BEER JUDGE CERTIFICATION PROGRAM
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BJCP EXAM STUDY GUIDE

Interim 2006 Revision of 1998 Study Guide
by Gordon Strong and Steve Piatz

This is an Interim Study Guide temporarily replacing the 1998 Study Guide which will undergo a complete update by a Study Guide Committee upon completion and approval of the new BJCP Judge Exam.

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I. INTRODUCTION

Since the inception of the BJCP, several tools have been developed to help potential judges study for the exam. The most widely used are the study guides written by Chuck Cox and Greg Walz. The former was assembled in the early 1990s with the help of readers of the Judge Digest and consists of an outline of the information and terminology needed to pass the exam. The latter is a more verbose discussion of ingredients, brewing procedures and flavors as they relate to beer styles and judging. The outline version is valuable because it encourages independent study; however the verbose version was used as the foundation for the first BJCP Study Guide because information could be added and updated without radically changing the presentation format.

This new edition of the BJCP Study Guide was written with a different approach that was motivated by the feedback and performance from those who have used other study guides. Most of these contain information that is outdated, incorrect or irrelevant to the types of questions asked on the exam. For example, a study guide should not be a tutorial on homebrewing, but should summarize the aspects of the brewing process that relate to beer flavors and styles. The information presented here was written by a group of technically proficient judges and brewers and tailored to the actual BJCP exam questions. The backgrounds of these authors are summarized at the end of the guide. The material has also been reviewed by the BJCP Exam Committee to ensure that it is technically correct and understandable. The goal was to prepare a document that is not only valuable in studying for the exam, but concise and complete enough to be used as a judging handbook. In addition, it is essential that this study guide be made freely available to potential judges. It is available for downloading in several formats on the BJCP web site (http://www.bjcp.org).

The study guide begins with a section describing the BJCP and the motivation and mechanics behind the judging process. Also included are links to BJCP scoresheets, a comprehensive list of possible exam questions and an outline of a study course for beer judges. The BJCP style guidelines are introduced and discussed, and links to the guidelines are provided. Other study guides feature more complete style descriptions, but we found that many potential judges relied on that information as their sole reference for information about beer styles. This may be sufficient to pass the exam, but is no substitute for the wealth of information that is found in Michael Jackson's Beer Companion and The New World Guide to Beer, for example. The last major section of the study guide is a review of technical information about the brewing process and flavors in beer. Although this material was written with the exam questions in mind, it is no substitute for gaining an understanding of the brewing process by reading the references and putting that knowledge to practical use by actually brewing a batch of beer.

We hope that this study guide fulfills its goal of offering a complete, concise and understandable overview of the information needed to pass the exam. We recommend that it be used in conjunction with the following references to gain a complete understanding of beer styles, beer flavors and the brewing process. Good luck!

Note: This guide has been revised to remove obviously outdated material and to update the document with program changes that have been made since 1998. A completely revised study guide will be produced after the current Exam Committee completes the revision to the BJCP Exam.

– Gordon Strong, March 2006.

Recommended Reading

1. Michael Jackson, Beer Companion (Running Press, Philadelphia, 1997).
2. Michael Jackson, The New World Guide to Beer (Running Press, Philadelphia, 1988).
3. John Palmer, How to Brew, (Brewers Publications, Boulder, CO, 2006).
4. Al Korzonas, Homebrewing: Volume 1 (Sheaf & Vine, Palos Hills, IL, 1997).
5. Dave Miller, Dave Miller's Homebrewing Guide (Garden Way Publishing, Pownal, VT 1996).
6. Gregg Smith, The Beer Enthusiast's Guide (Storey Communications, Pownal, VT, 1994).
7. Ray Daniels, Designing Great Beers (Brewers Publications, Boulder, CO, 1996).

Advanced Reading

8. *Classic Beer Styles Series*, (Brewers Publications, Boulder, CO). There are presently seventeen books in this series, plus three additional books on Belgian beer styles: Pale Ale, 2nd Ed. and Porter, both by Terry Foster; Continental Pilsner by David Miller; Lambic by Jean-Xavier Guinard; Vienna, Maerzen, Oktoberfest by George and Laurie Fix; Bock by Darryl Richman; Scotch Ale by Greg Noonan; German Wheat Beer by Eric Warner; Belgian Ale by Pierre Rajotte, Stout by Michael Lewis, Altbier by Horst Dornbusch, and Barleywine by Fal Allen and Dick Cantwell, Bavarian Helles by Horst Dornbusch, Brown Ale by Ray Daniels and Jim Parker, Kölsch by Eric Warner, Mild Ale by David Sutula, Smoked Beer by Ray Daniels and Geoffrey Larson, Farmhouse Ales by Phil Markowski, Wild Brews by Jeff Sparrow, Brew Like a Monk by Stan Hieronymus.
9. Gregory J. Noonan, New Brewing Lager Beer (Brewers Publications, Boulder, CO, 2003).
10. George Fix, Principles of Brewing Science, 2nd Edition (Brewers Publications, Boulder, CO, 1999).
11. George and Laurie Fix, An Analysis of Brewing Techniques, Brewers Publications, Boulder, CO, 1997).
12. *Brewing Techniques* (New Wine Press, Eugene, OR). Contains a wealth of information about the ingredients, history and flavors in beer. While no longer being published some articles are available at www.brewingtechniques.com.
13. *Zymurgy* Special Issues (Association of Brewers, Boulder, CO). Of particular use are the 1997 issue on Hops, the 1995 issue on Grains, the 1991 issue on Traditional Beer Styles, the 1989 and 1998 issues on Yeast and the 1987 issue on Troubleshooting. Back issues available at www.beertown.org.
14. Charlie Papazian, et al, Evaluating Beer (Brewers Publications, Boulder, CO, 1993).
15. Michael Jackson, Michael Jackson's Great Beers of Belgium (Media Marketing Communications, Antwerp, 2001).
16. Roger Protz, The Taste of Beer (Orion Publishing, London, 1998).
17. Michael Jackson, Ultimate Beer (DK Publishing, New York, 1998).
18. Michael Jackson, Great Beer Guide (DK Publishing, New York, 2000).
19. Roger Protz, The Ale Trail (Eric Dobby Publishing, Kent, 1995).
20. Horst Dornbusch, Prost! The Story of German Beer (Brewers Publications, Boulder, CO, 1997).
21. Charles Bamforth, Beer: Tap into the Art and Science of Brewing (Plenum Press, New York, 1998).

II. BEER JUDGING AND THE BJCP EXAM

A. The BJCP Guide

The Beer Judge Certification Program (BJCP) is a non-profit organization that encourages the advancement of education of people who are concerned with the evaluation of beer and related fermented products. The BJCP certifies and ranks beer judges through an exam and monitoring process.

The program was created in 1985 through the joint efforts of the Home Wine and Beer Trade Association (HWBTA) and the American Homebrewers Association (AHA). Since 1995, the BJCP has operated independently of either founding organization, governed only by its membership of participating judges.

In 1985 some 30 people took the BJCP exam and became certified. Since that first exam, over 200 judges have joined the ranks annually. At this time (March 2006) there are approximately 2,300 judges active in the BJCP and a total membership of 3,900.

> The purpose of the BJCP is to promote beer literacy and the appreciation of real beer, and to recognize beer tasting and evaluation skills.

The BJCP Exam

The three-hour BJCP exam is given in two parts: essay and tasting. The essay portion, worth 70 percent of the final score, is designed to determine an individual's overall knowledge of beer and his or her ability to clearly express the information in writing. Essay questions cover the following areas:

- Technical aspects of brewing, ingredients, brewing process and possible faults.
- World beer styles, including characteristics, history, ingredients and brewing techniques.
- The BJCP. Judges represent the BJCP and should be able to explain the program to potential judges and others in the homebrewing community.

The tasting portion of the exam is worth 30 percent of the final score. Each candidate will judge four beers as he or she would at a competition. The prospective judge must score the beer and describe all significant aspects of it, as well as comment on style characteristics.

In preparing for the exam, you should acquire a broad understanding of beer styles, know different brewing methods, and understand how brewing methods correlate with style and flavor. Brewing processes should be understood to the point where you can intelligently discuss various techniques and ingredients and how they may have affected the beer being sampled. Frequent tasting of commercial beers will help you gain further understanding of style differences.

Judging Levels

Judges vary widely in their skill and experience. As a result, the BJCP recognizes various levels of accomplishment. An individual's level of certification is determined by two factors: exam score and experience points earned through AHA/BJCP Sanctioned Competition Program events. The different levels and the criteria for achieving them are outlined below.

- **APPRENTICE** - someone who has taken the BJCP exam, but failed to score at least 60 percent. No experience points are required, but the judge must remain active.
- **RECOGNIZED** - minimum score of 60 percent on the exam. No experience points are necessary to attain this level.
- **CERTIFIED** - minimum score of 70 percent on the exam and at least five experience points, 2.5 of which must be judging points.
- **NATIONAL** - minimum score of 80 percent on the exam and at least 20 experience points, 10 of which must be judging points.
- **MASTER** - minimum score of 90 percent on the exam and at least 40 experience points, 20 of which must be judging points.
- **GRAND MASTER** - FIRST DEGREE - minimum score of 90 percent on the exam and at least 100 experience points, 50 of which must be judging points. A service requirement for the BJCP must also be fulfilled; rules for the Grand Master Service Requirement can be found at http://www.bjcp.org/gmsr.html. Additional degrees can be earned in 100 experience point increments with additional service requirements.
- **HONORARY MASTER** - is temporarily bestowed on judges who serve as operatives of the program (Regional Director, Exam Director, Program Administrator, etc.) at their discretion for the duration of their service if they have not already earned at least the Master rank. The rank may also be awarded, in special cases, to judges who have demonstrated Master Judge proficiency but who have not necessarily taken the exam. This status is determined by the BJCP Board of Directors.
- **HONORARY GRAND MASTER** – Created in 2005, this is a permanent rank bestowed upon individuals by the BJCP Board of Directors for extraordinarily long and meritorious service involving significant, meaningful and continuous work for the BJCP program. Individuals receiving this rank are authorized to wear and use the Grand Master pin and rank.

A person who has not taken the BJCP exam but who judges in competitions is generally referred to as a **Novice** Judge. This is not an official BJCP rank, but this description is used on the BJCP score sheets. Novice judges should only judge in AHA/BJCP sanctioned competitions if approved by the competition organizer.

Advancing in the BJCP

Because both exam scores and experience points determine the level of recognition achieved in the BJCP, a judge should strive to meet both types of criteria on an ongoing basis. A judge may wish to retake the exam at a reduced fee in order to achieve the higher score necessary to advance to the next level. A judge will be placed on an inactive list if no experience points are recorded for two years. After two years on the inactive list, a judge will be dropped from the BJCP roster. This policy encourages judges to maintain their skills and assures competition organizers that they are using experienced judges with up to date knowledge of beer styles and judging practices. When promoted to a new rank, the judge receives a handsome certificate and a wallet-size card showing the date of award and level of recognition.

Experience Points

The BJCP awards experience points to judges and staff who participate in AHA/BJCP Sanctioned Competition Program events or in BJCP exams. The point award varies depending on the size of the event and the job an individual performs. There are two groups of experience points: Judging points and Non-Judging points.

Individuals earn Judging points for actually judging in a registered competition, including Best of Show (BOS) judging. Individuals earn Non-Judging points for serving (or assisting) as a competition organizer, a steward, an administrator (or assistant) for a BJCP exam, or participating in a Continuing Education Program. While competition organizers may use their discretion in deciding to whom and how many Staff points they allocate, Judge points must be earned by the individual receiving them and cannot be allocated.

As of 2006, the AHA and BJCP have merged the separate competition programs into a single unified program: the AHA/BJCP Sanctioned Competition Program. All past BJCP or AHA events will continue to be recognized. The point award schedule for the program is as follows:

BJCP EXPERIENCE POINT AWARD SCHEDULE (Revised July 2005)

Program Participants are individuals who take part in a BJCP-sanctioned competition. Important categories of program participants are organizers, judges, best-of-show judges, stewards and staff. Each has different rules that govern the awarding of experience points.

Organizers are the only program participants to receive Organizer points, which are non-judging points that are allocated based on the total number of competition entries as shown in Table 1. Any other program participant is eligible to receive any combination of Judge, Best-of-Show Judge, Steward, or Staff points in a single competition, except as noted. However, the total points (judging plus non-judging points) awarded to any program participant may not exceed (but may equal) the points designated for the Organizer of the competition.

Judges earn points at a rate of 0.5 judging points per session, but the following limitations apply:

- Judges earn a ***minimum*** of 1.0 point per *competition*.
- Judges earn a ***maximum*** of 1.5 points per *day*.

The total number of judging points a judge may earn in a competition is limited by the organizer points, and is shown in Table 1.

Best-of-Show (BOS) Judges are eligible to receive a 0.5 judging point bonus if they judge in any BOS panel in a competition. The BOS bonus is in addition to any other judging and non-judging points earned in the competition, and may only be awarded to a single judge once per competition. BOS points may only be awarded if a competition has at least 30 entries in at least five beer and/or three mead/cider categories.

The number of judges eligible to receive the BOS bonus is correlated to the number of entries in each BOS panel as follows:

- 5-14 entries, including beer = 3 BOS Judges
- 3-14 meads and/or ciders (only) = 3 BOS Judges
- 15 or more entries of any type or combination = 5 BOS Judges

This limitation applies to each individual BOS panel. Competitions may seat separate homebrew, commercial and mead and/or cider BOS panels, if desired.

A best-of-show judge receives the BOS bonus if the judge judges at least one other flight. If the judge only judges in a BOS panel, the 1.0 point competition minimum is earned.

Stewards receive 0.5 non-judging points per day with a maximum of 1.0 points per competition. Participants may not earn both Judge and Steward points in a single competition. Steward points are awarded separately from Staff points and do not come from the Staff point pool shown in Table 1. A program participant may earn both Steward and Staff points.

Staff Points are non-judging points awarded by the Organizer to one or more program participants in minimum increments of 0.5 points. The sum of all staff points awarded to all program participants may not exceed the Table 1 Staff point maximum.

Note: *In order to maintain competition integrity, staff members with access to entry data should refrain from judging as they may be able to associate entry numbers or entry descriptions with an entrant's identity.*

TABLE 1 — Maximum Points Earned

# of Entries	Organizer	Staff*	Judge
1 - 49	2.0	1	1.5
50 - 99	2.5	2	2.0
100 - 149	3.0	3	2.5
150 - 199	3.5	4	3.0
200 - 299	4.0	5	3.5
300 - 399	4.5	6	4.0
400 - 499	5.0	7	4.5
500 - 599	6.0 Max	8	5.5 Max
		+1 staff point for each additional 100 entries	

***Note:** The Staff point numbers represent the total points which can be awarded to all staff members collectively. No single person can receive more total points than the Organizer. For each 100 entries over 500 one additional staff point may be awarded. Organizer points are capped at 6, regardless of competition size.

DEFINITIONS

COMPETITION — An event held in a single geographical area where beer and possibly other fermented beverages are formally evaluated against a set of pre-defined style guidelines or category descriptions for the purpose of constructive feedback and acknowledgment of excellence. A competition is comprised of one or more sessions spanning one or more days.

