," and begins to secrete enzymes which activate the Aleurone Layer, which in turn creates amylase and protease enzymes which go to work on the bundles of water-insoluble starches, lipids (oils) and proteins which make up the endosperm. Enzyme activity breaks down complex starches, lipids and proteins into simple molecules which the embryo can use to grow. As it grows, the embryo produces Rootlets and an Acrospire. Eventually the rootlets will grow into a full root system, while the acrospire will develop into all the above-ground portions of the plant.

During processing for food, grains are usually de-hulled (also called winnowing) to remove the woody, inedible outer layer. They are often further processed to remove the bran (the Aleurone layer) and the germ (the embryo), leaving behind just the starchy endosperm. Brown rice, barley groats and whole wheat groats are examples of grains that have only been winnowed, and which retain the germ and the bran. White rice, pearled barley and wheat products such as farina or white flour are made from grains which have had the bran and germ removed.

**About Barley:** Barley is the preferred grain for making beer because it was traditionally cheaper than wheat, since barley flour makes poor bread. Barley also has the advantage that it will grow on poorer soil than that required for wheat. Barley is native to Eurasia, but is now grown worldwide. *It prefers cooler temperatures than those required to grapes, although there is some overlap in growing zones. Historically, for this reason, there was a "wine belt" which stretched from the Mediterranean through France and down the Rhine and Moselle valleys in Germany, and a "beer belt" which covered the British Isles, the Low Countries, Germany, Scandinavia and the other Baltic nations.*

**Barley comes in two-row, four-row and six-row varieties.** All of these designations refer to number of *fertile* rows of flowers on the barley stalk. With six-row barley all flowers are fertile; on two-row barley only two rows are fertile. Four-row barley is actually a form of six-row barley rarely used in brewing due to its high protein content. **Two-row barley varieties have lower yields, but the smaller number of grains means that each grain is larger, yielding more starches in proportion to husk. Traditional German and English strains of malting barley are two-row strains, so strains of two-row barley also have the weight of long and successful brewing history to recommend them.**

**Six-row barley varieties yield more grains, but those grains have traditionally been smaller, meaning a lower starch to husk ratio. It is associated with American brewing, especially producers of "industrial light lagers," who use a high percentage of adjunct grains in their beers. This is because six-row barley malt has very high enzyme levels which allow it to convert its own starches, plus the starches in the adjunct grains. The drawback of six-row barley is that beer made from just six-row barley is more likely to have problems with protein haze and flavor degradation during storage.**

Practically, there is little difference between modern two-row and six-row strains. Any barley strains designed for malting will be suitable for making beer, as long as the type of malt matches the style of beer you wish to make. Like varietal grapes, different malts have different flavors, depending both on the strain of barley and the location where it is grown. German and

Moravian barley strains are responsible for the flavor of German and Czech lagers, while English barley strains, such as Maris Otter, form the base flavors of English, Scottish and Irish ales. If you use American six-row malt or English pale malt to make a German-style Pilsner, don't be surprised if the flavor isn't right!

**The Malting Process: Malting consists of tricking grain into sprouting, and then killing the seedling after it has produced lots of enzymes, but before it has consumed too much of the endosperm.** Malting consists of six steps:

**1. Selection:** Barley (Hordeum *Vulgare*) is most commonly malted, but also wheat, rye and oats. Only the best-quality "malting grade" barley suitable. It must have less than 10.5% protein, 12% moisture content and 96% or better viability. 2-row varieties are traditional; American "6-row" is generally higher in protein with thicker husk.

**2. Steeping:** The grain is soaked in well-aerated, alkaline water at a temperature of 50-65 °F water for 2-3 days, until it has achieved 35% moisture content. The water is drained and the grains are turned at 8-12 hour intervals to promote germination & to rinse grains (which naturally are covered with dust, bacteria and wild yeast). Moisture percentage increases to 43-46%. "Steely" or high-protein barley requires even higher moisture content. Steeping ends when rootlets (called "chits") first emerge from the grains, signaling the start of Germination.

**3. Germination:** Once germination starts, the grain is drained and is moved to humidity-controlled "tank" or "bed" where it is **allowed to sprout for 4-10 days at 50-70 °F. It is turned or raked at 12-24 hour intervals** to control heat, humidity and oxygen levels within the grain bed and to keep growing rootlets from tangling. **It is sprouted for 3-15 days (usually 4-6 days).**

**During germination, enzymes act on the proteins and gums (water-insoluble starches) within the endosperm to make them water soluble.** This is important for brewers because only water-soluble proteins and starches can be easily converted during mashing. Water-insoluble gums and proteins can contribute to haze and other problems in the finished beer.

**Enzymes are produced within the Aleurone Layer of the grain, which act on the Starchy Endosperm, converting insoluble starches & proteins into water-soluble compounds. Important enzymes produced during this type, including Alpha- & Beta-Amylase, glucosidase, dextrinases & Proteases.**

**Germination continues until endosperm partially or fully modified. Degree of "Modification" is determined by length of Acrospire (i.e., baby plant stem) and Rootlets** (AKA "Culms"), and by "steely" vs. "mealy" (i.e., hard vs. crumbly) endosperm texture. Malt is typically fully-modified when acrospire length equals grain length. Acrospire is usually at 50% of grain length by 6$^{th}$ day.

There are many different ways of sprouting the barley during germination, but traditional floor malting produces the most uniform growth and the best quality malt. The grain is laid in a layer 8-12 inches thick on a waterproof floor and is held at an ambient temperature of 45-60 °F for 6-10 days. It is wetted and turned periodically to aerate it and keep the temperature even. Cooler germination temperatures (below 55 °F) encourage greater enzyme and soluble carbohydrate production by impeding acrospire growth.

**Modification is the term used to describe the degree to which the grain has germinated and the degree to which starches and proteins have been converted.**

### Important Malting Terminology

**° *Lovibond (abbreviated °L):*** A measure of malt (and beer) color. Roughly corresponds to SRM. °EBC (European Brewing Convention) are about double °Lovibond. U.S. brewers typically use Lovibond, European brewers often use EBC. Color scale for Lovibond ranges from 0° (clear) to 500°+ (black).

**° *Lintner:*** A measure of diastatic power, that is, the ability of the malt to fully convert its starches. It ranges from 0° (no diastatic power) to 150°+ (excessive diastatic power, typical of "hot" American 6-row lager malts designed to be used with adjunct grains). The European equivalent scale is °Windisch-Kolbach (abbreviated °W-K).

**If the grain doesn't have sufficient time to germinate, it is said to be undermodified or "steely." Undermodified malt has a more complete set of enzymes, but it also has higher protein levels, requiring the brewer to use a protein rest during mashing. If the grain is allowed to germinate for too long, it is said to be "overmodified" - the acrospire and rootlets take too much starch from the endosperm, resulting in malt with lots of husk in relation to the amount of soluble starch.**

Maltsters (malt-makers) carefully watch the degree of rootlet and acrospire growth during germination to judge the degree of modification. Degree of modification is based on the length of the acrospire in relation to the length of the barley seed. A longer acrospire means more modification. This is expressed as a ratio of grain: acrospire length. A 1:1 ratio means fully modified malt. A higher ratio means overmodified and a lower ratio means undermodified.

**Fully Modified malts have lower protein content, more soluble starches, lower starch content, less potential yield (because of greater growth) and endosperm fully converted to water-soluble gums.** UK malts are typically fully modified. This maximizes enzyme levels and explains, in part, why British malt works well in a single-temperature infusion mash.

**Undermodified malts have a higher protein content, higher nitrogen compound complexity, fewer soluble starches, lower diastatic and proteolytic enzyme levels and greater potential extract yield (because less growth). But they require a protein rest to degrade albuminous proteins. Undermodified malts are typically 50-75% modified.** Some Continental and American lager malts are undermodified. U.S. maltsters typically don't modify their malt as fully, stopping germination when acrospire length is only 2/3 to ¾ of the length of the kernel. This is because American malt typically has higher protein levels, so it already has high enough enzyme levels. Many German malts were also traditionally undermodified, although this is rarely the case with modern malts.

Two measures of degree of malt modification are the Kolbach index (which describes the soluble nitrogen level within a particular malt sample) and the Fine/Coarse Difference (which measures soluble proteins compared to total proteins).

**4. Drying/Heating:** When the maltster judges that germination has proceeded to the optimum point, the "green malt" is transferred to a drying room. **All types of malt except for crystal and caramel malts undergo drying.**

**The temperature of the "green malt" gradually raised to 90-100 °F,** with constant air movement over and through the grain bed. This drives out moisture. **Drying lasts for about 24**

**hours to permit enzyme action. By the end of this time, moisture content is reduced to about 4-6%.**

**5. Curing: All types of malt except for crystal and caramel malts undergo curing. Green malt is heated to 120 - 220 °F for up to 12 hours in order to dry it out and to stop enzymatic activity.** Air is typically blown over the grain in order to aid in drying, while the grain bed is turned frequently in order to maintain a uniform temperature.

**6. Kilning/Roasting: All malts go through this process. In addition to degree of modification, the time and** temperature of Kilning/Roasting **defines the character the malt's character. The malt is heated at temperatures of up to 450 °F for various lengths of time in order to dry it out completely and to develop toasty, bready or biscuity flavors via Maillard reactions, and toffee, caramel, coffee and chocolate flavors via caramelization. Lower roasting temperatures and shorter roasting times produce paler malts with greater enzyme levels and breadier, grainer flavors and aromas. Roasting malt at high temperatures or for longer periods of time kills enzymatic activity, darkens color and gives roastier flavors and aromas (e.g., chocolate, coffee).**

Kilning kills certain enzymes, leaving behind only those enzymes which can survive at higher temperatures. Any kilning temperature above 160° F destroys amylase enzymes, however, resulting in malt which has no diastatic power. This means that it is incapable of converting starches remaining in the grain. The exact temperature and the length of kilning time depends on the type of malt – the darker the malt, the higher the temperature and the longer the kilning time. During this time the malt is constantly kept in motion in order to insure an even kilning temperature throughout the malt bed. **At the end of kilning, moisture content is reduced to less than 4%. Crystal/caramel malts go directly to this step, skipping Drying and Curing.**

**7. Cooling/Dressing:** The malt cooled to 100 °F or less. It is then winnowed to remove dried acrospires & culms, along with loose husks, dust, and other undesirable materials.

**8. Resting:** Finally, the malt is rested for approximately 1-2 months (minimum 20 days), depending on type, prior to mashing, to allow astringent compounds produced during curing to mellow. This reduces astringency and improves wort clarity of beers made using the malt.

# Part 2: Malts*‡

**Types of Malts: Brewers divide malts into two basic categories: "Base Malts," which retain some or all of their diastatic power (starch conversion ability), and which need to be mashed in order to develop their full flavor potential, and "Specialty Malts," which have no diastatic power and which only need to be steeped in order to release their full flavors.**

**A. Basic Malt Types.** Maltsters divide their products into six categories:

**1. Pale Malts (AKA Base Malt):** Base or Pale Malts are dried at 90 °F, kilned at 120-140 °F for 12-20 hours and cured at 175-185 °F for 4-48 hours when dry (3-10% moisture).

**They provide the majority of the malt in any all-grain beer recipe, but must be mashed in order to release their sugars, although steeping will release some of their flavors.**

**Base malts have the ability to convert their own starches, as well as some or all of the starches in adjunct (unmalted) grains or specialty malts.** They have the highest diastatic power (40-150 °Lintner) and the lightest color (2-4 °Lovibond - straw to golden color). They are bready, grainy, malty, sweet, and sometimes slightly toasty. Some types have excess diastatic power and can be used to convert adjunct grains.

**Examples:** American 2-row, American 6-row, Pilsner, English Pale, English Mild, Belgian Pale.

**Associated Styles:** All pale beers, e.g., American light lagers (American 6-row), Pilsner (Pilsner malt), English pale ale (English pale), Mild (Mild malt), American ales (American 2-row malt).

**2. Amber/Toasted Malt.** Amber or Toasted Malts are dried at 90 °F, kilned at 120-145 °F for 12-20 hours and cured at ~220 °F until proper color achieved.

**They have reduced diastatic power but usually capable of self-conversion (i.e., converting own starches, but not adjunct grains, 20-40 °Lintner). Most must be mashed. They add color and complexity to beer and usually form 5-20% of the grist for amber or copper-colored beers.** They can be made at home by toasting base malt. Higher kilning temperatures produce melanoidins from amino acids and malt sugars giving beers made with them golden to dark amber color (4-70 °L) and grainy, malty and sweet flavors with bready, biscuity, crusty or toasty notes.

***Examples:*** Vienna, Munich, Aromatic/Melanoidin (e.g., Dark Munich, Biscuit™, Victory™), Amber, Brown, Special Roast.

***Associated Styles:*** All amber and brown beers, but especially malt-oriented styles, e.g., Vienna lager (Vienna malt), Oktoberfest (Munich malt), Bock (Munich, Vienna), California common, American brown ale, English brown ales, mild.

**3. Crystal/Caramel Malt (AKA Roasted Malts):** Roasted, Crystal or Caramel malts are not dried before they are kilned, but are kilned wet (~50% moisture) at a temperature of 150-170 °F for 1.5-2 hours without ventilation to "mash" starches within husk. It is then roasted at 220-320 °F to achieve desired color & flavor. Since the starches within the grain are in a semi-liquid state and the enzymes are still active when the grain is kilned, the starches within the husk are "mashed" during the drying process. The resulting malt has glassy or flinty texture and sweet to the taste.

**Crystal malts have no diastatic power and can be steeped rather than malted. They usually form 1-5% (up to 10%) of grist to adjust color, mash pH, and/or to add aroma and flavor.** Different maltings produce unique products with distinct flavor profiles. Color ranges from 2-220 °L (golden to dark brown) and beers made from them have sweet, caramel, honey, toffee, toasted, burnt sugar, dark fruit flavors and aromas. Crystal malts have light honey, caramel or toffee aromas with hints of raisins and burned sugar in the darkest colors of caramel malts.[1] They typically contribute reddish or amber colors to the beer and provide body without adding many fermentable sugars

***Examples:*** Dextrin, Crystal, Cara-™, malts, BruMalt™, Special B™.

[1] Greg Noonan contends that crystal and caramel malts are actually different types of malt. Caramel malts have higher moisture content, are not completely saccharified, and aren't kilned to the point that the endosperm is entirely vitrified. Crystal malts are completely saccharified and are sweeter, giving a fuller body, improved head retention and better storage stability without darkening beer color.

***Associated Styles:*** Sweet, full-bodied beers, especially Bock, Southern English brown, some Stouts (e.g., Russian Imperial Stout), strong Belgian ale, strong ales.

**4. Kilned and Roasted Malts:** Kilned-and-roasted, malts are typically undermodified and then kilned while green to a moisture content of 5-15% before being roasted at high temperatures for up to 2 hours. This kills the diastatic enzymes, but produces strong baked and caramelized flavors and aromas.

Amber malt is produced by roasting pale malt at temperatures up to 335 °F. It has toasty, biscuity and nutty flavors. Brown malt is virtually identical to amber malt, except that it is roasted for a longer time and has very dry, dark toast flavors, darker color and a hard "glassy" texture to endosperm.

Chocolate malt is roasted with more moisture than normal roasted malt. Roasting begins at 165°F and is increased to 335 °F. At this point, the malt begins to fume and the temperature is raised to 420 °F to develop chocolaty flavors through Maillard and caramelization reactions.

Black (patent) malt is roasted at 428 to 437 °F, producing coffee-like flavors. To prevent the malt from burning (at 480 °F or above), it is sprayed with water to keep the temperature down. Roasted barley is produced using a similar process, except that unmalted grains are used.

**Roasted and kilned malts have no diastatic power and can be steeped. Different varieties have different flavors & properties due to special kilning techniques. They usually form 5-10% of grist for color, body, complexity.** These malts are typically undermodified (less than 50%) and/or made from non-premium malt, since they are used in small amounts and have no diastatic power. No protein rest is needed when using such malts, since the starches and proteins are degraded by roasting. Many have proprietary names. These malts can vary in color from *1*00-600 °L (makes dark brown to black beer). They give nutty, bittersweet, bitter, chocolate, coffee and/or roasted flavors and aromas to beer.

Some brewers recommend adding dark malts at the end of mashing to reduce harsh flavors, "capping" the mash with added dark grains, especially when brewing with "soft" (low-bicarbonate) water. Dark grains are always used in small amounts, and are sometimes ground fine to achieve a better color contribution with a smaller addition.

***Examples:*** Chocolate malt, Rostmalz, Black/Patent malt.

***Associated Styles:*** Dark beers, especially dark lagers, porter and stout.

**5. Non-Barley Malts: While they are lower in diastatic power than barley-malt, other grains can be malted.** Wheat malt has enough diastatic power to convert its own starches, but has extremely high protein levels, which is why wheat beers tend to be hazy. Rye and oat malts also contain just enough diastatic enzymes to convert their own starches, but they tend to be very gummy (due to a large percentage of non-soluble starches). Rye malt is used to produce Roggenbier and other forms of rye beer and has a distinct "dry" flavor. Oat malt contributes a creamy texture (due to the high levels of gums) and a slightly sour flavor. Rice malt is used for specialty beers, but it has little flavor and contributes little body.

Like barley malts, non-barley malt can also be toasted or roasted to develop color and flavor. Due to their relative lack of starches and higher protein levels, non-barley malts aren't made into crystal/caramel malts, however.

Non-barley malts are usually made in a manner similar to pale malt. They are often huskless and are higher in higher in proteins & gums, so are more prone to stuck mash, haze and flavor instability. They usually have limited diastatic power, but pale malts are capable of self-conversion. They have unique flavor, aroma and texture characteristics. They are sometimes up to ~10% of grist to improve body and head retention and to add complexity. They form 25-70% of grist in wheat/rye beers (50%+ by law for German wheat & rye). They are typically 2-3 °L in color for pale malts, up to 600 °L for darker varieties.

***Flavor/Aroma:*** Dry, slightly sour, spicy, creamy, grainy. Darker versions can have amber/brown or roasted/kilned notes.