DAY — A calendar date when judging is held. Competitions may take place on one or more days, and the days do not have to be contiguous.

SESSION — An uninterrupted time period when at least one panel of judges sits to judge one or more flights of entries.

FLIGHT — A single grouping of entries that are combined for the purposes of judging, that are evaluated by a single panel of judges, and that result in a ranked ordering for purposes of determining awards. In large competitions, a single category may be divided into multiple flights with the overall winner determined in a Mini-BOS round.

MINI-BOS ROUND — A subsequent flight within a session during which judges compare the leading entries of two or more separate flights in order to determine overall class or category winners. This shall not qualify as a separate session for the purpose of awarding points.

BEST OF SHOW (BOS) PANEL — A single session awarding top honors for a competition from at least 5 beer category winners or three mead and/or cider winners.

ORGANIZER — The single program participant who completes and signs the application to register or sanction a competition and who in all ways assumes responsibility for the direction of that competition.

JUDGE — Any program participant who evaluates entries, completes score sheets, and determines the final score and rank of entries in a flight.

BOS JUDGE — A program participant who evaluates entries and selects a winner during a BOS panel.

STEWARD — A program participant who assists judges, obtains entries and supplies, handles paperwork, and manages the competition logistics at a judging table.

STAFF — Program participants who, under the direction of the Organizer, perform duties in support of the competition other than as a Judge, Steward, or BOS Judge. These duties include, but are not limited to, Assistant Organizer, Head Steward, Registrar, Cellarmaster, Table Captain, Data Entry, Head Judge, Lunch Caterer, and Committee member.

Exam Administration

Exam administrators are appointed by the Exam Director and earn non-judging experience points according to the schedule below. Two or three BJCP judges who serve as Exam Proctors (i.e., those who write score sheets) earn 1.0 judging points for their service.

Number of Exam Takers	Administrator Points	Proctor Points
1-9	1	1
10+	2	1

BJCP Administration

The Beer Judge Certification Program is governed by a Committee consisting of seven elected representatives of seven regions of North America. This board manages BJCP policy and bylaws. Communication with BJCP members is handled by the Communication Director, who also handles outside communications. He may be reached by e-mail at communication_director@bjcp.org.

There are also two exam directors responsible for the scheduling, administration, grading and review of BJCP exams. To schedule an exam or to find out when the next exam in your region will take place, please send an e-mail message to exam_director_east@bjcp.org or exam_director_west@bjcp.org.

Complete contact information for all BJCP officers and directors can be found on the BJCP web site in the Administration Center at http://www.bjcp.org/officers.html.

B. Beer Evaluation and the Judging Process

by Edward W. Wolfe

Beer Evaluation

Product evaluation is an important part of brewing, whether performed informally or formally and whether the product is from a commercial or home brewery. Formal beer evaluation serves three primary purposes in the context of brewing competitions. First, the beer evaluations provide feedback to the brewer concerning how well an individual recipe represents its intended beer style. This feedback can be useful as recipes are fine-tuned and attempts are made to improve the beer. Second, beer evaluations may provide brewers with troubleshooting advice. These diagnostic suggestions are particularly helpful when the brewer cannot identify the source of off-flavors or aromas. A knowledgeable beer evaluator can provide the brewer with suggestions for changing procedures and equipment that can help eliminate undesirable flavor and aroma components. Third, beer evaluation provides a fairly unbiased method for selecting and recognizing outstanding beers in brewing competitions.

Environment

One important condition that is necessary for accurate beer evaluation is the establishment of a suitable environment. The environment should be well-lit, odor-free, and distractions should be minimized. Natural, diffuse lighting is best, with incandescent lighting preferred over fluorescent lighting. Table cloths and walls should be free of patterns that might obscure visual inspection of the beer, and light colored or white walls and tablecloths are ideal. The room in which evaluation takes place should be as free of odors as possible. Restaurants and breweries can be particularly troublesome locations for evaluating beers because food and brewing odors are likely to interfere with a beer judge’s ability to smell the beers being evaluated. Smoking and perfumes should also be eliminated as much as possible. In addition, the evaluation environment should be as free from other distractions. Noise should be kept to a minimum, and privacy should be preserved to the greatest extent possible. Every effort should be made to make the beer judges comfortable by carefully selecting chairs and tables, monitoring the temperature of the evaluation room, and providing assistance to judges during the evaluation process (e.g., stewards).

Equipment

A second important condition that is necessary for effective beer evaluation is suitable equipment. That is, judges need sharp mechanical pencils with erasers—mechanical so that the aroma of wood does not interfere with detecting beer aromas and erasers so that comments and scores can be changed. Beer judges also need suitable cups for sampling the beer—impeccably clean plastic or glass, odor-free, and clear. Also, judges need access to style guidelines. Tables should be equipped with water and bread or crackers for palate cleansing, buckets and towels for cleaning spills or gushes, bottle openers and cork screws, and coolers and temporary caps for temporary storage of opened bottles.

Presentation

As for the presentation of beers, two methods are common, each with positive and negative points. One method of presentation permits judges open and pour the beer into their own cups. A second method of presentation requires stewards to pour beer into pitchers, and the beer is transferred from the pitcher into judges' cups. When judges are allowed to pour their own beers, there is some danger that moving bottles to the evaluation table will stir up yeast and that judges' opinions of a beer's quality will be influenced by the appearance of the bottles that it comes in. On the other hand, when judges transfer beer from a pitcher, it is more difficult to capture many of the fleeting aromas that might dissipate between the time the bottle is opened and the time that judges are presented with the beer. Another problem with using pitchers is that it is more difficult to temporarily store beer samples so that judges can taste them again at a later time.

The Judging Process

Decision Strategies

There are two general decision making strategies that judges use when evaluating a beer. In a top-down decision making strategy, the judge forms an overall impression about the quality of the beer, decides what overall score to assign that beer, and deducts points for each deficient characteristic of the beer based on the overall impression. The problem with this top-down approach to beer evaluation is that it is difficult to ensure that the points allocated to each subcategory (e.g., aroma, appearance, flavor, body) agree with the comments that were made about that feature of the beer. In a bottom-up decision making strategy, the judge scores each subcategory of the beer, deducting points for each deficient characteristic. The overall score is determined by summing the points for each subcategory. The problem with this bottom-up approach to beer evaluation is that it easy to arrive at an overall score for the beer that does not agree with the overall impression of the beer. In short, judges who use a top-down approach to judging beers may "miss the trees for the forest," while judges who use a bottom-up approach to judging beers may "miss the forest for the trees."

Most judges use a combination of these two extremes. Regardless of which approach seems more comfortable to an individual beer judge, there are several general guidelines that judges should follow when assigning scores to beers. In the current BJCP scoring systems, each beer is evaluated on a 50-point scale, allocating 12 points for Aroma, 3 for Appearance, 20 for Flavor, 5 for Mouthfeel and 10 for Overall Impression. This scoresheet can be found on the BJCP web site. In addition, there are sliding scales on the bottom right hand corner for rating the stylistic accuracy, technical merit and intangibles of each beer. Potential judges should be familiar with each scoresheet until the new version has been approved for general use.

Overall scores should conform to the descriptions given at the bottom of each scoresheet. Excellent ratings (38-44) should be assigned to beers that are excellent representations of the style. Very Good ratings (30-37) should be assigned to good representations of the style that have only minor flaws. Good ratings (21-29) should be assigned to good representations of the style that have significant flaws. Drinkable ratings (14-20) should be assigned to beers that do not adequately represent the style because of serious flaws. A problem rating (13) should be assigned to beers that contain flaws that are so serious that the beer is rendered undrinkable. The scoresheet reserves the 45-50 range for outstanding beers that are truly world-class.

In general, the best beers at a competition should be assigned scores in the 40+ range, with real evaluations of the beer identifying some characteristics of the beer that make it non-perfect. In reality, there is no "perfect beer," so even the best beers are not assigned a score of 50. When providing feedback about very good beers, it is important to identify ways in which the beer can be improved and mention these characteristics on the score sheet. Any serious flaw or missing aspect of a particular beer style (such as lack of clove character in a Bavarian weizen) generally results in a maximum score around 30. Also, note the cut-off score of 21 determines if a beer adequately represents a particular style. No beer deserves a score below 13. Brewers who enter competitions pay money to receive helpful, unbiased evaluations of their beers. There is no need to scar a brewer's esteem with extremely low scores and unhelpful, deprecating remarks. Always look for positive comments to make about a beer, and then let the brewer know what aspects of the beer need attention and how to correct any flaws.

Procedure

Beers should be evaluated using the following procedure:

1. Prepare a score sheet. Write the entry number, style category and subcategory names and numbers, your name, and any other necessary information (e.g., judge rank, e-mail address) on a score sheet.
2. Visually inspect the bottle (if given the bottle). Check the bottle for fill level, clarity, sediment, and signs of problems (e.g., a ring around the neck of the bottle). Identification of such characteristics may be helpful in describing flaws that are discovered during the formal evaluation process. However, be careful not to prejudge the beer based on a visual inspection of the bottle.
3. Pour the beer into clean sampling cup, making an effort to agitate the beer enough to produce a generous head (but not enough to produce a head large enough to interfere with drinking the beer). For highly carbonated beers, this may require pouring carefully into a tilted cup. For beers with low carbonation, this may require pouring directly into the center of the cup, with a 6 inch drop from the bottle. It is important that the same pouring technique be used for all of the beers in a flight.
4. Smell the beer. As soon as the beer is poured, swirl the cup, bring it to your nose, and inhale the beer's aroma several times. When a beer is cold, it may be necessary to swirl the beer in the cup, warm the beer by holding it between your hands, or putting your hand on the top of the cup to allow the volatiles to accumulate in a great enough concentration to be detected. Write your impressions of the beers aromas. Particularly, note any off aromas that you detect. Do not assign scores for aroma yet.
5. Visually inspect the beer. Give your nose a rest, and score the appearance of the beer. Tilt the cup, and examine it through backlighting. For darker beers, it may be necessary to use a small flashlight to adequately illuminate the beer. Examine the beer's color, clarity, and head retention. Write comments about the degree to which the color, clarity, and head retention are appropriate for the intended style and record a score. Score the beer for appearance, allocating a maximum of one point for each of these characteristics.
6. Smell the beer again. Again, swirl the cup, bring it to your nose, and inhale the beer's aromas several times. Note how the beer's aroma changes as the beer warms and the volatiles begin to dissipate. Write your impressions of the beers aromas, noting particularly the appropriateness of the malt, hops, yeast, and fermentation byproduct aromas. Also, note any lingering off aromas. Do not assign scores for aroma yet.
7. Taste the beer. Take about 1 ounce of beer into your mouth, and coat the inside of your mouth with it. Be sure to allow the beer to make contact with your lips, gums, teeth, palate, and the top, bottom, and sides of your tongue. Swallow the beer, and exhale through your nose. Write down your impressions of the initial flavors of the beer (malt, hops, alcohol, sweetness),

intermediate flavors (additional hop/malt flavor, fruitiness, diacetyl, sourness), aftertaste (hop bitterness, oxidation, astringency), and conditioning (appropriateness of level for style). Do not assign scores for flavor yet.

8. Score the beer for body (mouthfeel on the new). Take another mouthful of beer and note the appropriateness of the beer's viscosity for the intended style. Write comments concerning your impression and assign between 2 and 5 points with higher numbers reflecting appropriate mouthfeel and lower numbers indicating increasing levels of lightness or heaviness for the intended style.
9. Evaluate the beer for overall impression. Relax. Take a deep breath. Smell the beer again, and taste it again. Pause to consider where the beer belongs in the overall range of scores (e.g., excellent, very good, good, drinkable, problem) and where similar beers are ranked within the judging flight. If you use a top-down decision making strategy, assign an overall score to the beer, then mentally subtract points from the remaining subcategories (i.e., aroma and flavor), consistent with your impressions of how the beer is deficient. Use the overall impression category to adjust your final score to the level you feel is appropriate for this beer. If you use a bottom-up decision making strategy, assign scores to each of the remaining subcategories (i.e., aroma and flavor), and assign a score for overall impression. Finally, write prescriptive suggestions for improving the beer in light of any deficiencies you noted in your evaluation. Also, check any boxes on the left side of the score sheet that are consistent with your comments.
10. Check your score sheet. Add your category scores. If you use a bottom up approach, double check to make sure you added correctly. If you use a top down approach, make sure that your subcategory scores sum to equal your overall score. When the other judges have finished scoring the beer, discuss the technical and stylistic merits of the beer and arrive at a consensus score. Be prepared to adjust your scores to make them fall within 5-7 points of the other judges at your table.

Notes on Smelling the Beer

When a beer judge smells a beer, the judge is literally inhaling small particles of the beer. The sense of smell works by detecting molecules that are diffused into the air. These molecules are inhaled into the sinus cavity where receptors (olfactory cells) detect and translate the chemical information contained in the molecules into information that the brain can interpret. Several things influence a judge's ability to detect the variety of aromas in beer. First, there are different densities of the receptors found in different people. Hence, some judges may simply be more sensitive to odors than are other judges. Second, the receptor cells can be damaged through exposure to strong substances (e.g., ammonia, nasal drugs), and this damage may take several weeks to heal. Third, changes in the thickness of the mucus that lines the nasal cavity may influence a judge's sensitivity. Any molecules that are detected by the olfactory cells must pass through a mucus lining, so daily changes in the thickness of that lining influences our sensitivity from day to day. The thickness of the lining can be influenced by sickness (e.g., colds), or exposure to a variety of allergens or irritants (e.g., pet dander, dust, smoke, perfume, spicy foods). Therefore, judges need to take into account their current levels of sensitivity, given their health and exposure to substances that could interfere with their sense of smell. Finally, the olfactory cells become desensitized to repeated exposure to the same odors. As a result, a beer judge may be less able to detect subtle aromas as a judging session progresses. One way to remedy this problem is to occasionally take deep inhales of fresh air to flush the nasal cavity. Another way to lessen desensitization to certain odors is to sniff something that has a completely different odor (e.g., sniffing your sleeve) (Eby, 1993; Palamand, 1993).

Regardless of a judge's ability to detect various odors in beer, that ability is useless if the judge cannot use accurately descriptive terms to communicate information to the brewer. Hence, it is important for beer judges to build a vocabulary for describing the variety of odors (and knowledge of the source of those odors). Meilgaard (1993) presents a useful taxonomy of beer-related odors. His organizational scheme categorizes 33 aromas into 9 overall categories (oxidized, sulfury, fatty, phenolic, caramelized, cereal, resinous, aromatic, and sour). Beer judges should make efforts to expand their scent recognition and vocabulary.