***Examples:*** Wheat malt, Rye malt, Oat malt.

***Associated Styles:*** Wheat & rye beers.

**6. Acidulated Malt (AKA Sauermalz or Sour Malt):** Acidulated malt is pale malt which has been allowed to sour mash and then dried. Brewers who wish to comply with the Reinheitsgebot use acidulated malt to acidify their mash rather than using acids, since it contains 1-2% lactic acid. Up to 10% acidulated malt can be added to the grist. *Color is* usually 2-4 °L. In excess amounts it can impart a lactic sourness to the beer.

***Examples:*** Acidulated malt.

***Associate Styles:*** None.

**7. Smoked and Peat Malts:** Smoked and peated malts are used to make smoke beers.

Smoked malt is kilned over a smoky fire to impart the flavor of the smoke (various monophenols compounds) in addition to drying the malt. Degree of smoke character determined by smokiness of fire, moisture content of malt and length of kilning time.

Peat malt, also known as Distiller's Malt or Whisky Malt, is used as the base malt for Scotch whisky, but isn't generally used for brewing traditional Scottish beers. Peat malt is produced by steeping grains in peat-flavored water before they are malted, rather than kilning green malt over a peat fire.

Smoke beers (and smoked and peated malts) are a leftover from the days when most malt was dried over wood fires, leaving it with a smoky taste. U.S. Smoked malt is generally nothing more than standard pale ale malt which has been smoked over a wood fire, often alder wood. American craft brews sometimes use unique smoked malts (e.g., alder, hickory, maple or mesquite).

Homebrewers can easily make their own smoked malt using a smoker or barbecue grill.

***Rauchmalz:*** Traditional Bamberg "rauchmaltz" is dried or kilned over a beechwood fire; other than the smoke flavor, it can have any color and any level of diastatic power. Rauchmaltz is otherwise similar to other German malts. It is associated with Bamberg, Germany and German smoked beers. Traditionally, the smoke kilning process is used to produce Munich/Vienna-type malt.

***Whisky Malt (AKA Peat Malt, Distillers Malt):*** Associated with Scotch whisky, but sometimes used in interpretations of Scotch Ale and specialty beers (e.g., peat-smoked Scottish Ale). Smoked over a peat fire. Traditionally used to produce pale or amber malt. *Many U.S. brewers produce Scottish Ale or Strong Scotch Ales which are made using a small percentage of peated malt, partially in homage to the many great Scottish whiskys and partially from misunderstanding of how traditional Scottish beers were made and how they are actually supposed to taste. (In actuality, peaty aromas and flavors in Scottish Ales and Strong Scottish Ales have historically come from the yeast.)*

**8. Grain Adjuncts: Many unmalted grains are added to beer but they are not actually malts.** Generally, these adjuncts must be cooked or processed separately and then added to the mash. Certain types of grains (i.e., wheat, oats, rye) are notorious for producing a gummy, sticky mash, so rice or oat hulls must be added to the grist to prevent a stuck mash.

**B. Malt Color: Malts can be further divided by the color they impart to the finished beer.** Malts are typically rated according to either the Standard Reference Method (°SRM) and or European Brewing Convention (°EBC) scales. Older references will sometimes refer to "degrees Lovibond" (°L), which roughly corresponds to SRM up to approximately 35 °L. SRM ratings range from 0 (colorless) to 500 (black).

*To convert from EBC to SRM, the following formula is correct for lightly colored malts and beers: SRM x 1.97 = EBC. As a rule of thumb, EBC is approximately twice SRM.*

**Malt Color Chart**

| **SRM/ Lovibond** | **EBC** | **Beer Color** | **Color** | **Example** |
|---|---|---|---|---|
| 2 | 4 | | Pale yellow/straw | Light Lager |
| 3 | 6 | | Yellow | German Pilsner |
| 4 | 8 | | Gold | Bohemian Pilsner |
| 6 | 12 | | Dark Gold | |
| 8 | 16 | | Amber | Weissbier |
| 10 | 20 | | | Pale Ale |
| 13 | 26 | | Copper | |
| 17 | 33 | | Red/Brown | |
| 20 | 39 | | Brown | |
| 24 | 47 | | | Dark lager |
| 29 | 57 | | Dark Brown | Porter |
| 35 | 69 | | | Stout |
| 40 | 79 | | | |
| 70 | 138 | | Black | Imperial stout |

**C. Diastatic Power:** When designing a beer recipe for which includes a high level of adjuncts, you must be aware of the Diastatic Power (also called Enzymatic Power) of your base malt. That is, your base malt must have sufficient amylase enzymes to convert not just its own starches, but also the starches in the adjunct grains. As a rule of thumb, base malts with higher protein contents contain more enzymes (because enzymes are proteins).

*Starch conversion potentials are listed on the specification sheets for your malt. If you know the brand of malt you're using, it's fairly easy to find spec sheets online. Look for Enzymatic or Diastatic Power (DP), which is either given as a short description (i.e., none, low, high, very high) or, as a number in Lintner degrees (sometimes referred to as IOB or .25 maltose equivalent) or W.K. (Windish Kolbach units) degrees.*

*°Lintner = ((W.K. + 16)/3.5) or ~ 0.3 W.K. + 4.*
*°W.K. = (3.5 x °Lintner) - 16.*

Malt with just enough power to self-convert has a rating near 35 °Lintner. DP for lightly-kilned amber malts such as Münich or Vienna range from 35-60. DP for well-converted, low-protein British ale malt can be as low as 35-40 °Lintner, but generally ranges from 60-80. DP is 100-130 for a European lager (Pilsner) malt, and 125 or higher for high-protein American two-row malt. The most powerfully diastatic six-row malts can have DPs as high as 160.

Diastatic power of malt falls off very quickly if it is kilned for any length of time. Lightly kilned amber malts, such as, Vienna, Münich and amber ale malt, generally only have enough diastatic power to convert their own starches and not much more. Moderately kilned malts, such as historical brown malt or home-made toasted malt made from pale ale malt, have very limited diastatic power; possibly not enough to convert all of their own starches. Crystal, caramel malts and heavily kilned malts, such as chocolate or patent malt, have no diastatic power (0 DP). Obviously, unmalted grains and starches also have no diastatic power (0 DP).

**Starch Gelatinization Temperatures**

| **Starch** | **° F** | **° C** |
|---|---|---|
| Arrow root (maranta) | 149-185 | 65-85 |
| Barley | 140-144 | 60-62 |
| Barley malt | 147-153 | 64-67 |
| Barley† | 140-150 | 60-65 |
| Large starch granules | 140-154 | 60-65 |
| Maize* | 144-171 | 62-77 |
| Maize*† | 143-165 | 62-72 |
| Millets* | 129-176 | 54-80 |
| Oats† | 127-138 | 53-59 |
| Potato | 133-160 | 56-71 |
| Rice* | 142-180 | 61-82 |
| Rice, long grain | 160-165 | 71-74 |
| Rice, short grain* | 149-154 | 65-68 |
| Rice† | 154-172 | 68-78 |
| Rye | 120-142 | 49-61 |
| Rye† | 135-158 | 57-70 |
| Small starch granules | 124-198 | 51-92 |
| Sorghum* | 124-167 | 69-75 |
| Tapioca | 145-176 | 63-80 |
| Waxy corn (amylose free)* | 144-176 | 62-80 |
| Wheat | 126-151 | 52-66 |
| Wheat† | 136-147 | 58-64 |

Table adapated from Palmer, ***How to Brew and*** http://braukaiser.com/wiki/index.php?title=Starch_Conversion, accessed 8/31/2010. I have not attempted to reconcile conflicting data.

† Palmer, How to Brew.

* Benefits from pre-boiling.

| Diastatic Power Table | | |
|---|---|---|
| °Lintner | °W.K. | Diastatic Power |
| < 35 | < 94 | Minimal (can't fully self-convert) |
| 35-62 | 94-200 | Very Low (self-conversion only) |
| 62-76 | 200 to 250 | Low |
| 76-90 | 250 to 300 | Average |
| 90-105 | 300 to 350 | Good |
| 105-119 | 350 to 400 | Very Good |
| >119 | > 400 | Outstanding (diastatic) |

*To calculate the total diastatic power of your grist multiply the diastatic power of each element of the grist by its weight, divide the total by the total amount of grain, then sum to the total:*

$DP = \Sigma(DP_n * W_n)/W_T$

*Where: DP = diastatic power, Σ = Sum,* $DP_n$ *= diastatic power of grist element,* $W_T$ *= total grist weight, and* $W_n$ *= weight of grist element.*

*Example 1: 60% American 2-row malt (125 °Lintner), plus 40% flaked corn (0 °Lintner) = (125 * 0.6) + (0 * 0.4) = 75 + 0 = 75 °Lintner.*

*Example 2: 70% Münich malt (60 °Lintner) + 20% Pilsner malt (125 °Lintner) + 5% crystal malt (0 °Lintner) + 5% flaked corn (0 °Lintner) = (60 * 0.7) + (125 * 0.2) + (0 * 0.5) + (0 * 0.5) = 42 + 25 + 0 + 0 = 67 °Lintner.*

*To determine the percentage of an ingredient required to achieve a particular level of diastatic power, or to determine an unknown level of diastatic power, solve for the unknown variables.*

*Example 3: If your base malt has DP 100 °Lintner, what is the absolute minimum percentage of base malt you can use and still achieve good conversion (80+ °Lintner), assuming that the other materials added to the grist have no diastatic power?*

*80 °Lintner = (X% 100 °Lintner)*
*80 °Lintner/100 °Lintner = X%*
*X% = 0.80.*
*X = 80% of total grist.*

*Practically, while it is possible to get complete mash conversion with a DP as low as 35 °Lintner, this results in unacceptably long mashing times. Instead, you should choose a level of diastatic power which will give your mash at least average diastatic power (76-90 °Lintner), allowing your mash to convert in a reasonable amount of time (1-2 hours).*

*As a rule of thumb, 6-row malts can convert up to ~75% non diastatic grains, Pilsner malt can convert up to ~70% and pale 2-row malt ~50%. British pale ale malt can convert up to about 40% adjuncts. A more important criterion is the amount of available Free Amino Nitrogen (FAN). With even 6 Row, FAN levels are low enough to stress yeast with 35% adjunct (corn, rice, etc). This percentage can go up for adding specialty malts which still have a measure of FAN, but few beers need more than 15% specialty malts for color and flavor.*[2]

**Decoction Mashing and Diastatic Power:** *A malt's DP can also be degraded if you use a decoction mash, since heating kills most of the amylase enzymes in the decoction. This is only likely to be a problem if you are pulling multiple decoctions while using malts with very low diastatic power (e.g., Münich/Vienna).*

*If possible, keep your decoction mash thin (1.75 to 2.5 quarts water per pound of grist), while keeping the decoction itself thick (about 1 quart of water per pound). This keeps more of the enzymes in the main mash, since they are quickly dissolved into the liquid portion of the mash after dough-in, while the decoction contains more starches and other grain materials.*

*If there is any question as to whether mashing is proceeding correctly, use an iodine test. If conversion is slow, mashing at high temperatures (160-168 °F) can speed things up. If that doesn't work, it might be necessary to add up to 10% Pilsner or pale ale malt to the grist to provide more enzymes.*

**Other Aspects of Diastatic Power:** *Higher DP can help to speed up mashing times, since higher DP malts have more enzymes. In any case, however, you have about 10 minutes to adjust mash temperatures down to your preferred mashing temperature, since it takes that long for the grain to fully saturate and release all of its amylase enzymes. For example, if your initial strike temperature is 190° F, but you reduce your mash temperature to 150° F in less than 5 minutes, you haven't lost much potential, but you may notice it takes a few minutes*

## Other Ways of Measuring Extract Yield

*Malt suppliers can measure potential extract yields in a variety of ways other than FG/CG ratios.*

***AICG:*** *Also described as "CG, As Is," this is an acronym meaning "As Is, Coarse Grind." It is a measurement of coarse grind extract yield performed on malt with the listed moisture content, rather than malt where the moisture has been removed first. It gives more realistic, lower, estimates of extract yield. In other respects, it is identical to DBCG.*

***AIFG:*** *Also described as "FG, As Is," this is an acronym meaning "As Is, Fine Grind." It is almost identical to DBFG, but uses malt with the listed moisture content, rather than malt where the moisture has been removed first.*

***Hot Water Extract (HWE):*** *This is a measurement of extract yield used by British maltsters. It is a measure of how many liters of wort at S.G. 1.001 a kilogram of a malt will give at 68 °F (20 °C). It can also be listed as hot water extract, or L°/kg at 7M (malt ground to particles an average of 0.7 mm in diameter - a coarse grind) or L°/kg at 2M (malt ground to an average particle size of 0.2 mm in diameter - a fine grind). Divide by 386 to get DBCG or DBFG, respectively, expressed as a decimal. HWE for two-row lager or pale shouldn't be less than 300 at 2M, 295 at 7M.*

***Cold Water Extract (CWE):*** *This is a measurement of malt modification sometime used by British maltsters. It measures the amount of extract that is soluble in cold water. CWE percentage of 19-23% indicates a malt suitable for infusion mashing.*

***DLFU:*** *This is a measurement of FG/CG used by continental maltsters. It is identical to that measurement.*

***Hartong (VZ 45°):*** *This is a measurement of FG/CG sometimes used by continental maltsters. It is similar to CWE, but the water is held at a higher temperature (113°F/45° C) to allow for some enzyme action. The range of values is approximately double that of CWE.*

[2] Kevin Pratt (Grand Master II BJCP judge and professional brewer), personal email, 8-3-2010.

*linger to reach the same first runnings gravity you're used to. If you hit 155° F and meant to hit 150F, you can take longer to reduce temperature, simply because Beta Amylase is not denatured that easily. B-Amylase only has about a 20 minute lifetime if exposed to excessive temperatures, though, while Alpha Amylase can last for several hours.*[3]

**Diastatic Power and Protein Levels:** *While excess protein levels can increase perception of body, cause haze issues and provide food for contamination bacteria, dextrins provide food for more organisms. Practically, this means that you don't need to worry about excessive levels of diastatic enzymes in your beer. An all 6-row beer has about the same body as pale ale made with 2-row malt, crystal malt and dextrin malt. Natural amylase enzymes do not cause fermentation issues, since they don't survive the wort boil. Even amylase enzymes added to the fermenter (as in the case of "dry beers") can be controlled through pasteurization or deactivation catalysts.*[4]

**Excessive Starch Conversion:** *In extreme cases, it might be possible for worts with extremely high DP to convert too much starch into fermentable sugars. In such cases, you will get beer with thin body, poor head retention and excessive ABV (although most homebrewers might not consider the last "problem" to be a flaw!) In conjunction with other mashing problems, such beers might also have problems with astringency and increased perception of bitterness.*

**D. Malt Analysis Sheets:** *A malt analysis sheet (sometimes called a malt spec sheet) is a document which describes the "vital statistics" of each type, or each lot, of malt. Since slight variations between different batches of malt can greatly affect malt character, professional brewers, and all-grain homebrewers striving for consistency from batch to batch, rely on malt analysis sheets when formulating recipes.*

*There are two types of Analysis Sheets, Typical Malt Analysis and Lot Analysis. Typical Malt Analysis represents the maltster's best estimate of the brewing properties of a particular variety of malt based on the current year's barley crop. Typical Malt Analysis figures are readily available on any maltster's web site and are useful when sourcing new varieties of malt or designing new recipes. Understanding the terminology in a Typical Malt Analysis is helpful if you wish to details about a particular malt's color, diastatic power, potential extract yield and suitability for use with a particular mashing regime.*

*Lot Analysis describes the brewing properties of a particular batch of malt. Even with modern levels of quality control, different lots of malt can have noticeably different lot analyses, which can affect the character of your brew! For this reason, if you're trying to "dial in" a recipe so that it's consistent from batch to batch, you must reformulate your recipe slightly every time you brew. Paying careful attention to differences between different lots of malt helps you do this.*

**Getting Malt Analysis Sheets:** *Homebrewers don't always have easy access to malt analysis sheets, especially lot analysis sheets, since they typically buy malt from a homebrew supply store rather than directly from the maltsters. If you are buying malt by the bag, better homebrew suppliers will typically supply you with a lot analysis, which they get (or should get) from the maltsters. If they do not, some manufacturers or suppliers have web pages where you can look up the lot analysis for your particular batch of malt.*

*If you are buying your grain by the pound from a homebrew store, the store might have a lot analysis on file which you can look at, although this usually isn't the case. Usually, the best they can offer you is a typical malt analysis for that particular malt. If the malt is sold out of large bags, however, you might be able to get the lot number off the bag and get a lot analysis directly from the maltster.*

*The lot number should be printed on each bag. If you're lucky you can find the lot analysis on the maltster's web site. If you're not so lucky, you might need to telephone, email or fax them.*

**Reading a Malt Analysis Sheet:** *At minimum, an analysis sheet should provide information about color, extract potential, mealiness (friability or vitreosity), moisture percentage, protein percentage (total and soluble) and size assortment of the malt. For base malts, the analysis should also include diastatic power. Tests and measurements are standardized by the ASBC (American Society of Brewing Chemists) or the EBC (European Brewers Convention), but exact information provided will vary from company to company. Specialty malts typically won't have complete analysis sheets, especially for traits such as diastatic power. A typical malt analysis sheet might look much like Figure 1.*

*Reading the top columns from right to left, the abbreviations are:*

**Barley Type:** *Two-row or six-row barley will be specified. Practically, this sort of information is limited use compared to other aspect of the analysis sheet.*

***Barley Variety:*** *Certain types of barley are traditionally preferred for certain types of beer and different strains of barley impart different flavors and aromas to beer. Strains such as Optic and Maris Otter are typically used for English ales, while strains such as Harrington are associated with certain types of American ale. While it's not likely to be mentioned on the analysis sheet, the location where the barley is grown can also play a role in its flavor and aroma. Just as with grapes and hops, terroir matters for barley as well!*

***Assortment:*** *This is a measurement of the average size of each kernel of malt, as determined by the percentages of kernels which fall through a sieve with openings of a certain size. Practically, malt size gives you an idea of malt quality as well as the gap needed on your malt mill in order to get a proper crush.*

*In ASBC testing, the listings for size indicate numbers mean the percentage of kernels which remain on a screen with 5/64 -in., 6/64 -in., or 7/64 -in. mesh and will be expressed in terms of "5/64 Max". The EBC test is similar, except that a 2.2 mm mesh is used. In some cases, though, the size might just be listed as the percentage which is "plump" or "thin." The term "Thru Max" is the maximum number of kernels which fall through the screen.*

*As a rule of thumb, 6-row malt and more highly modified malts will also be a bit smaller, while 2-row malt will be a bit plumper. Typically, the plumper the kernels, the better the extract yield. Malt with more than 1% thin kernels (those which fall through a 5/64-in opening) or 2% less than 2.2 mm is likely to be undermodified or otherwise unsuitable for brewing.*

*Equally important is uniformity of kernel size, since a large variation means a less uniform grain crush. Higher size variation between kernels can mean lower quality malt, although this isn't usually a problem with modern malts. Regardless of plumpness, a lot of malt must have at least 90% adjacent sizes in*

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3 Kevin Pratt, personal email, 8-20-2010.