Notes on Tasting the Beer

The sense of taste is very similar to the sense of smell. Taste is the sense through which the chemical constituents of a solid are detected and information about them is transmitted to the brain. The molecules are detected by four types of taste buds that are on the tongue and throat. Sweetness is detected on the tip of the tongue. Saltiness is detected on the front and sides of the tongue. Sourness is detected on the sides of the tongue toward the back of the mouth. And, bitterness is detected on the back of the tongue near the throat. In addition, sweetness, sourness, and bitterness can be detected on the palate (i.e., roof of the mouth). Since all of these flavors are present in beer, it is important that beer judges completely coat the inside of their mouths with beer when evaluating it and that the beer be swallowed. As is true for the scent receptors in the nose, different people have different densities of taste buds and, thus, have different sensitivities to various flavors. Also, taste buds can be damaged (e.g., being burnt by hot food or through exposure to irritants like spicy foods, smoking, or other chemicals), so a judge's sensitivity may be diminished until tastebuds can regenerate (about 10 days). Judges need to be aware of their own sensitivities and take into account recent potential sources of damage when evaluating beers. In addition, taste buds can be desensitized to certain flavors because of residual traces of other substances in the mouth. Therefore, it is best for judges to rinse their mouths between beers and to cleanse their palates with bread or salt-free crackers (Eby, 1993; Palamand, 1993).

Of course, as is true for the sense of smell, a judge's ability to taste substances in beer is useless unless that judge can accurately identify the substance and use appropriate vocabulary to communicate that information to a brewer. Meilgaard's (1993) categorization system for beer flavors includes 6 general categories (fullness, mouthfeel, bitter, salt, sweet, and sour) consisting of 14 flavors that may be present in beer. Judges should continually improve their abilities to detect flavors that are in beer, their abilities to use appropriate words to describe those perceptions, and their knowledge of the sources of those flavors so that brewers can be provided with accurate and informative feedback concerning how to improve recipes and brewing procedures.

Notes on Making Comments about Beer

There are five things to keep in mind as you write comments about the beers you judge. First, your comments should be as positive as possible. Acknowledge the good aspects of the beer rather than focusing only on the negative characteristics. Not only does this help make any negative comments easier to take as a brewer, but it gives your evaluation more credibility. Second, and related, be polite in everything that you write about a beer. Sarcastic and deprecating remarks should never be made on a score sheet. Third, be descriptive and avoid using ambiguous terms like "nice." Instead, use words to describe the aroma, appearance, and flavors of the beer. Fourth, be diagnostic. Provide the brewer with possible causes for undesirable characteristics, and describe how the recipe or brewing procedure could be adjusted to eliminate those characteristics. Finally, be humble. Do not speculate about things that you do not know (e.g. whether the beer is extract or all-grain), and apologize if you cannot adequately describe (or diagnose) characteristics of the beer that are undesirable.

Other Considerations

Before the Event

Before a judging event, you should take steps to mentally and physically prepare yourself. Thoroughly familiarize yourself with the style(s) that you will judge if you know what those styles are ahead of time. Sample a few commercial examples and review the style guidelines and brewing procedures for those styles. Also, come to the event prepared to judge. Bring a mechanical pencil, a bottle opener, a flashlight, and any references that you might need to evaluate the beers. Also, make sure to come to the event in the right frame of mind. Get adequate rest the night before; shower; avoid heavily scented soaps, shampoos, and perfumes; avoid eating spicy foods and drinking excessively; and avoid taking medication that might influence your ability to judge (e.g., decongestants). You can also prepare your stomach for a day of beer drinking by drinking plenty of water and eating a dinner that contains foods that contain fats the night before the event and by eating extra sugar the morning of the event (e.g., donuts) (Harper, 1997).

Fatigue & Errors

During a judging flight, it is important to keep in mind that errors can creep into your judging decisions as a result of fatigue (palate or physical), distractions, or the order in which beers are presented. More specifically, judges may tend to assign scores (central scoring) in a much narrower range as time progresses simply because palate fatigue causes the beers to taste more and more similar over time. Conversely, judges may assign one or two beers much higher scores than other beers simply because they stand out as being much more flavorful (extreme scoring). In addition, as judges become tired (and possibly intoxicated) during long flights, they may allow impressions of some very noticeable characteristics of particular beers to overly influence their perceptions (and scores) of other characteristics of the beers (halo effect). For example, a weizen that is too dark may (falsely) also seem too heavy and caramel-flavored. Also during long flights, judges need to be mindful of the fact that proximity errors (e.g., assigning scores that are too high to a beer that follows a poor example of the style) and drift (e.g., assigning progressively lower (or higher) scores to beers as time progresses) may influence the validity of the scores that they assign (Wolfe, 1996; Wolfe & Wolfe, 1997).

Unfortunately, it is nearly impossible to know when errors such as these have crept into your judgments. Therefore, it is extremely important to retaste all of the beers in a flight, especially the ones in the top half of the flight. In general, most flights should contain less than 12 beers, so this would entail retasting at least the 6 that receive the highest scores. Each beer should be carefully reevaluated to make sure that the rank ordering of the assigned scores reflects your overall impression of the actual quality of the beers. Only after retasting and a discussion of these impressions should awards be assigned to beers within the flight. Note that the competition coordinator may request that you readjust your scores to reflect any discrepancies between the ordering of awards and the ordering of assigned scores.

When You Are Finished

When you have finished judging a flight of beers, make sure that your score sheets are complete, that the score sheets have been organized in a way that the competition organizer can identify the scores and the awards that you assigned, and that the table at which you judged is ready to for another judging flight or that (following the final flight of the day) it is cleaned. Most importantly, avoid causing distractions to other judges who have not yet finished judging their flights (e.g., loud conversations, interrupting judges who are still making decisions, etc.). In fact, this would be a good time to leave the judging area for a beer or a breath of fresh air. Also, be conscientious in what you say to others about the beers that you judged. It is often tempting to tell others about the worst beer in your flight or to make remarks about the overall poor quality of entries that you judged. Not only are comments such as these in poor taste, but since you do not know who entered the beers that you judged, you may offend the person to whom you are talking (or judges who are still judging).

Practicing

Of course, one of the best (and most enjoyable) things that you can do to maintain your judging skills is to continually practice by sampling a variety of beers and brewing your own beers. In addition to visiting pubs and microbreweries, you can sample homebrew regularly by attending homebrew club meetings. Entering beers in competitions is also a practical way to compare your flavor perception and troubleshooting skills with those of experienced judges. You can also brush up on your judging skills by coordinate tasting sessions and mini-competitions with other judges or by sampling beers that have been “doctored” to simulate common flavors and flaws in beer (Wolfe & Leith, 1997). Dr. Beer ® is a commercial example of this program, but several authors have described methods for preparing beers using readily-available ingredients (Guinard & Robertson, 1993; Papazian & Noonan, 1993; Papazian, 1993). Guidelines for a doctored beer session are also given at the end of the BJCP Exam Study Course later in this section.

References and Additional Reading

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10. Wolfe, E.W., "Unbeknownst to the right honourable judge—Or how common judging errors creep into organized beer evaluations" Brewing Techniques, v. 4(2), 56-59 (1996).
11. Wolfe, E.W. and Wolfe, C.L., "Questioning order in the court of beer judging—A study of the effect of presentation order in beer competitions," Brewing Techniques, v. 5(2), 44-49 (1997).
12. Wolfe, E.W. and Leith, T., "Calibrating judges at remote locations: The Palate Calibration Project," submitted to Brewing Techniques (1997).

C. Important BJCP Reference Materials

Current competition materials can be found on the BJCP web site in the Competition Center. Other important BJCP references include the most current program rules, information and structure. These documents can be found in the following locations:

BJCP Beer Scoresheet	http://www.bjcp.org/SCP_BeerScoreSheet.pdf
BJCP Cover Sheet	http://www.bjcp.org/SCP_CoverSheet.pdf
BJCP Judge Instructions	http://www.bjcp.org/SCP_JudgeInstructions.pdf
Judge Procedures Manual	http://www.bjcp.org/Judge_Procedures_Manual.pdf
BJCP Competition Requirements	http://www.bjcp.org/rules.html
BJCP Member's Guide	http://www.bjcp.org/membergd.html
Sample Score Sheets	http://www.bjcp.org/examscores.html
Mastering the BJCP Exam	http://www.bjcp.org/mastering.pdf

D. The BJCP Exam

Overview

The BJCP exam is closed book and consists of an essay portion worth 70 percent and a tasting portion worth 30 percent of the total score. On the essay portion, there are ten questions covering beer styles and brewing techniques, with the latter focusing on the relationship of ingredients and the brewing process to flavors in the finished beer. The style questions typically ask for descriptions and comparisons of related beer styles, including information on the historical development, ingredients, style parameters, commercial examples and the brewing process. See the following two sections for a list of the BJCP exam questions and an example of an answer with enough content and depth to receive a very high mark. In addition to style and technical questions, since judges represent the BJCP, part of one question asks for a brief description of the purpose and levels of judging program. It should be noted that although the current exams are formed from a large pool of essay questions, the BJCP exam committee is currently investigating the feasibility of replacing some of these with short-answer, true/false, or multiple choice questions.

The exam is criteria-based, so if the essay questions are not answered correctly or do not contain enough information (a good rule of thumb is one page per answer), then it will be difficult to get a passing score on the written portion. Similarly, if the descriptions and feedback on the beer scoresheets are weak, it will be difficult to pass the tasting portion. The recommended materials should therefore be read before the study sessions and reviewed along with the BJCP Study Guide before the exam. The style categories in the questions below are based on the BJCP Guidelines, which are also used by the AHA for its national homebrew competition.

The tasting portion of the BJCP exam requires the judging of four beers as if one were at a competition, with the scoresheets evaluated on the basis on scoring accuracy, perception, descriptive ability, feedback and completeness. Grading is done by volunteer National and Master judges, with their scores and feedback reviewed by both an associate exam director and an exam director. These reviews ensure that the scores from different exams and graders are consistent between different exams and with the criteria expected for the different judging levels.

The following is from the instructions to the BJCP exam. It clearly states what a complete answer to the typical exam question should contain.

> **For a passing score, beer style descriptions must include the aroma, appearance, flavor, and mouthfeel descriptions as in the BJCP Style Guidelines. If time permits, for maximum credit, a more complete answer should consider the history of the style, geography, commercial examples, style parameters, unique ingredients, and fermentation techniques and conditions. When a question asks for a *classic* commercial example of a style the correct answer is one of the styles listed in the BJCP Style Guidelines.**

BJCP Exam Questions

Judging

J1. In one page or less, describe the purpose of the Beer Judge Certification Program and outline the requirements for the judging levels and their requirements.

Styles

S1. Identify, describe and then provide a statement detailing the differences and similarities between three *top-fermenting* beer styles with original gravities greater than 1.070. Give at least one *classic* commercial example of each style.

S2. Identify, describe and then provide a statement detailing the differences and similarities between three distinctly different German *bottom-fermented* beer styles. Note that color or strength differences do not count as different beer styles. Give at least one *classic* commercial example of each style.

S3. Identify, describe, and then provide a statement detailing the differences and similarities between three distinctly different beer styles that contain wheat as a primary ingredient. Note that color or strength differences do not count as different styles. Give at least one *classic* commercial example of each style.

S4. Identify, describe and then provide a statement detailing the differences and similarities between three distinct Belgian beer styles. Give at least one *classic* commercial example of each style.

S5. The question asks you about the differences and similarities between three sub-styles.

> Describe each of the following sub-styles and then provide a statement detailing the differences and similarities between the sub-styles. Give at least one *classic* commercial example of each sub-style.

The three sub-styles are selected from large list that looks something like:

a) Ordinary Bitter	b) Best Bitter	c) Strong Bitter (English Pale Ale)
a) Maibock	b) Traditional Bock	c) Doppelbock
a) Old Ale	b) English Barleywine	c) Strong Scotch Ale
a) Robust Porter	b) Dry Stout	c) English Pale Ale
a) Scottish 60/-	b) Scottish 70/-	c) Strong Scotch Ale
a) American Stout	b) Dry Stout	c) Foreign Extra Stout
a) Dortmunder Export	b) Munich Helles	c) German Pilsner
a) Mild	b) American Brown	c) Northern English Brown
a) German Pils	b) Bohemian Pilsner	c) Standard American Lager
a) Robust Porter	b) Sweet Stout	c) Foreign Extra Stout
a) American Pale Ale	b) American Amber Ale	c) California Common Beer
a) Cream Ale	b) Kölsch	c) Munich Helles
a) Scottish 70/-	b) Scottish 80/-	c) Strong Scotch Ale
a) Traditional Bock	b) Maibock	c) Eisbock
a) Scottish 60/-	b) Scottish 80/-	c) Strong Scotch Ale
a) Mild	b) American Brown Ale	c) Southern English Brown
a) Oktoberfest	b) Altbier	c) Best Bitter
a) American Pale Ale	b) American Brown Ale	c) California Common Beer
a) American Stout	b) Dry Stout	c) Sweet Stout
a) Brown Porter	b) Munich Dunkel	c) Northern English Brown
a) Old Ale	b) American Barleywine	c) Strong Scotch Ale
a) Doppelbock	b) Maibock	c) Eisbock
a) Traditional Bock	b) Doppelbock	c) Eisbock

a) Mild	b) Scottish 60/-	c) Ordinary Bitter
a) Brown Porter	b) Munich Dunkel	c) Southern English Brown
a) American Stout	b) Foreign Extra Stout	c) Oatmeal Stout
a) Bière de Garde	b) California Common	c) North German Altbier
a) Belgian Blond Ale	b) Belgian Dubbel	c) Belgian Tripel
a) Dry Stout	b) Foreign Extra Stout	c) Sweet Stout
a) Flanders Red Ale	b) Berliner Weisse	c) Straight Lambic
a) Baltic Porter	b) Imperial Stout	c) Belgian Dark Strong Ale
a) Weizen	b) American Wheat	c) Straight Lambic
a) English IPA	b) American IPA	c) Imperial IPA
a) German Pilsner	b) Bohemian Pilsner	c) Classic American Pilsner
a) Weizen	b) Roggenbier	c) American Wheat or Rye
a) Brown Porter	b) Munich Dunkel	c) Schwarzbier
a) American Stout	b) Dry Stout	c) Oatmeal Stout
a) Irish Red Ale	b) Oktoberfest	c) North German Altbier
a) Weizen	b) American Pale Ale	c) Straight Lambic
a) Belgian Tripel	b) Belgian Blond Ale	c) Belgian Strong Golden Ale
a) Irish Red Ale	b) Oktoberfest	c) California Common Beer

S6. Identify, describe and give at least one classic commercial example of a major beer style commonly associated with (three cities will be given):

a) Düsseldorf	b) Berlin	c) Einbeck
d) Köln (Cologne)	e) Edinburgh	f) Bamberg
g) Burton-on-Trent	h) Newcastle	i) Senne Valley
j) Dublin	k) San Francisco	l) Vienna

Troubleshooting

T1. Describe and discuss the following beer characteristics. What causes them and how are they avoided and controlled? Are they ever appropriate and if so, in what beer styles? (three will be given)

a) cloudiness	b) buttery	c) low head retention
d) astringency	e) phenolic	f) light body
g) fruitiness	h) sourness	i) cooked corn
j) bitterness	k) cardboard	l) sherry-like
m) acetaldehyde	n) alcoholic	

T2. Explain how the brewer gets the following characteristics in his/her beer:

a) good head retention
b) clarity in a beer
c) a proper diacetyl level for style

T3. What are body and mouthfeel? Explain how the brewer controls body and mouthfeel in his/her beer.