4 Ibid.

*order to crush reasonably well (i.e., about 90% must have be left on the 6/64 -in., and 7/64 -in. screens).*

***H2O % Max:*** *This row indicates the moisture percentage within the malt. It is also sometimes expressed as "Moisture content," "% m.c." or just MC. Moisture content on the malt is very important since, not only is it an indicator of quality, it also helps determine extract yield and storage stability of your malt. The lower the moisture content the better. Malt can have a moisture content of as low as 1.5% MC. Malts with higher moisture content are more prone to mold growth and lose more aroma and flavor during storage. No malt should have moisture content above 6% and colored malts shouldn't have moisture content above 4% (except for caramel/crystal malts where 3.5-6% moisture content is acceptable - although lower moisture is still better). British ale malts have the lowest moisture content, followed by Munich, Vienna, Pilsner, and lager malts. Caramel malts trap more water during drying, so they have slightly higher moisture content than other specialty malts. Malts with an excessively high level of moisture are said to be "slack" and are likely to have been poorly stored, dried or kilned.*

*Moisture content also affects extract yield, since each percentage increase of moisture content results in an identical drop in potential extract yield. You can't turn water into sugar!*

***Color ASBC Deg. Lov.:*** *This column indicates the malt's color. Malt color is sometimes expressed as "degrees SRM," "degrees Lovibond" or "degrees EBC" or just "°SRM," "°L," or "°EBC."*

*Not only is color a likely indicator of how a malt is likely to smell and taste in your beer, but it's an indicator of how dark your beer is likely to be. While exact malt color isn't so important for dark beers, it's critical if you wish to make very light colored beers, such as Light Lagers or Pilsners.*

*The color of a particular type of malt can vary widely from manufacturer to manufacturer and lot to lot. It's particularly important to pay attention to malt color if you are switching between different brands of malt, since each maltings has its own color range. Differences in color are more pronounced at the dark end of the color range, with dark malts from the same maltings varying by up to 40° L from batch to batch!*

*The color of U.S. and Canadian malts is expressed in terms of Standard Research Method (SRM) values or in degrees Lovibond. The color of European malts is usually measured in European Brewing Convention (EBC) units.*

*A rough conversion between the different units:*

*Degrees Lovibond = Degrees SRM*

*Degrees EBC = (degrees L x 2.65) - 1.2*

*Degrees Lovibond = (Degrees EBC + 1.2)/2.65*

***Protein Max:*** *This column is a measure of how much protein or nitrogen is in the malt and how much of that material can be dissolved in water. It indicates the maximum percentage of protein (or nitrogen) by weight.*

*Protein percentage depends a great deal on the type of barley used to make the malt, but it can also be an indicator of its degree of modification and diastatic power. Indirectly, protein percentage can also be used to measure nitrogen percentage at a rate of 1% Nitrogen per 6.25% Protein.*

*Highly diastatic American 6-row malts have the highest protein percentages (up to 13%), while European malts have slightly lower protein content (8-10%). North American malts are traditionally a bit higher in protein than their European equivalents.*

*Malts with total protein values greater than 12% (1.9% Total Nitrogen) are more vulnerable to mash runoff and problems, protein haze and storage instability, unless adjuncts are used to reduce the total protein percentage of the grist. Likewise, when adjunct grains or sugars are used, malts of at least 10% protein are required to get appropriate levels of Free Amino Nitrogen (FAN) for yeast nutrition and to achieve proper head and body for all but the thinnest of beers.*

***"Sol."*** *indicates the percentage of soluble proteins by weight. It is sometimes expressed as "Soluble protein" or "% SP." Alternately, there might be a line for "Total Soluble Nitrogen," or "% TSN," instead, which indicates the total percentage of all soluble nitrogen in the malt. Regardless of the*

**Fig. 1. Typical Malt Analysis Sheet**

| | Barley Type | Barley Variety | Assortment | | | H20 % Max. | Color ASBC Deg. Lov. | Protein Max. | | | Extract Dry Min. | | F-C Diff. Max. | D.P. Min. | Viscosity Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 7/64 Min. | 6/64 Min. | Thru Max | | | Sol | Total | S/T | FG | CG | | | |
| Brewers Malt | | | | | | | | | | | | | | | |
| ESB | 2-Row | Harrington | | 80 | 5.0 | 4.0 | 3.0-4.0 | 6.0 | 11.0 | 53.0 | 82.0 | 80.0 | 2.0 | 90 | 1.60 |
| Colored Malt | | | | | | | | | | | | | | | |
| Vienna | 2-Row | Harrington | | 80 | 5.0 | 4.5 | 5.0-6.0 | 6.0 | 12.0 | 53.0 | 80.0 | 79.0 | 1.5 | 90 | 1.60 |
| Munich 10 | 2-Row | Harrington | | 80 | 5.0 | 4.0 | 9.0-11.0 | 6.0 | 11.5 | 53.0 | 80.0 | 79.0 | 1.5 | 90 | 1.60 |
| Munich 30 | 2-Row | Harrington | | 80 | 5.0 | 4.0 | 30-35 | 6.0 | 11.5 | 53.0 | 80.0 | 79.0 | 1.5 | 90 | 1.60 |
| Specialty | | | | | | | | | | | | | | | |
| Honey Malt | 2-Row | Harrington | | 80 | 5.0 | 4.0 | 20-25 | 7.0 | 11.5 | 55.0 | 83.0 | 78.0 | 0.5 | 50 | 1.60 |
| Organic 2row Pale | 2-Row | Harrington | | 80 | 5.0 | 4.5 | 1.8-2.8 | 6.0 | 11.0 | 53.0 | 83.0 | 78.0 | 0.5 | 50 | 1.60 |
| Organic Pilsen | | | 80 | 15 | | 4.0 | 1.3-2.8 | 4.5 | <9.9 | 40.0-45.0 | 52.0 | 80.0 | <3.0 | | 1.60 |
| Organic Wheat | | | 70 | 25 | | 4.5 | 1.8-2.8 | 4.5 | <12 | 40.0-45.0 | 84.0 | 82.0 | <2.0 | | 2.25 |

Data taken from: http://www.specialtymalts.com/gambrinus/malt_analysis.html *calculation uses, the soluble protein or total soluble nitrogen percentages are used to calculate the soluble nitrogen ratio.*

***"Total"*** *indicates total protein percentage by weight and can also be expressed as "Protein %" In some cases, the analysis sheet might also give a "total nitrogen" or "TN" percentage, or substitute that figure for the total protein percentage. Where total nitrogen is given, it indicates the percentage, by weight, or all nitrogenous matter in the malt, not just proteins.*

***"S/T"*** *[Soluble/Total] indicates the ratio of soluble protein to total protein as a percentage. This figure can also be described as "Soluble Nitrogen Ratio," or "% SNR. Where Soluble Nitrogen and Total Nitrogen figures are given, Soluble Nitrogen/Total Nitrogen, SN/TN or Kolbach Index is listed instead.*

*In all cases, this ratio is calculated by dividing soluble protein (or nitrogen) value by the percentage of total protein (or nitrogen) to get a ratio between the two.*

*The soluble protein (or nitrogen) ratio is an important indicator of malt modification; the higher the number, the greater the degree of modification. Malts destined for infusion mashing, such as English pale malt should have an SNR of 36-42%, up to 45% for light-bodied beers. Beer made using just malt with 45% or higher SNR, will have a thinner body and poorer head due to lack of soluble nitrogen. For traditional lager malts, 30-33% indicates undermodification, while 37-40% indicates overmodification.*

*For a lot of malt with SNR than usual, the brewer must adapt by adding or modifying protein rests during mashing. Likewise, when dealing with a lot of malt with a lower than normal SNR, the brewer must shorten or eliminate protein rests.*

***Extract Dry Min.:*** *This column lists the minimum potential extract yield, as a percentage, at 0% moisture content. It is sometimes listed as Extract Yield.*

*Even for homebrewers who don't particularly care about consistency from batch to batch, Extract Yield percentages are of interest since it is an indicator of brewhouse efficiency - how much sugar you can wring out of your mash - which directly relates to wort gravity and the finished beer's ABV.*

***FG:*** *This line indicates minimum extract yield, as a percentage. It is obtained by grinding a sample of malt into flour (0.2 mm average particle diameter), mashing the powder under laboratory conditions and then determining the amount of soluble materials (sugars, dextrins, starches and proteins) extracted. Since it is just a measure of maximum extract yield, the test ignores problems associated with a very fine grain crush, such as tannin extraction and mash runoff problems.*

*FG is usually read side by side with the CG column. Taken on its own, it can be seen as an indicator of malt quality. The higher the extract percentage, the better the malt.*

*More typically, FG is expressed as DBFG, also described as %DBFG or FGDB. This is an acronym meaning "Extract Yield - Dry Basis, Fine Grind." A higher %DBFG indicates a malt with less protein and husk material and more soluble sugars and starches which can be extracted during mashing. Base malts should yield a minimum of 78% DBFG.*

***CG:*** *This line indicates minimum extract yield, as a percentage, using a coarser grain crush (0.7 mm average particle diameter), which is more like that obtained in brewery operations.*

*More typically, CG is expressed as DBCG, %DBCG or CGDB. This is an acronym meaning "Extract Yield - Dry Basis, Coarse Grind." It is used in conjunction with %DBFG to determine the degree of starch modification the grain experienced during the malting process. Unlike DBFG, the malt is crushed in a way which simulates a typical brewhouse malt crush, although actual brewhouse efficiency figures will be 5-15% lower than DBCG percentages.*

*Even though CG figures are likely to be closer to actual brewhouse extract yields, they are still higher than "real world" yields. As a rule of thumb, actual brewhouse efficiency figures will be 5-15% lower. This is because, the malt has all its moisture removed before crushing begins, laboratory mashing equipment is more efficient than brewhouse mash tuns and the laboratory mash attempts to extract as much material as possible, ignoring potential problems with tannin extraction.*

*The coarse-grind results are intended to demonstrate to the brewer the maximum that can be achieved using a crush that approximates that used by most breweries.*

***F/C Diff. Max:*** *This is a measurement of the maximum difference between Fine Grind and Coarse Grind extract yields, listed as a percentage and obtained by subtracting the coarse grind percentage from the fine grind percentage. It can also be expressed as just F/C or FG/CG.*

*The difference between FG and CG percentages is another indicator of malt modification. An undermodified "steely," "glassy" or vitreous malt, which requires a protein rest, has a FG/CG difference of 1.8-2.2%. Well-modified, "mealy" malt suitable for infusion mashing will have a FG/CG difference of 0.5-1.0%.*

***D.P. Min.:*** *A measurement of Minimum Diastatic Power, sometimes just expressed as DP. North American maltings measure diastatic power in degrees Lintner. The terms IOB or .25 maltose equivalent are also sometimes used and are equivalent to degrees Lintner. European maltsters measure diastatic power in terms of °WK (Windisch-Kolbach units).*

*DP °Lintner = (°WK + 16) / 3.5*

*DP °WK = (°Lintner x 3.5) -16*

*DP is a measurement of the malt's ability to convert starch into fermentable sugars. Malts with a DP of 25-30 °Lintner will just convert their own starches, while those with higher values can convert excess starch into sugars, making them suitable for making beers which use adjunct grains.*

*DP values range from 25-30 °Lintner for Munich, Vienna or lightly toasted malts, to 35-40 for English pale malt, ~100 for pale lager malt up to 125+ for "hot" American 6-row pale malt. Toasted, roasted or kilned malts have no diastatic power, so DP usually isn't listed for them.*

***Viscosity Max.:*** *This is a measure of the breakdown of beta-glucans during malting. It is often expressed as cP (centipoises units) or sometimes IOB. Malt with a high laboratory wort viscosity (over 1.75 CP) will need a beta-glucan rest to get the wort to run off easily during sparging. If viscosity is measured in IOB units, it should range between 6.3-6.8 at 158 °F [70 °C].*

**E. Other Malt Sheet Figures and Terms**

***1,000-Kernel Weight or Bushel Weight:*** *The weight of a fixed volume of malt. This is an old measurement which gives a rough estimate of the plumpness or thinness of the malt kernels, as well as moisture content. An acceptable range for 1,000-*

## Using the Numbers

*Once you have obtained the numbers from your malt lot analysis, you can use them to adjust or design your recipe.*

*AICG = DBCG/(1 + Moisture Content) - 0.002*

*Adjusted yield = AICG/brewhouse efficiency.*

*Where brewhouse efficiency is expressed as a decimal instead of a percentage.*

*Once you know brewhouse yield, you can predict the likely starting gravity (in SG or °Plato) per pound of malt in a gallon of water:*

*SG per 1 lb. malt in 1 lb. water = Adjusted yield x 46.214*

*°Plato per 1 lb. malt in 1 lb. water = Adjusted yield x 11.486*

*Working backwards, you can determine brewhouse efficiency using the following formula:*

*Brewhouse efficiency = ((SG x gal. of wort)/46.214)) / ((DBCG/(1 + moisture content) - 0.002) x lb. of malt*

*Brewhouse efficiency = ((°P x gal. of wort)/11.486)) / ((DBCG/(1 + moisture content) - 0.002) x lb. of malt*

*kernel weight is 36-45 g, while 42-44 lbs. is acceptable for bushel weight.*

***Alpha-Amylase or Dextrinizing Units (DU):** Also sometimes described as Alpha Amylase Minimum. This measurement is similar to DP, but describes the malt's ability to produce alpha amylase (which breaks down dextrins). Lager malts will have 35-50 DU, English pale malt has around 25 DU, while Munich/Vienna malt might have 10 or fewer DU.*

***Conversion Time (minutes):** Sometimes given instead of, or in addition to, diastatic power. European base malts should start to convert starches to sugars in less than 10 minutes, American base malts should start converting within 5 minutes.*

***Degree of Clarity:** Another estimate, based on ASBC standards, of the clarity of wort the malt will produce. "Normal" to "slightly hazy" are acceptable values.*

***Degree of Crystallization:** This measurement is only used for specialty malts which are supposed to have a vitreous texture, such as crystal malt. Caramel malts should have a degree of crystallization above 85%, while crystal malts should have a score of 95% or higher.*

***DMS precursor (DMS-P):** This is a measure of the levels of S-methyl methionine (SMM) and dimethyl sulfoxide (DMSO) in the malt, which are converted to dimethyl sulfide (DMS) when the wort is heated. These compounds are generally present in higher quantities (5-15 ppm) in continental lager malts, less for ale malts. The greater the degree of modification, the lower the DMS-P levels.*

***Friability:** This is a measure of the malt's likelihood of crumbling when crushed. It is similar to mealiness and is sometimes substituted for that test. Any malt should be at least 80% friable, while those used for infusion mashing should be at least 85% friable.*

***Growth:** Also described as Acrospire Growth. This is another traditional method of assessing the degree to which malt has been modified. Acrospire growth is expressed in ranges 0-1/4, 1/4-1/2, 1/2-3/4, 3/4-full, or overgrown (measured in length of acrospires to length of the barley kernel). The longer the acrospires, the more modified the malt. American maltsters typically let the acrospire grow to ¾ length, while the acrospires is allowed to grow ¾ to the entire length of the kernel for English pale malts. By contrast, traditional German lager malts only allowed the acrospire grow to ½ to ¾ the length of the kernel.*

***Mealiness (%):** The texture of a malt kernel's endosperm can be described as "mealy" ""half-glassy/glassy-ends" (AKA "hard ends") or "glassy" (AKA "vitreous" or "steely") depending on degree of modification during mashing. Mealiness measures the percentage of kernels in a sample which are classified as mealy (i.e., no more than 25% of the endosperm is "glassy"). Kernels are "half-glassy"/"glassy ends" if the endosperm is 25-75% glassy. Kernels where the endosperm is over 75% glassy are described as being "glassy," "vitreous," or "steely."*

*Mealiness is another measure of malt conversion and is also a useful measurement of how well the malt will crush. Since mealy endosperm is more permeable by water, it is also more accessible to starch conversion enzymes, so mealiness is an indirect indicator of extract yield.*

*A higher degree of modification during malting results in more mealy malt kernels. Less modified malts have more a steelier texture and give less extract. Any base malt should be at least 90% mealy, while malts intended for infusion mashing must be at least 95% mealy. Where mealiness/half-glassy/glassy is expressed as a ratio, the percentage should be at least 92%/7%/1% for decoction or step mashing, and 95%/4%/1% or better for infusion mashing.*

***Odor of Mash:** This is a one or two word description of how the mash smells, based on ASBC standards. Often there will be no listing, or a listing of "normal." "Aro" or "aromatic" indicates a greater than normal aroma while "V. Aro" or "very aromatic" means a much higher than normal aroma. Other descriptors include "bread," "crackers" and "burnt coffee."*

***Speed of Filtration:** An estimate, based on ASBC standards, of the levels of beta-glucans in the malt, as well as the degree of starch and protein conversion. It can be used as an estimate of the speed of runoff during sparging.*

***Vitreosity:** This is the opposite of mealiness. It is a measurement of the average level of "glassiness" of the endosperms in a sample of malt kernels. It is measured by taking a set number of malt grains, slicing them open and examining the endosperm. A score of 1 is assigned to kernels with glassy endosperms; 0.5 to half-glassy kernels; 0.25 to those with glassy ends; and 0 to mealy kernels. The sum is totaled and averaged, with a vitreosity of 0-0.25 preferred.*

*Due to the unreliability of this test (it depends on subjective observations of vitreosity) it is seldom listed.*

# Part 3: Off-Flavors

# Dimethyl Sulfide (DMS) & Related Compounds*†‡

**Description:** Dimethyl Sulfide (DMS) and related volatile sulfur compounds (diethyl sulfide, and di-isopropyl sulfide) are chemical compounds found naturally in grain and malt or produced naturally during the malting and mashing processes.