Ingredients

T4. Discuss hops, describing their characteristics, how these characteristics are extracted, and the beer styles with which the different varieties are normally associated.

T5. Explain the malting process, identifying and describing the different types of malts by their color and the flavor they impart to the beer. Give the styles with which they are associated.

T6. Describe the role of yeast in beer production and the positive and negative effects on the finished product of oxygen introduction during the various stages of fermentation.

T7. Describe the stages of yeast development and give five considerations in selecting the appropriate yeast strain for a given beer style.

T8. Discuss the importance of water characteristics in the brewing process and how water has played a role in the development of world beer styles.

The Brewing Process

T9. Discuss the following brewing techniques. How do they affect the beer?

a) kräusening b) adding gypsum c) fining

T10. What is meant by the terms *hot break* and *cold break*? What is happening and why are they important in brewing and the quality of the finished beer?

T11. Describe and explain the role of *diastatic* and *proteolytic* enzymes in the brewing process and how they affect the characteristics of the finished beer.

T12. What are five primary purposes for boiling wort? How does a brewer achieve these objectives?

T13. Explain what happens during the mashing process. Describe three different mashing techniques and the advantages and disadvantages of each.

T14. Provide a complete ALL-GRAIN recipe for a <STYLE>, listing ingredients and their quantities, procedure, and carbonation. Give volume, as well as original and final gravities. Explain how the recipe fits the style's characteristics for aroma, flavor, appearance, mouthfeel, and other significant aspects of the style.

Styles may include:

a) Belgian Tripel	b) Oktoberfest	c) Classic American Pilsner
d) Doppelbock	e) American IPA	f) Bohemian Pilsner
g) Robust Porter	h) Weizen	i) German Pilsner
j) Dry Stout	k) English Pale Ale	

Example of a Complete Answer

Q: Describe and differentiate Abbey and Trappist beers. Give commercial examples of each.

A: The primary difference between Abbey and Trappist beers is that the latter is an appellation which restricts its production to the seven Trappist monasteries in the Low Countries. They are Chimay, Orval, Achel, Rochefort, Westmalle and Westvleteren in Belgium and Schaapskooi in the Netherlands. Abbey beers on the other hand, are either brewed at non-Trappist monasteries or by commercial breweries to which abbies have licensed their names. Commercial examples of these include Affligem, Leffe and Grimbergen.

Both Abbey and Trappist breweries are best known for the dubbel and tripel styles. The former is a tawny beer with an OG in the 1.060-75 range, 6-7.5% alcohol, and enough bitterness to balance, approximately 15-25 IBUs. The color is generally deep ruby to brown and derived from both Belgian specialty malts and caramelized candi sugar. The flavor is dominated by a full-bodied malty sweetness reminiscent of plums, raisins and black currents. Ester levels are generally subdued by Belgian standards, but some examples do have moderate bubble-gum or banana esters. Tripels, on the other hand, are much paler in color at 3-5

SRM, but have higher OG (1.075-85) and alcohol levels (7.5-9 %). The malts used are almost entirely pilsner, with light candi sugar used to increase the alcohol content and prevent the beer from being too cloying. Hop rates are higher at 25-38 IBUs, with some noble hop flavor and aroma acceptable. The ester levels are often more assertive in this style, though the increased alcohol content should be subtle. Westmalle Dubbel and Tripel are classic examples of these styles.

Some Trappist breweries also produce beers which would better fit into the strong ale category due to high ester levels or unusual brewing procedures. In the latter category are Chimay (Premiere, Cinq Cents and Grand Reserve) and Rochefort (6, 8 and 10) brews, which have very distinctive signatures from the yeast. One of the most unusual beers in Belgium is made by Orval, the only (readily available) beer brewed by that monastery. It has a moderate gravity in the 1.055-60 range, is dry hopped with Styrian Goldings and undergoes a secondary fermentation with a mixture of five yeast strains that includes *Brettanomyces*. As the beer ages, the flavors become more complex, picking up leathery/oaky and even phenolic notes from the yeast.

E. BJCP Exam Study Course

by Scott Bickham

The ten session course outlined below is a modification of ones that have been effective in preparing judges for the BJCP exam. One or two members of the study group are usually assigned to the task of collecting commercial and homebrewed examples of a given style. They should also prepare and distribute handouts that outline the background and characteristics of each style, as well as a technical topic relevant to the exam. All but one of the beers are then served blindly and discussed, with positive and negative attributes identified. After the tasting session, a technical topic concerning ingredients, the brewing process, or beer flavors is reviewed. Finally, the study group takes a mini-exam that consists of two essay questions taken from the BJCP question pool and judges the remaining beer using the BJCP beer scoresheet. The exam questions should be correlated with the style and technical information that was presented in the class, and there should be forty minute time limit that is well-matched to the three hours required for the actual exam. The total time for each class should be approximately three to four hours, depending on the number of commercial examples and depth of the presentations and discussions.

It should also be easy to persuade local beer experts to participate in the review sessions (bribery with free beer is very effective), but the work can also be divided among those studying for the exam. The commercial examples below are based on beers which were available in the Mid-Atlantic in the late 1990s, but a similar collection can be assembled in other geographic areas. The number of beers served in each class should be limited to 8-10, depending on the alcoholic strength and sample size, to prevent palate fatigue and promote responsible drinking. It is also recommended that a flat fee be charged for the class, payable in advance or at the first study session. The Brewers United for Real Potables homebrew club set this fee at $50 for its most recent study course, and while this did not quite cover the actual expenses, the club gladly covered the remainder due to the intangible benefits of having an educated membership. This amount may seem a bit steep from the perspective of the participants, but keep in mind that they are tasting as many as one hundred commercial examples and picking up invaluable information about beers styles and the brewing process.

Class 1. Light Lagers: American Light (Budweiser, Coors, Michelob) and Pre-prohibition Pilsner, Bohemian and German Pilsners (Pilsner Urquell, Bitburger, DeGroen's), Dortmunder Export (Stoudt's Gold), Munich Helles (Augustiner Edelstoff Helles).

Technical topic: Malt, including the malting process, types, adjuncts, kilning and the styles with which different malts are associated.

Class 2. Amber and Dark Lagers: Vienna (Dos Equis, Negra Modelo), Oktoberfest/Märzen (Spaten, Paulaner), Munich Dunkel (Spaten), Schwartzbier (Köstrizer), Bock (Paulaner), Helles/Maibock (Ayinger, Fordham), Doppelbock (Paulaner Salvator, Ayinger Celebrator), Eisbock (Kulmbacher Reichelbraü).

Technical topic: Water, including minerals, pH, hardness, adjustment, and the effect on the development of world beer styles.

Class 3. Bitters and Pale Ales: Ordinary (Boddington's Draught), Special (Young's Ramrod, Fuller's London Pride), ESB (Fuller's), English and American Pale Ales (Bass, Whitbread, Sierra Nevada Pale Ale, Tupper's Hop Pocket), English and American IPA (Young's Special London Ale, Anchor Liberty, Sierra Nevada Celebration Ale), California Common (Anchor Steam).

Technical topic: Mashing, including types used for different beer styles, mash schedules and enzymes.

Class 4. Brown, Scottish and Strong Scotch Ales: Light and Dark Mild (Grant's Celtic Ale), English and American Brown (Newcastle, Sam Smith's Nut Brown Ale, Brooklyn Brown Ale, Pete's Wicked Ale), Scottish Light, Heavy and Export (McEwen's Export, Belhaven, MacAndrew's), Scotch (McEwen's, Traquair House).

Technical topic: Hops, including varieties, IBUs, hopping scheduled and the association with different beer styles.

Class 5. Stout and Porter: Dry Stout (Guinness Draught, Murphy's), Sweet Stout (Watney's, Mackeson's), Oatmeal Stout (Anderson Valley Barney Flats, Young's), Foreign and Imperial Stout (Sheaf Stout, Sam Smith's Imperial Stout, Victory Russian Imperial Stout), Brown Porter (Anchor, Sam Smith's Old Taddy Porter), Robust Porter (Sierra Nevada).

Technical topic: Yeast and fermentation, including characteristics of different yeast strains, bacteria, by-products and relationship to world beer styles.

Class 6. Barleywines and Old Ales: English Old Ale (Theakston's Old Peculier, Thomas Hardy, Hair of the Dog Adambier), English and American Barleywines (Young's Old Nick, Sierra Nevada Bigfoot, Anchor Old Foghorn, Rogue Old Crustacean, Dominion Millennium, Victory Old Horizontal).

Technical topic: Brewing procedures, including sparging, boiling, fining and carbonation methods. Reasons for each should be discussed, along with potential problems.

Class 7. German Ales, Wheat Beers and Rauchbiers: Düsseldorf and North German Alt (Bolten Alt, Fordham Alt), Kölsch (Reissdorf Kölsch), American Wheat (Pyramid Wheathook, Anchor Wheat), Bavarian Weizen (DeGroen's, Paulaner, Victory Sunrise, Schneider Weisse), Dunkelweizen (Hacker-Pschorr), Weizenbock (DeGroens, Schneider Aventinus), Berliner Weiss (Kindl), Bamberger Rauchbier (Kaiserdom, Schlenkerla).

Technical topic: Troubleshooting I, which includes a discussion of how positive and negative attributes are perceived and produced, the beer styles with which they may be associated and corrective measures. The flavor descriptors on the beer scoresheet or the BJCP Study Guide should be split into two sections.

Class 8. Strong Belgian and French Ales: Dubbel (Affligem, La Trappe), Tripel (Affligem, Westmalle), Strong Golden and Dark Ales (Duvel, Chimay, Orval, Scaldis, La Chouffe), Bière de Garde (Jenlain, 3 Monts), Saison (Saison du Pont).

Technical topic: Troubleshooting II.

Class 9. Other Belgian Ales: Oud Bruin and Flanders Red (Rodenbach Grand Cru, Liefman's Goudenband, Liefman's Framboise), Gueuze and Fruit Lambic (assorted Boon, Cantillon and Mort Subite), Wit (Celis White, Hoegaarden), Pale Ale (Corsendonk Pale, Celis Pale Bock).

Technical topic: Recipe formulation, including the selection of appropriate hops, malt, water, yeast and brewing procedure for different beer styles.

Class 10. Doctored beer seminar. This is an informative and practical method of learning how isolated flavors taste in beer. A clean lager is generally doctored with near-threshold amounts of compounds which either occur naturally in beer or mimic those that do. Examples include artificial butter for diacetyl, sherry for sherry-like oxidation, vodka for alcohol, almond extract for nuttiness, grape tannin for astringency, hop oils for hop flavor and aroma, and lactic and acetic acid for sourness. Recommended amounts are given in the table below. Note that some of these compounds have very strong flavors, so they should be diluted in water or beer before adding to the base beer. For example, a detectable amount of lactic acid is approximately 0.4 ml of 88% USP lactic acid to a 12 oz. sample of beer. Since most of us do not have access to pipettes to measure such a small quantity, 1/8 tsp. may be added to 3/8 tsp distilled water, and 1/3 tsp of this solution added to the reference beer. This is equivalent to adding 1/12 tsp times 5 ml/tsp, or approximately 0.4 ml of lactic acid.

Recommended amounts of several substances are listed in the table at the end of this section. For more information on doctored beer seminars, contact Jay Hersh at drbeer@doctorbeer.com or refer to the Focus on Flavors column in Brewing Techniques. The base beer should be a clean light lager with a crown (non-twist-off) cap so that it can resealed after doctoring. The amounts in the table below are appropriate in a 12 oz. sample, but may be scaled to larger volumes. Note that spices and other solids should be extracted in vodka, since the addition of dry substances to a carbonated beer will cause gushing. For the same reason, the beers and adulterants should also be chilled to the same temperature before combining.

The material in these classes can be comfortable covered in a time frame of three to five months, depending on the needs and experience of the study group. Shorter courses have the advantage of keeping the material fresh, while longer courses allow more intensive reading and reviewing in between classes. Note that the lead time required to schedule a BJCP exam is approximately three months, so keep this in mind when planning the study sessions. For more information, e-mail may be sent to the BJCP exam directors at exam_director_east@bjcp.org or exam_director_west@bjcp.org.

Guidelines for Doctoring Beers

Flavor	Adulterant	Quantity
Sour/Acidic	USP lactic acid	0.4 ml (1/3. tsp of solution of 1/8 tsp. lactic acid plus 3/8 tsp. distilled water)
Sour/Acidic	White wine vinegar	3/4 tsp.
Bitterness	iso-hop extract	1 or 2 drops, to taste
Sweetness	sucrose (table sugar)	1/4 tsp. dissolved in 1/2 tsp water
Astringency	Grape tannin	2 tsp. of solution of 1/8 tsp. tannin dissolved in 5 tbs. water
Phenolic	Chloroseptic	0.4 ml (1/3. tsp of solution of 1/8 tsp. Chloroseptic plus 3/8 tsp. distilled water)
Clovelike	Clove solution	Make solution of 8 cloves soaked in 3 oz. of beer and add liquid to taste (about 4 tsp)
Sulfitic	Potassium metabisulfite*	Make solution of one tablet dissolved in 3 oz. of beer and add to taste (about 1/2 tsp.)
Alcoholic	Ethanol	2 tsp. (increases alcohol by 2.7%). 3 tsp. vodka may also be used
Sherry-like	Dry sherry	3/4 tsp.
Nutty	Almond extract	0.1 ml (1/8 tsp of solution consisting of 1/8 tsp. almond extract plus 5/8 tsp. distilled water)
Papery/Stale	N/A	Open bottles to air, reseal, and keep at 100 F or warmer for several days
Winey	White wine	2 tbs.
Diacetyl	Butter extract	4-5 drops
Estery	Banana extract	6-7 drops
Lightstruck	N/A	Expose commercial beer in green bottles to sunlight for 1-3 days.

* Should not be tasted by persons with asthma or sulfite allergies.

III. BJCP STYLE GUIDELINES

A. Introduction

by David Houseman

When beers of similar character are grouped together, the resulting classifications are called "styles." In the BJCP Style Guide, these are called categories. Sub-classifications of similar beers with distinct differences are called sub-categories. Historically, types of beers were a consequence of the local water, ingredients and technology available at the time. In most cases, brewers did not set out to develop a specific "style," or type of beer. For example, the high sulfates in the hard water around Burton-on-Trent resulted in a drier flavor that accentuated the bitterness of well-hopped ales, while the soft water in Plzen enabled the brewers to produce a pale lager with a high hop bitterness and soft palate that would not be possible with hard water. Thus these classic styles were determined by the water of the region. Style guidelines also make distinctions between similar styles. There are a number of Pilsners brewed in Germany, and although there are variations, they can all be broadly classified in the German Pilsner style, but are sufficiently different from the Bohemian Pilsners to deserve a separate sub-classification in the beer taxonomy.

Beer styles are not static but change over time in history as ingredients, brewing technology and consumer demand change. For example, the IPA described in the style guidelines originated in the UK, but is now rarely brewed due to the high taxes imposed on beers of this strength. History and geography highly impact the development of brewing; it is important that BJCP judges have an understanding of these factors. The examinee should be able to discuss these factors on the exam and use this depth of knowledge when providing feedback to brewers.