DMS has the following chemical structure:

$H_3C\text{-}S\text{-}CH_3$

The most important DMS precursor is S-Methyl methionine (SMM). Both DMS, and its precursor, SMM are highly volatile compounds.[5]

**Flavor and Aroma:** DMS is first perceived at 30-33 ppb[6]. At lower concentrations (30-60 µ/L) it is perceived as being malty or slightly sulfury. At higher concentrations (above about 60 µ/L) it can give beer the taste and aroma of cooked corn, celery, cooked cabbage, parsnip or black currant. In very high concentrations it can be reminiscent of shellfish such as oysters, or cat urine.[7]

The combination of DMS and other sulfur compounds (e.g., hydrogen sulfide and/or mercaptan) can produce very offensive odors.

**Origins:** The DMS precursor, S-methylmethionine (SMM) occurs naturally in corn and rice. It also is produced during malt germination. SMM turns into DMS when heated, either during kilning of green malt or during mashing. DMS is also formed by yeast during normal fermentation, and during slow cooling of wort by non-microbiological chemical reactions. Certain bacteria (Obesumbacterium, Hafnia or Zymomona) produce large amounts of DMS. Coliform bacteria strains can also produce strong cooked-vegetable notes.

**Malt:** Different strains of barley have somewhat different SMM levels, but SMM and DMS are most heavily affected by the temperature at which the green malt is kilned. This means that heating or exposure to gas will eventually drive them off. For example, both Pilsner malt and Münich malt are made using the same strain of barley, but only Pilsner malt imparts noticeable levels of DMS to beer. This is because the SMM and DMS produced during malting are driven off when Münich malt is kilned. For this reason, light lagers like Münich Helles have low, but noticeable, levels of DMS, while Märzens do not.

Pilsner malt is very high in SMM since it is kilned at lower temperatures, so beers made with light lager malt will have DMS concentrations in the range of 30-90 µ/L. American 6-row malt is higher in SMM, but is also kilned at a higher temperature. By contrast, English pale malts are lower in SM and are kilned at higher temperatures, so they have DMS concentrations of 0-20 µ/L.[8]

**Yeast and Fermentation Process:** While normal brewing yeast strains produce DMS in low amounts, DMS production is generally blocked by other minor sulfur products (e.g., methionine sulfoxide) in the wort. Elevated yeast pitching (above 100 million cells/ml) rates can produce unwanted sulfur compounds which carry over into the finished beer.

[5] Ibid.

[6] PPB = Parts Per Billion, synonymous with micrograms per liter (µ/L). To get milligrams per liter, divide by100.

[7] Principles of Brewing Science, George Fix, pp.32-35.

[8] Ibid.

More importantly, warmer fermentation temperatures and vigorous fermentation which produces lots of $CO_2$ will scrub DMS out of the beer during fermentation, so lagers, fermented at cooler temperatures, will retain more DMS than ales, which have vigorous, higher temperature fermentation.

**Bacterial Infection:** Wort-spoiling bacteria such has E. Coli, Obesumbacterium, Hafnia or Zymomona, produce large amounts of DMS among other, stronger sulfur compounds such as hydrogen sulfide (which has a characteristic rotten egg or fecal odor). The combination of DMS and hydrogen sulfide generally produces strong, unpleasant odors.

**Typically Occurs:** In beers made with corn, rice or Pilsner malt or badly-infected beers.

**When is it appropriate?** DMS is acceptable at very low levels in light lagers (BJCP category 1), German and American Pilsner (sub-styles 2A and 2C), Dark American Lager (4A), Helles Bock (5A) and Cream Ale (6A). It is inappropriate in other styles, except possibly Specialty beers (23A) made using a high proportion (~50%+) of Pilsner or American 6-row malt, or a significant percentage (~10-20%+) of corn or rice. In any style of beer, it is undesirable in high concentrations.

**Increased by:** High percentage (more than 10-20%) of corn and/or rice adjuncts in mash. High percentage of American 6-row or German or Continental pale or Pils malt in grist. Use of improperly stored malt with high moisture content. High percentage of corn/rice sugar/syrup in malt extracts. Over-sparging with water below 160 °F. Closed, weak and/or short wort boil. Slow wort cooling (overnight) before pitching yeast. Poor sanitation (infection by wild yeast or bacteria). Underpitching yeast. Contaminated yeast (especially packet yeast and recovered sediment).

**Decreased/Prevented by:** Lower percentage of corn or rice in mash. Lower percentage American 6-row or German or Continental pale or Pils malt in grist. A rolling boil of 60-90 minutes or more. Proper storage of malt in a cool, dry place. Use of high quality malt extracts. Proper sparging technique. Quickly cooling the wort. Practicing good sanitation. Using a fresh yeast culture. Increasing yeast pitching rates.

# Nuttiness (Oxidation, Malt)

**Detected in:** Aroma, flavor.

**Described As:** Almond, 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).

**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.

# 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 use. 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.

# Part 4: Hybrid Beers

Hybrid beers are beers that are neither ales nor lagers. They might be ales which are (or can be) fermented using a low-temperature ale yeast strain (55-65 °F) or ales which undergo a significant period of cold conditioning before they are released. Alternately, they mighbe fermented at the upper end of the temperature range using a lager yeast. Some beers in these categories are just ales, however.

Cream ale is typically fermented using a high-temperature fermentation lager yeast or low-temperature ale yeast and is cold conditioned. Blonde ale and American wheat and rye beers are is typically just fermented using ale yeasts. Kölsch is fermented at cool to average ale temperatures and then cold-conditioned.

Altbiers are fermented using special low-temperature ale yeast and are then cold conditioned. California Common beer is fermented with a high temperature lager yeast strain and then cold conditioned.

# BJCP Category 6 - Light Hybrids

This category covers light-colored "hybrids," beers which somehow "break the rules" in that they are neither lagers nor ales. Unlike some categories, Category 6 is something of a catchall; it combines a traditional American beer style, a relatively modern interpretation of ancient German brewing traditions, and two modern craft beer styles.

**Cream Ale:** *This is a traditional American style of beer, possibly based on English "sparkling ales" or "dinner ales", developed in the late-19$^{th}$ century by Northeastern, Mid-Atlantic and Midwestern ale brewers to compete with light lagers introduced by German and Austrian immigrant brewers. Historically, cream ale reached its zenith of popularity during the 1930s, before rapidly losing ground to the ascendant and, now ubiquitous, standard and premium American lagers. Today, light lagers are popular world-wide, while cream ale is a relatively obscure style.*

*Before Prohibition, there was much more variation within this sub-style, both in terms of ingredients and original gravity. Light-colored "steam beers" were sometimes sold as "cream ales," as were some light-colored beers which we would now classify as Blonde Ales or American Wheat Beers. Pre-Prohibition versions were stronger, hoppier and were sometimes called "Sparkling Ales."*

Most brewers use lager strains to brew this beer, although some use English or American ale yeasts. As with Classic American Pilsners, Cream Ale is adapted to use American brewing techniques and ingredients, using up to 20% corn or rice to counter the excessive protein levels of American 6-row malt. It is designed to be a light-bodied, easy-to-drink "lawnmower" beer. The term "cream" in the name comes from the creaminess of the head and the smoothness of body rather than from milk sugar or other dairy products in the beer.

**Blonde Ale:** *As with American Wheat or Rye Beers, this is a catchall category. It covers English Summer Ales, American Kölsch-style beers, less assertive American and English pale ales, many of which are offered as summer seasonal beers. Homebrewed examples might include German light lager styles brewed using ale yeast.*

Since this style gets called by a number of names, when tasting commercial examples you need to ignore the name on the bottle and pay attention to your senses and the beer's vital statistics. As with Cream Ale, Blonde Ales are light-bodied, balanced, mild-flavored easy-drinking beers. Sadly, they are often perceived as being "entry-level" or "training-wheels" beers designed to appeal to beer-drinkers who normally only drink light lagers. Better examples of the style stand on their own, featuring some blend of pale malt, yeast and hop complexity while still being refreshing. In recent years, the blonde ale style has lost ground as craft beer drinkers' palates have become more sophisticated.

Blonde Ales are made using 100% American or English Pale malt, perhaps with a bit of light crystal or wheat malt for added body. Hops are typically citrusy American-style, but are subdued with medium to low hop bitterness. Yeast is typically American or English ale yeast. Water is typically of medium to medium-low hardness.