The beers documented in the BJCP style guide are those that are most commonly brewed by home brewers in the US. It is not a complete list of all known beers, even those available throughout the world today. This style guide is continually kept up to date as newer information is made available. Its purpose is to provide a definition of the commonly brewed beers which should be used by both the brewer and the judge as criteria against which each style is evaluated. The BJCP style guidelines are not intended to be the complete source of information for the prospective BJCP judge, although the latest edition is quite complete and thorough. It's recommended that the potential judge read and study Michael Jackson's New World Guide to Beer and Beer Companion, the *Classic Beer Style Series* and other sources of information to obtain a complete understanding of the history, geography, and characteristics of the beers described in the BJCP Style Guidelines. The BJCP Style Guidelines, however, should serve as an accurate, quick reference to the different types of beers.

Most of the figures for starting gravity (SG), percent alcohol by volume (v/v), International Bittering Units (IBU) and color (degrees Lovibond or SRM) are taken from one of several sources assimilated by the BJCP Style Committee, including brewers of well-regarded commercial examples.

To receive full credit for beer style questions on the BJCP exam, examinee should provide at least approximate SG and IBU ranges for the style and, where relevant, other parameters such as alcohol content.

It is strongly suggested that the section of this study guide providing sample exam questions pertaining to beer styles be read carefully. These provide an indication of the range and type of questions to expect on the BJCP exam. You will note that not only will you potentially be asked to "describe" styles but also to "differentiate" among them. In this case, it is expected that you will be able to compare the similarities and differences of the indicated styles. In almost all cases, the examinee is expected to provide relatively well known commercial examples of different styles requested on the exam. While the examinee may not have traveled to the respective countries to try local commercial beers or these beers may not be available in your area, it still is expected that you will have knowledge of the commercial examples from the BJCP Style Guidelines, Michael Jackson's books and other references.

LAGERS are produced using bottom-fermenting lager yeasts, *Saccharomyces uvarum* (or *S. carlsbergensis*). This family of yeasts works well at lower temperatures, generally between 45 and 55 °F. This colder fermentation reduces or eliminates the production of esters and other flavor components, generally resulting in a cleaner tasting beer. During the fermentation and lagering process, at temperatures down to approximately 32 °F, the lager yeast remains active, continuing to reduce fermentation by-products, resulting in a cleaner, mellower flavor in the finished beer. Lagers are a relatively new beer style, only produced commercially after the introduction of mechanical refrigeration in the 1800s.

ALES are produced using top fermenting ale yeast, *Saccharomyces cerevisiae*. These strains of yeast works at warmer temperatures and ferment out faster than their lager counterparts. Fermentation byproducts such as fruity, estery flavors are usually evident and make up a significant part of the ale profile. Ale yeast are usually temperature-sensitive and will flocculate and become dormant when lagered at cool temperatures for extended periods of time.

MIXED STYLES use one or more variations of temperature and yeasts, such as fermentation with ale yeast at colder temperatures, use of ale and lager yeasts in combination, use of lager yeasts at warmer, ale-like temperature, or use of special yeast strains.

BELGIAN STYLES are generally ales, but with sufficient differences in process and taste profile to warrant their inclusion as a separate style section. Some Belgian styles, such as the Lambics, use a combination of wild yeasts and various bacteria in their fermentation process.

The **SPECIALTY**, **CIDER** and **MEAD** categories should be understood by the potential BJCP judge since s/he will not know in advance which categories s/he may have to judge in an actual competition and a judge should be prepared to judge any category. However they are not required knowledge for the BJCP Exam.

The BJCP Style Guidelines were extensively revised in 2004. The current style guidelines can be found on the BJCP Web Site in the Style Center: http://www.bjcp.org/stylecenter.html.

The BJCP Exam only covers beer styles. No meads or ciders are on the exam. No fruit, spice or specialty beers are covered on the exam. Separate mead and cider exams are planned for future implementation.

IV. INGREDIENTS AND THE BREWING PROCESS

A. Water

by Ginger Wotring

Water constitutes 85-90% of beer, with the remainder being compounds derived from malt, hops and yeast. As a general rule, if it is drinkable, it may be used in brewing, although some adjustments may be needed to mimic the water used in some historical beer styles. Most tap water is also treated with chlorine to inhibit bacterial growth, and this should be removed to produce high-quality beer. Chlorine gas may be eliminated by boiling, but charcoal filtration must be used to eliminate the more commonly used chloramines. Reverse osmosis is not recommended since it also strips out minerals needed by the yeast. Most water generally also has very low concentrations of nitrogen-containing ions, iron, manganese, copper and zinc; trace amounts of these last four minerals are essential to a healthy fermentation. Finally, most water contains very low concentrations of bacteria, so it must be sterilized by boiling at some point in the brewing process.

Alkalinity, pH and Hardness

Water is a solution of ions with negative (anions) and positive (cations) charges. The water molecules (H_2O) themselves are also partially dissociated into hydroxide (OH^-) and hydrogen (H^+) ions, and the *pH*, or percent Hydrogen, indicates the relative concentrations of these ions. Neutral water has OH^- and H^+ concentrations of 0.1 ppm, which corresponds to a pH of 7. Lower pH values indicate a higher H^+ concentration and a higher acidity, while higher pH values correspond to a higher OH^- concentration and a higher alkalinity. In brewing, the pH is determined by the hardness, alkalinity and buffering salts derived from the ingredients.

Alkalinity is a measure of the capacity of the dissolved anions to neutralize reductions in the pH value of the solution. The most important anion at the pH of brewing water and wort is bicarbonate $(HCO_2)^-$, which reacts with Calcium (Ca^{+2}) ions when heated to form a calcium carbonate precipitate and water:

$$Ca^{+2} + 2(HCO_2)^- = Ca_2CO_3\ (ppt) + H_2O + CO_2\ (gas)$$

This removes Calcium ions from the water, reducing the *temporary hardness*. *Permanent hardness* is a measure of the cations that remain after boiling and racking the water from the precipitate, and is primarily due to Ca^{+2} and Magnesium (Mg^{+2}) ions. These cations are permanent if they are derived from sulfate or chloride salts and temporary if they originate in carbonate or bicarbonate salts.

An important process in brewing that helps adjust the pH of the mash is the enzymatic degradation of phytin in the malt to form phytic acid and calcium or magnesium phosphates, which precipitate. Most of the phytic acid combines with free Ca^{+2} to form more calcium phosphate, releasing hydrogen ions in the process. This reaction generally takes place during the acid rest and regulates the mash pH to the 5.2-5.7 range, which is appropriate for the breakdown of starches and proteins. Some water supplies are too alkaline for this process to be effective, in which case the pH must be reduced to the proper level by adding lactic or sulfuric acid.

Ions in Brewing

The most important cation in brewing is Calcium, which is essential for reducing the mash pH to the appropriate range, keeps oxalate salts in solution (they form haze and gushing if they precipitate), reduces the extraction of tannins, and assists in protein coagulation in the hot and cold breaks. Magnesium ions participate in the same reactions, but are not as effective. Yeasts require 10-20 ppm as a nutrient, but higher amounts give a harsh, mineral-like taste. Another cation is Sodium, which accents the sweetness at low levels, but tastes salty at higher concentrations.

The most important anion in brewing is bicarbonate, which neutralizes acids from dark and roasted malts, reacts with Calcium to reduce the hardness and promotes the extraction of tannins and coloring compounds. It is normally in solution with the carbonate $(CO_3)^{-2}$ ion, but the bicarbonate is by far the most important component at typical pH values of water and wort. The sulfate $(SO_4)^{-2}$ ion does not play a significant role in the brewing process, but accents hop bitterness and dryness at the high concentrations found in the waters at Burton-on-Trent. Another anion is chloride (Cl^-), which enhances sweetness at low concentrations, but high levels can hamper yeast flocculation.

Famous Brewing Waters

The ions described above are found in different concentrations depending on the source of the water, as shown in the table below for several major brewing centers (data is in ppm and taken from Greg Noonan's water workshop at the 1991 AHA Conference):

Mineral	Calcium	Magnesium	Sodium	Sulfate	Bicarbonate	Chlorine
Plzen	7	2	2	5	15	5
Dortmund	225	40	60	120	180	60
Munich	75	18	2	10	150	2
Vienna	200	60	8	125	120	12
Burton	275	40	25	450	260	35
Dublin	120	5	12	55	125	20
Edinburgh	120	25	55	140	225	65
London	90	5	15	40	125	20

These water compositions have played an important role in the development of world beer styles. In London, Dublin and Munich, the high bicarbonate content is needed to balance the acidifying properties of the dark and roasted malts used in porters, stouts and bocks. When brewing pale beers with this type of water, the alkalinity generally needs to be reduced through an acid rest, the use of acid malt or directly adding lactic or sulfuric acid to the brewing liquor. The water at Burton is extremely hard, and the high concentrations of sulfate and magnesium ions lend a dryness that accents the hoppiness of English bitters and pale ales from this region. On the other end of the spectrum is Plzen, which has very low concentrations of dissolved ions (which is not the same as being very soft). The adoption of decoction mashing may have been in part due to the lack of minerals in the water, along with the use of undermodified malts. The elaborate series of temperature steps in a decoction mash helps the various enzymatic reactions proceed at a reasonable rate, even though the enzymes are working slowly due to the lack of calcium.

Water Adjustment

The waters at these brewing centers may be reproduced by adding various salts to locally available water. For additions meant to improve the buffering capacity of the mash, use the volume of your mash for your calculations. For salt additions to change flavor in the finished beer, the target volume of the finished beer should be used. The most common salt additions are gypsum ($CaSO_4 \cdot 2H_2O$ -- $CaSO_4$ hydrated with two water molecules), Epsom salts ($MgSO_4 \cdot 7H_2O$), non-iodized table salt (NaCl), calcium carbonate ($CaCO_3$) and calcium chloride ($CaCl_2 \cdot H_2O$). The addition of gypsum and Epsom salts is known as Burtonizing, since it elevates the hardness and sulfate concentrations to levels similar to that found at Burton-on-Trent. Other salts may be used, but these are by far the most common additives in brewing.

Further Reading

1. Dave Miller, Dave Miller's Homebrewing Guide (Garden Way Publishing, Pownal, VT 1996).
2. Gregory J. Noonan, New Brewing Lager Beer (Brewers Publications, Boulder, CO, 1996).
3. George Fix, Principles of Brewing Science (Brewers Publications, Boulder, CO, 1989).

B. Malts and Adjuncts

by Dave Sapsis

Barley Malt

Barley is the most common source of the fermentable sugars in beer. The barley kernel is the seed of a plant of the grass family, *Gramineae*. Barley malt is formed by sprouting barley kernels to a desired length, then stripping off the rootlets and kilning (drying) the kernels to a specific color. These kernels consist of a germ, which is the actual germinating portion, and the endosperm, which is the starch or reserve food source for the germinating embryo. Both are surrounded by the husk, which is almost all cellulose. The acrospire is the portion of the developing plant that will become the above-ground shoot. Growing from the germ, the length of the acrospire has historically been used as an index of malt progress. As germination proceeds, enzymes acting on both proteins and carbohydrates are activated and transformed. The degree of germination is called modification; modification usually refers to the degree to which the protein/gum matrix of the endosperm has been broken down, and the degree to which proteins have become soluble in water.

A variety of measures can be used to indicate the degree of modification of malt. It is important to recognize that while the malting process is designed to initiate enzyme development that will be used to catalyze mashing reactions, the effects of varying malting regimes is dependent on barley strain. While undermodified malts usually have a more complete set of enzymes, they also have more proteins that require additional enzymatic breakdown to avoid protein-polyphenol induced haze (i.e., chill haze). The goal of the maltster is to accomplish the appropriate degree of protein degradation and starch availability, while not allowing too much carbohydrate substrate to be used up in plant development. Thought of another way, the maltster tries to manage desirable malt characteristics while still maximizing the potential yield from the barley.

It has become increasingly difficult to find truly undermodified malt that requires extensive protein rests as part of the mashing schedule. Measured both as a function of soluble Nitrogen (Kolbach Index) and as coarse:fine difference in extract, most modern malts have undergone a high level of protein degradation and most of the formerly bound starch is free in the friable endosperm. While there is no *de facto* assurance that malt will be suitable for brewing to a particular style, it is beneficial to understand modern barley growing and malting practices.

Selection

Two types of barley are commonly used in brewing. They are distinguished by the number of fertile flowers on the heads along the central stem. Two-row barley (*Hordeum vulgare*) has only two of the six flowers on the head fertile and able to produce kernels. Six row barley has all kernels fertile. An intermediate variety, called four-row, is in fact a six-row variety. It is not widely used in brewing due to the high protein content of the kernels.

Two-row barley will have bigger kernels, and thus higher yield than six-row. It usually has a lower nitrogen and protein content and also has a lower husk content, which makes 2-row beers taste less grainy. Six row barley, however, generally gives more yield per acre and has a higher diastatic power (more enzymes), so it is the choice whenever large amounts of adjuncts are used. The extra husk content of six-row also aids in providing a lautering filterbed.

Malting

The process of malting is done to convert the large, insoluble starch chains of the endosperm to water-soluble starches, and to activate both the proteolytic and diastatic enzymes that will reduce the proteins and starches into desirable components in the mash. The most important enzymes for malting are debranching enzymes, which break 1-6 links in α-glucans, and β-amylase, which produces maltose units by breaking 1-4 links near reducing ends. During the germination phase, the cell walls are broken down by the cytase enzyme complex, which includes hemicellulases and the β-glucanases. This clears a path for other enzymes into the endosperm so that degradation can proceed more easily.

Malting is basically sprouting the grains to a desired modification. The acrospire grows from the germ end of the corn to the opposite end. The ratio of the acrospire length to the length is the degree of modification, expressed as a percent or ratio. A ratio of 1.0 is indicative of fully-modified malt. Such a malt will be low in protein content and will have the endosperm almost fully converted to water-soluble gum. However, the starch content and potential yield will be reduced through its consumption during the growth of the acrospire and the rootlets.

American and Continental malts are generally less modified. Continental malt is modified only to 50-75%, which retains more of the endosperm for fermentability and creates greater nitrogen complexity, but at the price of reduced enzyme activity. American six-row is also modified to between 50-75%, but the higher protein and nitrogen content of six-row gives greater enzyme strength. Both Continental and American malts require a protein rest (at ~122 °F) to degrade the albuminous proteins into fractions that can be both used to promote yeast growth and give good head retention.

The barley is steeped in 50-65 °F water for about two or three days, then allowed to germinate for six to ten days between 50 and 70 °F. The acrospire will usually grow to 50% at about the sixth day of germination. At the end of germination, the malt is gradually raised in temperature to 90 °F, held there for 24 hours to permit enzyme action, and then gradually raised to 120 °F. It is held at this temperature for 12 hours to dry the malt, as it is essential that the malt be bone-dry before being heated to kilning temperatures to prevent the destruction of the enzymes.

Kilning

Kilning, or roasting the malt, combined with the degree of modification, determines the type and character of the grain. Vienna malts are low-kilned at around 145 °F, British and American pale malts at between 130 and 180 °F and Czech malts are raised slowly from 120 to 170 °F to dry, and then roasted at 178 °F. Dortmund and Munich malts are first kilned at low temperatures before the malt has dried, then the temperature is slowly raised to 195-205 °F for Dortmunder malt, and 210 to 244 °F for Munich malt. This process creates flavor and body-building melanoidins from amino acids and malt sugars. Amber malt is well-modified, and then dried and rapidly heated to 200 °F. The temperature is then raised to 280-300 °F and held there until the desired color is reached.

Crystal and caramel malts are fully modified, then kilned at 50% moisture content. The temperature is raised to 150-170 °F and held for 1 1/2 to 2 hours. This essentially mashes the starches into sugars inside the grain husk. The malt is then heated to the final roasting temperature, with the time and temperature determining the Lovibond color index.

Chocolate and Black Patent malts are undermodified (less than 1/2), dried to 5% moisture, then roasted at 420-450 °F for up to two hours, depending on the degree of roastiness desired. The high heat helps degrade the starches, so no protein rest is require for these malts even though they are not fully modified. Malts kilned over smoky beechwood fires, as in Bamberg, pick up a rich, heavy smokiness (which is imparted to the beer) from the phenols in the smoke. Whiskey malt is made in a similar manner by smoking over peat fires.

Kilning at the maximum temperature is generally done only until the grains are evenly roasted. They are then cooled to below 100 °F and the rootlets removed. Malts should be allowed to rest for a month or so before being mashed.

Other Malted Grains

The most widely used malted grain besides barley is wheat, which is a key ingredient in German and American wheat beers and used in small quantities in others to improve head retention. It has sufficient diastatic power to breakdown its own proteins and starches, but since it does not have a husk, it is usually mashed with barley malt in order for an adequate filter bed to be formed during the lautering stage. The protein and β-glucan content of wheat is high compared to barley, so a more extensive mash schedule with an extended protein rest may be needed when large quantities are used. Other malted grains used in brewing include rye, oats and sorghum, but these are more commonly used in their raw forms.

Malt Content

The barley corn contains sugars, starches, enzymes, proteins, tannins, cellulose, and nitrogenous compounds for the most part. The starches will be converted into simple and complex sugars by diastatic enzymes during the mash. Proteins in the kernel serve as food for the germ. These are primarily reduced by proteolytic enzymes into polypeptides, peptides and amino acids. Since enzymes are proteins, the protein content of the malt is an indication of its enzymatic strength. Peptides of the B-complex vitamins are also present and necessary for yeast development. The phosphates in the malt are responsible for the acidification of the mash and are used by the yeast along with other trace elements during the fermentation.

Cellulose, polyphenols and tannins are present in the husk and can lead to harsh flavors in the finished beer if they are leached out by hot or alkaline sparge water. Fatty acids and lipids support respiration of the embryo during malting, but oxidative off flavors and low head retention may result if excessive levels are carried into the wort. Hemicellulose and soluble gums are predominantly polysaccharide in nature and for about 10% of the corn weight. The gums are soluble, but the hemicellulose must be reduced by the appropriate enzymes into fractions that permit good head retention, otherwise they may cause clarity problems in the finished beer.

Cereal Adjuncts

Unmalted cereal grains have been introduced into brewing because they offer a cheap source of carbohydrates and tend to make a minimal contribution to the wort protein level. They can therefore be used in conjunction with high-protein malts such as American 6-row to give a more fermentable wort and a less filling beer. The starches must be gelatinized before mashing, either by doing a preliminary boil in the double-mash procedure or by flaking them through hot rollers. The most common cereal grains are corn (flaked maize, refined corn grits, corn starch or corn grits), rice grits, sorghum (in Africa), flaked barley, flaked rye and wheat (hard red winter wheat or flaked wheat). The corn and rice adjuncts are used heavily in the American light lager styles, while raw wheat is a key ingredient in Belgian white and lambic beers.

Other Adjuncts

An adjunct is defined as any unmalted source of fermentables in brewing. These include corn and cane sugars, which provide a cheap source of sugar, but are fully fermentable and tend to yield more alcohol and dry out the beer. Honey is a common adjunct in specialty beers, and although it contributes some aromatics, the high sugar content tends to make a beer thinner and more alcoholic than its all-malt counterpart. To achieve a fuller palate, malto-dextrin syrup or powder may be used, but the dextrin content may also be increased by adjusting the malt bill or mashing procedure. Finally, adjuncts that add color, flavor and fermentables include caramel, molasses, maple syrup and licorice.

Color

Beer color is determined by the types of malts used, and is an important characteristic of any style. Two scales are used for color determination - the EBC scale used in Europe, and the SRM scale in the USA. Both scales go from low to high, with low numbers referring to lighter colors. For example, an American light lager would be around 2-3 SRM, a Pilsner between 2-5, an Oktoberfest in the 7-14 range, and a traditional bock in the 14-22 range. Some stouts can be over 60 degrees in color and are essentially opaque. The beer color is primarily determined by the malt, but factors such as the intensity and length of the boil also play a role. For a detailed discussion of beer color, the reader is referred to Ray Daniels' three-part series on beer color that begins in the July/August 1995 issue of Brewing Techniques.

Further Reading

1. Dave Miller, Dave Miller's Homebrewing Guide, (Garden Way Publishing, Pownal, VT 1996).
2. Gregory J. Noonan, New Brewing Lager Beer, (Brewers Publications, Boulder, CO, 1996).
3. George Fix, Principles of Brewing Science, pp. 22-47, 87-107 (Brewers Publications, Boulder, CO, 1989).
4. George and Laurie Fix, An Analysis of Brewing Techniques, pp. 10-14 (Brewers Publications, Boulder, CO, 1997).

C. Wort Production

by David Houseman and Scott Bickham

Mashing

The primary goal of mashing is to complete the breakdown of proteins and starches that was begun during the malting process. This is accomplished by several groups of enzymes that degrade different substrates during a series of rests at specific temperatures.

Acid Rest

With pale lager malts, this enzymatic degradation begins with the acid rest, where phytase breaks down phytin into calcium- and magnesium-phosphate and phytic acid. This helps acidify the mash when the brewing water has low calcium content and roasted grains are not part of the grist. This rest occurs at temperatures in the 95-120 °F range. Another group of active enzymes in this range are the β-glucanases, which break down hemicellulose and gums in the cell walls of undermodified malts. Some adjuncts, particularly rye, have high levels of these substances, and stuck mashes or other problems can result if they are not degraded to simpler substances by the β-glucanases.

Protein Rest

For most malts, the mash begins with the protein rest, which is normally carried out at temperatures in the 113-127 °F range. This process begins with the proteinases, which break down high molecular weight proteins into smaller fractions such as polypeptides. These polypeptides are further degraded by peptidase enzymes into peptides and amino acids, which are essential for proper yeast growth and development. Proteins of molecular weight 17,000 to 150,000 must be reduced to polypeptides of molecular weight 500-12,000 for good head formation, and some of these further reduced to the 400-1500 level for proper yeast nutrition.

Starch Conversion

The final enzymatic process involves the conversion of starches into dextrins and fermentable sugars. The starches must be gelatinized for this to take place, and this occurs at temperatures of 130-150 °F for barley malt. The gelatinization temperature is higher for raw grains, such as corn grits, so these adjuncts must be boiled or hot-flaked before adding to the mash. The breakdown of starches is carried out by the combined action of debranching, α-amylase and β-amylase enzymes during the saccharification rest. Debranching enzymes break the 1-6 links in starches, reducing the average length and complexity of the molecules. The diastatic, or amylase, enzymes work in tandem, with the β-fraction breaking off maltose units from reducing ends and the α-fraction breaking 1-4 links at random. Temperatures below 150 °F favor β-amylase, producing a more fermentable wort, while temperatures above 155 °F favor α-amylase, producing a more dextrinous wort.

The simplest sugars produced in the above manner are monosaccharides, with only one basic sugar structure in the molecule. Monosaccharides in wort include glucose, fructose, mannose and galactose. Disaccharides are made up of two monosaccharides coupled together, and include maltose, isomaltose, fructose, melibiose, and lactose. Trisaccharides (three monosaccharides) include maltotriose, which is slowly fermentable and sustains the yeast during lagering. Oligosaccharides constructed of glucose chains (many monosaccharides joined together), are water soluble and called dextrins. The relative concentrations of these sugars are determined by the types of malt and whether the mash schedule favors α-amylase or β-amylase activity.

Mash-out

After this phase is completed, many brewers mash-out by raising the temperature of the mash to 168 °F and holding it there for several minutes. This ensures the deactivation of the amylase enzymes, halting the conversion of dextrins to fermentable sugars. It also reduces the viscosity of the wort, helping to make the lautering easier and more efficient. There is some controversy whether this step is necessary depending on the final mash temperature. However it is generally agreed that the best extraction rates are achieved when the mash is heated to this range.

Mashing Procedures

The mashing process begins by doughing-in the crushed grains with approximately 1-2 liters of water per pound of grain. The starch granules take up water with the aid of liquefaction enzymes, and the rests described above are carried out according to the degree of modification of the malt. The simplest mashing method is the single-step infusion, where the malt is combined with hot water to reach a temperature appropriate for starch conversion. This is the method of choice for fully-modified malts such as those used to brew British ales. It has the advantage of requiring a minimum of labor, equipment, energy and time, but prohibits the use of undermodified malt or adjuncts. A step-infusion mash allows a little more flexibility by moving the mash through a series of temperature rests. The temperature is increased by external heat or the addition of boiling water. This requires more resources than a simple infusion mash, but undermodified malts may be used.

Decoction mashing involves the removal of a thick fraction of the mash (usually one-third) and running it through a brief saccharification rest at a relatively high temperature. It is then boiled it for 15-30 minutes before mixing it back into the main mash. This is repeated as many as three times, depending on the modification of the malt and the beer style. The decoction helps explode starch granules and break down the protein matrix in undermodified malt, improving the extraction efficiency, and also promotes the formation of melanoidins. These compounds are formed from amino acids and reducing sugars in the presence of heat and are responsible for the rich flavors in malty lagers. This mashing method is the most resource intensive, but is the traditional method for many lagers. A possible side-effect of the extended mash schedule is the extraction of higher levels of tannins and DMS precursors from the grain husks, though this is not significant at typical mash pH levels.

A fourth mashing method is the double mash, which can be viewed as a combination of infusion and decoction. As the name implies, it involves two separate mashes: a main mash consisting of crushed malt, and a cereal mash consisting of raw adjuncts and a small charge of crushed malt. The latter is boiled for at least an hour to gelatinize the starches and is then added to the main mash, which has undergone an acid rest. The mixture is then cycled through protein and saccharification rests using the step-infusion method. The double mash is the most common way of producing beer styles such as American light lagers that contain a high proportion of corn grits or rice.

Lautering

Lautering is the process of separating the sweet wort from the grain fractions of the mash. It is usually done in a vessel—appropriately called a lauter tun—that holds the grain and wort with some form of strainer in the bottom to separate the liquid wort from the grain. In most homebrewing setups, the mash tun, where the mash process occurs, and the lauter tun are the same unit. Where the brewer chooses to utilize two vessels and convey the mash contents from the mash tun to a special purpose lauter tun care must be taken to not introduce oxygen into the hot wort. This hot side aeration can introduce oxidative off flavors the finished beer that are often perceived as sherry-like, wet paper or cardboard-like.

Lautering consists of draining the wort off the grain and sparging, or the addition of hot liquor (treated brewing water) to the top of the grain bed to rinse the sugars from the grain. This procedure should be done slowly, with the wort returned to the tun until the run-off is clear. This initial runoff and return of wort to the lauter tun is called a vorlauf and is critical to preventing astringency and haze in the finished beer. Lautering too fast will give poor yield, poor extraction rates, and possibly flush starch and protein fractions into the wort. Failing to re-circulate the initial runoff through the lauter tun until it is reasonably clear will have a similar effect.

A temperature range of 160-170 °F should be maintained throughout the entire process; this ensures that the greatest extraction of sugars from the grain without excess tannin extraction from the husks. Temperatures above 170 °F will leach tannins and permit undissolved starch balls to explode and get past the filterbed, and gums and proteins may also be released into the wort. This starch will pass on to the finished beer without being fermented until broken down over a period of time by wild yeast or bacteria present.

Another potential problem is a stuck sparge, which may be caused by an inadequate amount of filtering material in the grain bed—usually barley husks—that allow wort to pass freely while holding back the bits of material to be filtered. When mashing with high quantities of wheat or rye malt that will not have their own husks to aid as a filter, it’s usually necessary to add additional filter material such as rice hulls, which themselves are neutral to the flavor or gravity of the resulting beer. Wheat, rye, oats and some other cereal grains also contribute a much higher proportion of gums that can help cause a stuck mash. These often require a β-glucanase rest in order to break down these gums and aid the resulting sparge.

Sparging is the addition of rinse water, or hot liquor, to the lauter tun. In general the water chemistry of the sparge water should match that used in mashing. The pH should be approximately 5.7 in order to prevent the mash pH from exceeding 6.0, which promotes the extraction of excess tannins.

The sparge rate should be slow, with the water (at 170 °F) added gently so that the filter bed is not disturbed. A hydrometer reading of the first runs from the tun should be about twice the value desired in the finished beer. If not, it should be returned to the tun. Sparging should cease when the gravity drops to below about 1.010 or the pH of the runoff increases above 6.0. Monitoring of the runoff is essential in order to stop the collection of wort before excess tannins are extracted. Learning to taste the sweet wort to recognize when to stop the collection will provide the brewer with an intimacy of the process that doesn't require the use of the hydrometer or pH meters and papers.

Boiling

Boiling wort is normally required for the following reasons:

1) Extracts, isomerizes and dissolves the hop α-acids
2) Stops enzymatic activity
3) Kills bacteria, fungi, and wild yeast
4) Coagulates undesired proteins and polyphenols in the hot break
5) Evaporates undesirable harsh hop oils, sulfur compounds, ketones, and esters.
6) Promotes the formation of melanoidins and caramelizes some of the wort sugars (although this is not desirable in all styles)
7) Evaporates water vapor, condensing the wort to the proper volume and gravity (this is not a primary reason, it's a side effect of the process)

A minimum of a one hour boil is usually recommended for making quality beer. When making all grain beer, a boil of 90 minutes is normal, with the bittering hops added for the last hour. One exception to boiling was historically used to brew the Berliner Weisse style. Here, the hops were added to the mash tun, and the wort is cooled after sparging and then fermented with a combination of lactobacillus from the malt and an ale yeast.

Boiling for less than one hour risks under-utilization of hop acids, so the bitterness level may be lower than expected. In addition, the head may not be as well formed due to improper extraction of isohumulones from the hops. A good rolling boil for one hour is necessary to bind hop compounds to polypeptides, forming colloids that remain in the beer and help form a good stable head. An open, rolling boil aids in the removal of undesired volatile compounds, such as some harsh hop compounds, esters, and sulfur compounds. It is important to boil wort uncovered so that these substances do not condense back into the wort.

Clarity will be also be affected by not using at least a full hour rolling boil, as there will not be a adequate hot break to remove the undesired proteins. This will also affect shelf life of the bottled beer, since the proteins will over time promote bacterial growth even in properly sanitized beer bottles. The preservative qualities of hops will also suffer greatly if the wort is not boiled for one hour, as the extraction of the needed compounds will be impaired.