**Kölsch:** *While the practice of brewing with top-fermenting yeast is ancient, and Köln brewers were still resisting lager-brewing techniques as late as 1750, Kölsch as we know it can only be dated to the late 19th century, in the form of "bitterbier".*

*Modern Kölsch was developed after World War 2, although it was based on traditional, hoppier pre-war light ales. Brewing in Germany was suspended for the duration of the war, and heavy damage to the city of Cologne (Köln), plus post-war privations prevented brewers from operating immediately afterwards. Once the city's breweries reopened, by mutual agreement they all began to brew the same basic style of beer.*

*In 1985, the 20 or so breweries in and around the city signed an agreement called the Kölsch Konvention, which defines Kölsch beer as a "light, highly attenuated, hop-accentuated, clear top-fermenting Vollbier" ("Vollbier" refers to "full beer" of 3-5.3% ABV, as defined by German tax law), as well as designating the shape of the serving glass and the region in which the beer may be produced. Since 1986, Kölsch is an appellation controlleé protected by European law, although brewers elsewhere in the world freely use the term to describe "Kölsch-style" beers. Historically, cloudy unfiltered "weiss" versions of Kölsch existed. In recent years, a few Köln brewpubs have revived the style.*

Kölsch is made using 100% German Pilsner malt with German bittering and flavor hops. Hop bitterness is on the low side with restrained floral, spicy "noble" hop flavor and aroma. Water is of moderate hardness.

Kölsch breweries typically use proprietary top-fermenting yeasts before cold-conditioning their beer at lager temperatures. Technically, this makes the beer neither ale nor lager, but *"Obergäriges Lagerbier"* (literally, top-fermenting lager beer).

Each brewpub or brewery has its own slightly different interpretation of the style, based on variations in ingredients and yeast strains, which is served on draft in its own pub or group of "tied houses."

Very few brewers bottle their products, and imported products available in North America are often in very poor condition; Kölsch is a notoriously delicate style of beer which must be handled carefully and consumed while young. For the same reason, Kölsch is served in 200 ml cylindrical glasses (called "stanges"), so that the contents of each glass are as fresh as possible.

For the sake of tradition and the tourist trade, there is something of a ritual to drinking Kölsch in Köln. The blue-coated waiters in these establishments are known as Köbes (pl. Köbessen), and are known for their brusque demeanor and rough sense of humor. They carry trays or metal holders filled with stanges of Kölsch, automatically replacing empty glasses with full ones and making tic marks on each customer's beer coaster to indicate the number of drinks they've had. When a customer has had enough to drink, he places his coaster on top of his empty glass as a sign that he wishes to settle his bill.

**American Wheat or Rye Beer:** *This is another catchall category. It covers any light-colored, lightly- to moderately-hopped, medium-strength wheat or rye beer which doesn't fit into the category of German Wheat or Rye Beer (BJCP Category 15) and which doesn't fit into one of the specialty categories (Belgian Specialty - BJCP sub-style 16E - or Specialty Beer - BJCP sub-style 23).* As with Blonde Ales, commercial examples of American Wheat or Rye beers are produced by craft brewers. Many fill the same role as Blonde Ales in a brewery's product line, designed to appeal to people more comfortable with American light lagers. As with Blonde Ale, their popularity has slipped in recent years.

American Wheat and Rye beers can vary widely in grain, yeast and hop character, although some degree of wheat and/or rye character should be evident. Some examples emulate German hefeweizen or roggenbier and are hazy or cloudy, while others are filtered. Filtered versions will have less body, lower head and poorer head retention, and slightly lower grain and yeast aromas and flavors.

Unlike German wheat or rye beers, American wheat or rye beers often have noticeable levels of hop bitterness, flavor and aroma. They shouldn't have the distinctive "clove and banana" notes associated with most German wheat and rye beers.

Grist should include a significant percentage of wheat or rye malt and/or unmalted wheat or rye. Hops are typically American varieties, although hop bitterness, aroma and flavor should be somewhat restrained. Yeast is typically American or British ale yeast. Water can vary from soft to moderately hard.

# Part 5: BJCP Category 7 - Amber Hybrids

**Altbier (Categories 7A & 7C):** *These two styles of beer are closely related, differing only in malt character and hopping rates. They are broadly reflective of German brewing traditions before lager beer became the norm although modern versions of Düsseldorf Alt can only be dated to Mid-19th century. Altbier is typically made using low-temperature fermentation ale yeasts (60-65°F) and is then conditioned at standard lagering temperatures for 4-6 weeks to give cleaner, smoother flavors. Northern German Alts tend to be moderately bitter brown lagers. Düsseldorf Alts are hoppier.*

Despite their proximity (Düsseldorf is just down the river from Köln) Altbier is similar to Kölsch only in that it is fermented using ale yeast. The two cities have a centuries-old rivalry; don't ask for Altbier in Köln (or vice-versa)! Despite this, the Düsseldorf drinking traditions are very similar to those found in Köln. The best examples of Düsseldorf Alt can be found in brewpubs in the Altstadt ("old town"), where it is served in narrow, cylindrical glasses.

*In addition to Northern German Alt and Düsseldorf Alt, there are three further variants of Altbier. The Düsseldorf brewers create a seasonal variant of their Alt called Sticke ("secret"), which is slightly stronger, darker, richer and more complex than their regular alt. Some brewers also produce a Doppelsticke (also called Export Sticke) for export to the U.S. market. It is even stronger than regular Sticke. Sticke is hoppier (up to 60 IBU), usually dry-hopped and is lagered for a longer period. Münster Alt (exemplified by Pinkus Alt) typically has lower O.G. and ABV, is lighter in color, has a slight sourness and can contain up to 40% wheat. Sticke alt, Doppelsticke and Münster alt are treated as specialty beers.*

Altbiers are made using German Pils malt and some percentage of crystal and toasted malt, with Northern German Alts being darker and sweeter than Düsseldorf Alts. Hops are German varieties, although hop character is more obvious in Düsseldorf Alt. Yeast is German Altbier yeast or, in some cases German lager yeast. Water is typically of moderate hardness.

**California Common Beer:** *California Common is an American original once known as Steam Beer. It was developed during the California Gold Rush (1849-1855) using German lager yeast adapted to the brewing conditions around the San Francisco Bay area and the primitive brewing equipment available. Large shallow open fermenters (coolships) were used to compensate for the lack of ice to cool the fermentation tanks and to take advantage of the cool ambient temperatures in the San Francisco Bay area. The original German lager strains adapted to ferment at higher than normal temperatures.*

*Originally, Steam Beer was very rough tasting and known for its high carbonation levels. Due to the combination of ale-style open fermenters and poorly-flocculating lager yeast, clarifiers were needed to "polish" the fermented beer and constant skimming of the wort surface was necessary to prevent contamination. The final product was only available on draft and was often left to settle for several days before being shipped to customers.*

*The origin of the name "steam" is unknown. According to Anchor Brewing, the name "steam" came from the fact that 19th century Bay Area breweries had no way to effectively chill the boiling wort using traditional means, so they pumped the hot wort up to the large, shallow, open-top coolships on the roof of the brewery so that it would be rapidly chilled by onshore breezes from the Pacific Ocean. Thus, as the wort cooled, the brewery had a distinct cloud of steam above the roof.*

*According to brewing legend, steam beer got its name due to the ferocious hiss of carbon dioxide vented when a keg was tapped, leading customers to jokingly ask for a "glass of steam." Presumably, the hiss was also accompanied by a mist of gushing beer, further enhancing the metaphor. Alternatively, in the mid-19th century, "steam brewery" or "steam brewed" beer indicated beer produced in a state of the art steam-powered facility.*

*(I think that name comes from the last two origins. Imagine a 49er with an ironic sense of humor, familiar with good beer from an actual "steam brewery" back East, confronted with an overpriced, foul-tasting mug of San Francisco Gold-Rush era beer, mostly frothy head, fresh from an overcarbonated keg that hissed, sprayed and gushed as it was tapped by an inexperienced barkeeper. Steam beer, indeed!)*

*Once common in American West, before Prohibition Steam Beer was brewed as far inland as Colorado and Idaho. After Prohibition, the style nearly vanished due to competition from light lagers until it was single-handedly revived from extinction by Fritz Maytag. In 1972, Maytag, an heir to an appliance-manufacturing fortune, sold his shares in the family business in order to save his favorite brewery, Anchor Brewing of San Francisco, from bankruptcy. After 10 years of effort and extensive renovations, Maytag turned Anchor became one of the flagships of American Craft Brewing renaissance with its newly trademarked "Anchor Steam" beer as its signature product. Because of the Anchor trademark on "Steam Beer," brewers now refer to this style by the less elegant name of "California Common."*

While historical steam beers varied in O.G., ABV and character (since "steam beer" referred to a brewing technique rather than any particular recipe), modern California Common is narrowly defined by Anchor Steam Beer, an amber beer of moderate ABV, with slightly caramel malt flavor backing up an assertive Northern Brewer hop flavor and aroma.

Grist is American two-row malt with some 40-60 °L crystal malt. Hops are Northern Brewer or some other variety which gives similar flavor and aroma profile. Yeast is California Common ale yeast. Water is moderately soft.