Boiling wort will also lower the pH of the wort slightly. Having the proper pH to begin the boil is not normally a problem, but if it is below 5.2, protein precipitation will be retarded and carbonate salt should be used to increase the alkalinity. The pH will drop during the boil and at the conclusion should be 5.2-5.5 in order for proper cold break to form and fermentation to proceed normally. Incorrect wort pH during the boil may result in clarity or fermentation problems.

The effects of boiling on the wort should match the intended style. It is often desirable to form melanoidins which are compounds produced by heat acting on amino acids and sugars. These add a darker color and a maltier flavor to beer. When desired, an insufficient boil will not form enough melanoidins for the style. Boiling the initial runnings of high gravity wort will quickly caramelize the sugars in the wort. This is desired in Scottish ales, but would be inappropriate in light lagers.

Vigorously boiling wort uncovered will evaporate water from the wort at a rate of about one gallon per hour, depending the brewing setup. In order to create a beer with the appropriate target original gravity, changes in the wort volume must be taken into account. Longer boil times or additions of sterilized water may be required to hit the target gravity.

Chilling

After boiling for a sufficient amount of time, the wort should be chilled at rapidly as possible, using either an immersion or counter-flow system. This minimizes the risk of contamination by *Lactobacillus* or wort-spoilage bacteria and produces an adequate cold break. This cold break consists of protein-protein and protein-polyphenol complexes and is often promoted by the addition of Irish moss to the kettle near the end of the boil. There is some debate on whether the cold break should be completely removed. On one hand, it can provide carbon skeletons that can be used by the yeast for sterol synthesis, but on the other, excessive levels may lead to elevated levels of esters and fusel alcohols and promote the formation of chill or permanent haze in the finished beer.

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D. Hops

by Peter Garofalo

Introduction

Hops are the spicy and bitter counterpart to the malt backbone of beer; they are essential to beer as we know it. Prior to the widespread acceptance of hops, various bitter herbs, seasonings, and spices were used to balance the malt sweetness. Hops also contribute many secondary attributes to beer: they provide a measure of bacteriological stability, aid in kettle coagulation, and contribute to a stable head.

Brewers' hops are the cone-like flower of the *Humulus lupulus* vine, a relative to the cannabis plant. The essential ingredients are concentrated in the lupulin glands, located at the base of the bracteoles, or leaves of the cone. The bracteoles are attached to the central stem of the hop cone (strig). The lupulin resin contains alpha acids and essential oils that contribute the characteristic bitterness, flavor, and aroma that are associated with hops in beer. The amount of alpha acid is usually expressed as a weight percent, and is determined by extractive and chromatographic methods.

History

Many varieties of hops are known, though they are generally divided into two subsets: aroma and bittering hops, although some are considered to be "dual-purpose." The finest of the aroma hops are referred to as "noble," due to their prized aromatic and subtle bittering properties; the noble varieties include Saaz, Spalt, Tettnanger, and Hallertauer Mittelfrüh, although some sources list other varieties. Aroma hops are generally lower in alpha acid content, but contribute desirable flavor and aroma characteristics. Bittering varieties are higher in alpha acid content, but their flavor and aroma characteristics are generally considered to be less refined. There are no hard and fast rules about aroma, bittering, and dual-purpose hops; the categorization is subjective. Generally, aroma hops consist of such varieties as Saaz, Tettnanger, Hallertauer, Spalt, East Kent and Styrian Goldings, Fuggles, Cascade, Willamette, Liberty, Crystal, Ultra, and Mount Hood. Bittering varieties include Brewer's Gold, Nugget, Chinook, Eroica, Galena, and Bullion. Dual-purpose varieties include Northern Brewer, Columbus, Cluster, Perle, and Centennial, among others.

Hops were introduced in beer making prior to 1000 A.D., and came into widespread use in the 16th century when they were legislated as a required ingredient in the famous Reinheitsgebot, or German Beer Purity Law of 1516. Hops are still grown in many of the traditional regions, such as the Zatec region of the Czech republic, home of Zatec Red, or Saaz variety. Hop varieties have been enriched through intensive cross-breeding, which has given us many of the newer, disease-resistant varieties.

Bitterness arises from the alpha acids, which consist of humulone, cohumulone, and adhumulone; the proportions of each will vary according to hop variety. They are isomerized into iso-alpha acids in a vigorous boil, rendering them much more soluble in the wort, in addition to increasing their bitterness. The essential oils, which contribute to flavor and aroma of the finished beer, consist of dozens of compounds. Many of these are volatile, and hence do not survive extended boil times. For this reason, flavor and aroma hops are generally added during the last 30 minutes of the boil.

Brewing hops are available in many forms: whole hops, plugs, pellets, and extracts. Whole hops are simply dried hop cones, and are the most traditional form of hops. Plugs (also known as type-100 pellets), are whole hops compressed into 1/2-ounce disks. Pellets are ground into powder, and then extruded through a die. Hop extracts include isomerized extracts, which may be used to add bitterness; hop aroma essences are also available.

Bitterness from hops

The bitterness imparted by hops is quantified in various ways, with varying degrees of precision. The simplest method is the Alpha Acid Unit (AAU), also known as the Homebrew Bittering Unit (HBU). This basic measure is simply the weight of hops in ounces times the alpha-acid content, expressed as a percent. In order to be meaningful, the brew length must be specified when using AAUs or HBUs. The main downfall of the AAU/HBU quantification method is that it describes the potential bitterness without accounting for many critical factors which determine the actual bitterness.

The more precise method of quantifying hop bitterness is the International Bittering Unit, or IBU. The IBU is a measure of the concentration of isomerized alpha acids present in the finished beer, and is expressed in milligrams per liter, or parts per million (ppm). The relationship between the quantity of hops used and the IBU level depends on many factors: length of the boil, wort gravity, vigor of the boil, wort pH, age/condition of hops, hop form (whole, plugs, or pellets), hopping rate, plus several other less important elements. The relative IBU level does not always translate directly to the perceived bitterness of the finished beer. The ionic makeup of the brewing water, particularly carbonate and sulfate levels, directly affect the perception of bitterness. The degree of attenuation also plays a role in the amount of bitterness that is needed to reach a balance for a given style.

The IBU content of a beer may be expressed as: $IBU = 7489 \times (W \times A \times U)/V$, where 7489 is a conversion from milligrams/liter to ounces/gallon, W is the weight of hops in ounces, A is the alpha acid content as a decimal, U is a percent utilization factor, and V is the final volume of beer, in gallons. The most important variable in the equation is the utilization factor, which depends on the aforementioned parameters. Utilization normally tops out at about 30 % in the home brewery; often, it is significantly lower. Some additional factors which affect the value of U are boiling temperature, whether or not hop bags are used, and filtration losses. U is the product of all correction factors and may be estimated by any of several methods for each set of conditions. In any case, a different utilization is typically assumed for each hop addition (when multiple additions are used); in this manner, the IBU contribution for each hop addition may be estimated, and then totaled. It should be noted that the only way to determine the IBU level in the finished beer is through a direct measurement in the laboratory.

The relationship between the various correction factors and hop utilization is often not simple, but certain tendencies are well known. Utilization is reduced by: reducing the contact time of hops with boiling wort; reducing the boiling temperature of the wort; increasing the wort gravity; using whole hops instead of pellets; increasing the hopping rate; using hop bags to contain the hops during the boil; using older hops; decreasing wort pH; using more flocculent yeast; and filtering the beer. Some bitterness is also lost to oxidation or staling of the finished beer.

The desired level of bitterness, as measured by IBUs, varies widely for different styles. For example, an Oktoberfest would be expected to have about 20 to 28 IBU, while a Bohemian Pilsener might have 35 to 45 IBU. Each style has different bitterness, flavor, and aroma expectations; only the α-acid level may be accurately quantified. Another way to characterize the bitterness of a given style is the BU:GU ratio introduced by Ray Daniels. This is simply the IBU content divided by the last two digits of the original specific gravity.

Hops are often added at different points in the brewing process, with the goal of contributing bitterness, flavor, or aroma to the finished beer. Bittering hops are usually most efficient at yielding their iso-alpha acids with 60 to 90 minutes of vigorous wort boiling. Hops boiled for 10 to 40 minutes are often referred to as "flavor hops," since they contribute less bitterness, but retain some essential oils which contribute characteristic flavors. Hops added at or near the end of the boil contribute little or no bitterness, some flavor, and aromatic quality to the finished beer. Hops added during or after fermentation ("dry" hops) contribute a fresh hop aroma.

Hop-derived compounds can also be altered in the finished beer. Oxidation (staling) reduces bitterness, and may also add a harsh edge to flavor, as well as diminishing aroma. One of the most well known hop-derived off flavors is that of skunkiness. This phenomenon is usually ascribed to light exposure, and is often described as "lightstruck;" however, it has been demonstrated that the free-radical reaction may be initiated by heating/cooling cycles, as well. The offending compound, prenyl mercaptan, results from the combination of a 3-methyl-2-butene radical (derived from an iso-α-acid) with a thiol radical (present in malt constituents).

First wort hopping

The newly re-discovered technique of first wort hopping is also gaining favor among homebrewers. It essentially consists of adding a portion of the hop charge (some insist that most or even all of the hops should be added at this point) to the first sweet wort runnings from lautering, during which time the higher pH is thought to extract some of the finer qualities of the hop flavor. The hops are kept with the wort throughout the boil, and contribute a more refined bitterness, though the exact amount is a matter of debate. What is beyond debate is the fresh hop flavor imparted by first wort hopping; some have speculated on possible formation of stable complexes, or perhaps esters, at the temperature range encountered in the mash runoff. Another possibility is the removal of undesirable, somewhat volatile constituents during the extended heating and boiling time; this coincides with the observation that even with increased IBU levels provided by first wort hopping, the resulting bitterness is usually described as smoother and more pleasant. Surprisingly, the technique also contributes aroma; in fact, first wort hopping has been suggested as a replacement for late hop additions. Less clear is how the aroma boost compares to dry-hopped aroma. The technique is an old German method that was originally used for hop-centered styles, such as Pilsener; recently, it has gained favor for a wide range of homebrewed styles. It was originally intended as a means for extracting more bitterness, and it has been found (analytically) to provide a favorable bittering and flavor compound profile.

Varieties

Hop varieties are often associated with particular beer styles; in fact, some styles are virtually defined by their hop character. British ales are normally associated with native hop varieties (East Kent Goldings, Northern Brewer, and Fuggles, for example), and most are expected to embody the characteristic flavor and aroma attributes associated with these hop varieties.

Continental styles, particularly the more hop-oriented ones, are also often associated with more local Continental hop varieties. Bohemian Pilseners, for example, are partially defined by the characteristic spicy Saaz aroma and flavor. On the other hand, German Pilseners are more usually associated with German hop varieties, such as Tettnanger, Hallertauer Mittelfrüh, and Spalt. Altbiers, although often subdued in hop aroma and flavor, are also normally associated with the bitterness attributes that arise from the use of low-alpha ("aroma") hops. Even the less hop-accented styles, such as bock or

Oktoberfest, benefit from the additional flavor complexity that the judicious use of Continental low-alpha hop varieties provides.

American styles, especially such hoppy examples as American pale ale and American brown ale, benefit greatly from the floral, citrusy character of the dominant American varieties such as Cascades, Centennial, Columbus or Chinook. In fact, it is often the hop character that sets these styles apart from their European prototypes.

It is important to note that the region of cultivation is as important as the hop variety in determining the character of the crop. Classic European hop varieties grown in a different climate in the United States exhibit different characteristics than the same varieties grown in European soil. Therefore, the place of origin is every bit as important as the genealogy when selecting the appropriate hop variety for a particular application.

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E. Yeast and Fermentation

by Chuck Hanning

Introduction

Most beer styles are made using one of two unicellular species of microorganisms of the *Saccharomyces* genus, more commonly called yeast. Generally, either an ale yeast (known as *S. cerevisiae*) or a lager yeast (known as *S. carlsbergensis* or by older terminology *S. uvarum*) is used for the appropriate style. Functionally these yeasts differ in their optimum fermentation temperatures, ability to ferment different sugars, environmental conditions, and ability to settle out upon completion of fermentation, and production and/or metabolism of fermentation by-products. The choice of the strain of ale or lager yeast and how these factors are controlled during the various stages of fermentation will determine how well a beer is made to style. While a list of all the possible strains is beyond the scope of this guide, readers are encouraged to review reference (1) for a more thorough review.

One of the common terms used to describe yeast is apparent attenuation. The attenuation of a particular yeast describes its ability to decrease the original gravity of wort upon fermentation. It is commonly listed as a percent, in which the numerator is the difference between final and original gravity and denominator is the original gravity. Because the density of ethanol is less than water, when a hydrometer is used to measure this attenuation, it will be measuring the apparent attenuation not the real attenuation (if the alcohol was replaced by water). Another common term used to describe different yeasts is flocculation, which is the ability of the yeast to settle out of the beer upon completion of fermentation; it can vary significantly with strain.

The environmental conditions that differ with each yeast type and strain are alcohol tolerance, oxygen requirements, and sensitivity to wort composition. Alcohol tolerance describes how well a yeast will continue to ferment as the alcohol concentration increases during fermentation. Most lager yeasts can ferment up to about 8% alcohol by volume, and some ale strains can ferment up to 12% (2,3). Oxygen requirements can differ with each strain as well; some need much more oxygen to be able to ferment without problems. Lastly, different worts will have different relative amounts of sugars present. The various strains can respond differently to the same wort upon fermentation.

The by-products that are produced (and also metabolized) by the yeast are esters, fusel alcohols, diacetyl, and sulfur compounds. Esters are produced by yeast combining an organic alcohol and acid. While approximately 90 different esters have been identified in beer, ethyl-acetate, isoamyl-acetate and ethylhexanoate are most commonly above their flavor thresholds. These impart a fruity, sweet aroma to the beer. Another by-product of fermentation is fusel alcohols, which contain more carbon atoms than the most common alcohol, ethanol. These are produced by the metabolism of amino acids (4), and tend to add harsher, more solvent-like tones the beer. Yet another by-product is diacetyl, which is generally reduced to more benign compounds during the secondary fermentation, but premature removal of the yeast can lead to elevated levels. Its presence imparts a buttery note to the beer. It is produced by an oxidation reaction which can be repressed by the production of the amino acid valine (5). Lastly, there are several sulfur compounds that can be produced by the yeast. One of these is hydrogen sulfide, which smells like rotten eggs. Other sulfur compounds exist, but their production is not yet completely understood (1).

Ale Yeast, for the purposes of beer fermentation, tend to work best in the 55-75 °F temperature range. Apparent attenuation can range from 69 to 80%. These yeasts can fully ferment the common sugars glucose, fructose, maltose, sucrose, maltotriose and the trace sugars xylulose, mannose, and galactose. They can partially ferment raffinose. These yeasts have traditionally been called top fermenting because they form colonies (groups of yeast that cling together) that are supported by the surface tension of the beer. Ale yeasts produce esters since they require higher temperatures to remain active. Styles that use these yeasts have varying degrees of fruity and sweet smelling aromas. It should be noted that the yeast used to produce the German weizen style are special strains that generate high concentrations of the clove-like phenols and "bubblegum" and "banana" esters, which are the signature of this style.

Lager Yeast generally tend to work best between 46-56 °F, but California Common Lager yeast is an exception having a range of 58-68 °F. Apparent attenuation usually ranges from 67-77%. Lager yeasts can ferment raffinose in addition to the sugars that are fermentable by ale yeasts. These yeasts have traditionally been called bottom fermenters, since they do not cling together to form colonies on the surface, but instead fall to the bottom of the fermenter. Lager yeasts can be further subdivided into the Frohberg type (also called dusty or "powdery") which ferment quickly, and do not flocculate as well. Due to the longer time it remains suspended in the wort, this subtype will have a greater attenuation. The other subtype of lager yeast is the Saaz type (also called the S.U. or "break"). These strains tend to flocculate more readily, and hence tend to have a lower attenuation (6). Lager yeasts, in comparison to ale yeasts, produce beers that lack the esters and fusel alcohols, since they are active at cooler temperatures. Lager beer styles should have a cleaner aroma to them, reflecting only the malt and /or hop aromas used to make the wort.

Bacteria, specifically *Lactobacillus delbrückii*, are used in the production of the Berliner Weiss style of wheat beer with an intense lactic sourness. Other microorganisms are also used in the production of some Belgian ales, specifically lambics. Lambics have varying degrees of sourness which is appropriate for their style. Yeasts of the *Brettanomyces* genus and various bacteria generate these flavors. Bacteria are commonly divided into two broad classes based on a laboratory Gram stain. The Gram-negative bacteria involved in lambic production are *Escherichia coli* and also various species of *Citrobacter* and *Enterobacter*, but fortunately they cannot tolerate even moderate alcohol levels and do not survive in the finished beer. The Gram-positive bacteria involved are from genus *Pediococcus* and *Lactobacillus*. These microorganisms use a different pathway than that of *Saccharomyces* yeast known as a mixed acid fermentation pathway. It involves the esterification of the various alcohols to the corresponding carboxylic acids, thus generating the sourness (7).

The Yeast Life Cycle

When yeast are pitched into fresh wort, the overall process of fermentation can be divided into several stages, all of which are part of the life cycle. While these stages can each be described separately, the transitions between each are continuous and should not be thought of as distinct phases. Also the relative time spent in each phase depends on several factors including the composition of the wort, the environment and the amount of yeast pitched.

The first phase of the cycle is called the lag phase. During this time the yeast will adapt to the new environment they are now in and begin to make enzymes they will need to grow and ferment the wort. The yeast will be utilizing their internal reserves of energy for this purpose, which is the carbohydrate glycogen. The yeast will acclimatize itself and assess the dissolved oxygen level, the overall and relative amounts of the amino acids and the overall and relative amounts of sugars present. Some of these amino acids, small groups of amino acids called peptides, and sugars will be imported into the cell for cell division. Normally this period is very brief, but if the yeast is not healthy, this period can be very protracted, and ultimately lead to problematic fermentation (8,1).

Based on these factors, the yeast will then move into the next phase of the life cycle, the growth phase. During this time the yeast will start to divide by budding to reach the optimal density necessary for the true fermentation. If an adequate amount of healthy yeast has been pitched and the proper nutrients are present, there should only be one to three doublings of the initial innoculum. The oxygen that was used to aerate the wort is absorbed during this time to allow the yeast to generate sterols, which are key components of the cell wall (9). It has also been proposed that cold trub can provide the unsaturated fatty acids needed for sterol synthesis (10, 11). Furthermore, it has been proposed that if an adequate amount of yeast has been pitched, such that cell growth is not necessary, then the oxygenation is not necessary (9, 12). While this theory has not been completely accepted (13, 14), perhaps further research will elucidate other variables which may be involved in this phenomenon. This sterol synthesis is the default pathway used in an all malt wort; however if the wort contains greater than 0.4% glucose then this pathway will not be used and the yeast will instead ferment the glucose, even in the presence of oxygen. This effect is called glucose repression, or the Crabtree effect.

Following the growth phase, the low kräusen phase of primary fermentation begins. During this time the yeast begins anaerobic metabolism, since all of the oxygen has now been depleted. This is characterized by a foam wreath, which has previously existed on the sides, now migrating to the center of the surface. The yeast have now completely adapted to the condition of the wort and transport of both amino acids and sugars into the cells for metabolism will be very active. During this period fusel alcohols and diacetyl can be produced. To minimize the formation of fusel alcohols, one should try to keep the temperature down, make sure that adequate dextrinous sugars are available, and minimize the amount of hot trub present in the yeast cake. To minimize the diacetyl in the finished beer, one should try to avoid the reintroduction of oxygen, excessive cooling of the fermentation in later stages and premature removal of the yeast.

At the high kräusen stage following this, an ale yeast will have metabolized most of the sugars present in the wort. A lager yeast, on the other hand, may still be in the growth phase while also reducing the extract by four gravity points/day. Lager yeast will be metabolizing most of the sugars during the high kräusen phase. Following this phase is the late kräusen phase. In lager yeasts this can be very important, since it is during this time that the yeast begin to metabolize some of the fermentation by-products they had previously excreted during the low kräusen phase. Specifically, a diacetyl rest may be performed to help with the re-absorption and subsequent reduction of the diacetyl and the related 2,3 pentanedione during this time. The temperature of the beer may be allowed to rise up to 68 °F. Generally as the extract reaches its terminal point the yeast will begin to flocculate out. It is important not to chill the beer too quickly, which might cause premature flocculation before the fermentation has been completed and all the by-products have been reabsorbed. The general rule of thumb is no more than 5 °F per day; otherwise it is possible to cold shock the yeast.

When the yeast begins to flocculate, the beer is generally racked into a secondary fermenter, which allows for the attenuation of the last remaining extract, usually consisting of the trace sugars. Also removal of the excess yeast and trub will prevent formation of off flavors due to autolysis and/or reactions with trub substrates. For ale styles this period may be very brief, while lager styles may be four to six weeks, or even as long as six months in the case of strong lager styles. It is important during this time to prevent reintroduction of air, since this can lead to oxidation flavors and may introduce contaminants that can infect the beer.

During packaging of the beer, fresh yeast may often be reintroduced, particularly if it has been lagered for an extended period of time and/or the remaining yeast are not that viable. Two common methods are 1) bottle conditioning, or the addition of a fresh yeast starter and corn sugar (glucose), as is commonly done for Trappist-style Belgian ales, and 2) kräusening, or the addition of freshly fermenting beer as is often practiced with German lagers. For bottle conditioned beers, a 250 ml starter is usually added for a five gallon batch along with the sugar; which provides fresh yeast to metabolize the added sugar. In the case of kräusening, an actively fermenting batch at high kräusen stage is added to the beer being primed. The volume of kräusen added is 20% by volume of the beer being primed. Adding this actively-fermenting beer serves two purposes; it carbonates and also helps clean up any off flavors generated from the previous fermentation.

Control of Fermentation By-Products

Esters may be controlled by the choice of yeast strain, wort gravity, wort aeration, and fermentation temperature. In general ale yeasts produce higher ester levels, although there are variances among different ale strains. Lager yeasts can, if fermented too warm, also produce esters as is practiced in the making of French Bière de Garde styles. Wort gravity also is a factor; the hallmark esters of Belgian Trappist styles are not only due to the yeast strains used but also a result of their high gravity wort. Wort aeration also plays an important role, as the ester production pathway directly competes with the absorption of oxygen and metabolism into sterols (15). Lastly, fermentation temperature also plays an important role. A four-fold increase in ester production may be observed as a result of increasing the fermentation temperature from 60 to 68 °F (1).

Phenols can be produced by certain wild yeasts. Hence their control in styles in which they are not desired is a matter of proper sanitation. The one exception to this is German wheat beers, which contain the phenol 4-vinyl guaiacol, which is produced by a special strain of *S. cerevisiae,* from its precursor amino acid, ferulic acid. This phenol may be controlled by the amount of precursor amino acid that is made in the mash during a protein rest at 111 °F (16).

Fusel alcohols are metabolized from amino acids. As mentioned previously, their production is increased as the fermentation temperature is increased. Also, like esters, fusel alcohols increase with wort gravity. Lastly, various wild yeasts tend to produce excessive amounts of fusel alcohols; hence proper sanitation is important for their reduction (1).

Diacetyl is produced at the beginning stages of fermentation and then later reduced. Maintaining or even increasing the temperature at the end of fermentation can help in its reduction, as will not prematurely removing the beer from the yeast. Oxygen reintroduction can cause its formation through oxidation of diacetyl precursors present in the beer. Ensuring the presence of adequate amounts of amino acids will also help prevent its formation. Extract brewers can often have problems due to the lack of amino acids in the extract. Lastly, diacetyl can be produced by some strains of bacteria. Again, proper sanitation and control during yeast propagation will help minimize its presence (1).

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F. Troubleshooting

by Scott Bickham

Introduction

This section is intended to give an overview of the more important flavors and flaws that may be encountered while judging. Some of these flavors may be appropriate in some styles, but not in others, and the desirability will depend on the concentration. For this reason, not all of these characteristics are considered to be off-flavors. There are several references that offer a more detailed description of potential flavor and appearance flaws in beer. Most homebrewing handbooks discuss them in appendices, and although it is somewhat outdated, the 1987 *Zymurgy* Special Issue on Troubleshooting is worth reading. The more technically inclined reader should consult George Fix's Principles of Brewing Science and George and Laurie Fixs' Analysis of Brewing Techniques. Finally, *Brewing Techniques* ran a Focus on Flavors column through 1998 that described the flavors that appear on the Beer Flavor Wheel.

Acetaldehyde

This compound has the taste and aroma of fresh-cut green apples, and has also been compared to grass, green leaves and latex paint. It is normally reduced to ethanol by yeast during the secondary fermentation, but oxidation of the finished beer may reverse this process, converting ethanol to acetaldehyde. Elevated levels are generally present in green beer or if the beer is prematurely removed from the yeast. It can also be a product of bacterial spoilage by *Zymomonas* or *Acetobacter*. Background levels of acetaldehyde can be tasted in Budweiser due to the use of beechwood chips to drop the yeast before it can be reduced to ethanol.

This can also be the result of inadequate wort oxygenation, though the resultant yeast byproducts are normally metabolic intermediates they can remain after fermentation in some cases.

Alcoholic

This flavor may be detected as a spicy, vinous character in the aroma and taste and is often accompanied by a warm or prickly mouthfeel. The simplest and most prevalent alcohol in beer is ethanol, which is produced by the fermentation of glucose and other reducing sugars. Higher, or fusel, alcohols are usually present at sub-threshold concentrations, but elevated levels are associated with underpitching, low levels of dissolved oxygen prior to pitching or low levels of free available nitrogen (FAN). These deficiencies force the yeast to metabolize fatty acids in the trub as a source of oxygen and carbon, producing a greater fraction of long chain alcohols. High gravity worts and high fermentation temperatures also tend to increase the concentration of these higher alcohols through increased yeast activity. Alcoholic characteristics are desired in strong ales and lagers as long as they are not coupled with the solvent notes associated with elevated ester or fusel alcohol levels.

Astringency

This flavor is a mouth-puckering sensation that is comparable to chewing on grape skins or grape seeds. It is often produced by the extraction of tannins from grain husks due to overcrushing oversparging, or sparging with alkaline or boiling water. Astringency may also be produced by polyphenols that result from spoilage by acetobacter or wild yeast. Another possible source is oxidation, in which case the responsible compounds are polyphenols and aldehydes. Finally, spices such as coriander, orange peel and cinnamon also contribute astringent flavors, but these tend to mellow with age. Note that over-attenuation and low dextrin levels can increase the perception of astringency.

Bitterness

Bitterness, or rather excessive bitterness, is perceived as a harsh dry taste on the back of the tongue. It is usually due to over-hopping, especially when high alpha hops are used. Roasted malts and high concentrations of magnesium and sulfate ions also contribute to the overall bitterness. Bitter compounds may also be produced by oxidation or contamination by wild yeast, in which case there are usually other off-flavors. High levels of hop bitterness are appropriate in IPAs and barleywines, while bitterness due to roasted barley/malt is appropriate in robust porters and dry stouts.

Body

The body of a beer is characterized as the fullness of the flavor and mouthfeel, and descriptors range from watery or characterless to satiating or thick. Body is technically separate from mouthfeel, which encompasses physical sensations such as astringency, alcoholic warmth and carbonation, but the combination determines how the beer stimulates the palate. The body is determined by the levels of dextrins and medium-length proteins. Lack of dextrins is caused by low saccharification temperatures, excessive use of adjuncts or by highly attenuative yeast strains. A low protein level may be caused by excessively long protein rests, excessive fining or the addition of large amounts of fermentable sugars. Light body is appropriate in American light lagers and lambics, but not in malt-accented styles such as barleywines and doppelbocks.

Diacetyl

This compound is responsible for an artificial butter, butterscotch or toffee-like aroma and taste. At low levels, it may also produce a slickness on the palate. A significant number of tasters cannot perceive diacetyl at any concentration, so every judge should be aware of his or her limitations. Diacetyl is a fermentation by-product which is normally absorbed by the yeast and reduced to more innocuous diols. High levels can result from prematurely separating the beer from the yeast or by exposure to oxygen during the fermentation. Low FAN levels or mutation may also inhibit the ability of yeast to reduce diacetyl. Note that high fermentation temperatures promote both the formation and elimination of diacetyl, but the latter is more effective. For that reason, lager breweries often employ a diacetyl rest, which involves holding the beer in the 60-65 °F range for a few days after racking to the conditioning tank. Diacetyl is also produced by lactic acid bacteria, notably *Pediococcus damnosus*. Low levels of diacetyl are permissible in nearly all ales, particularly those brewed in Scotland, and even some lagers, including Czech pilsners and Vienna-style beers.

Though rarely used by homebrewers, kräusening is a technique that can be used to eliminate diacetyl in beer. The technique works because of the introduction of fresh yeast that is actively multiplying and is thus able to rapidly remove diacetyl.

DMS

DMS, or dimethyl-sulfide produces the aroma and taste of cooked vegetables, notably corn, celery, cabbage or parsnips. In extreme cases, it may even be reminiscent of shellfish or water in which shrimp has been boiled. DMS is normally produced by the heat-induced conversion of S-methyl-methionine, but most of this evaporates during an open, rolling boil. A closed boil or slow cooling of the wort may therefore lead to abnormally high levels. Some DMS is also scrubbed out during a vigorous fermentation, which is why lagers and cold-conditioned ales may have slightly higher levels than warm-fermented ales. Wild yeast or *Zymomonas* bacteria may produce high enough levels of DMS to make the beer undrinkable. Low levels of DMS are appropriate in most lagers, particularly American light lagers and Classic American Pilsners, but are not desirable in any ale style.

Estery/Fruity

This is an aroma and taste that recalls bananas, strawberries, pears, apples, plums, papaya and/or other fruits. The responsible compounds are esters, which are formed from the combination of an alcohol and an organic acid. High ester levels are a product of the yeast strain, high fermentation temperature, high gravity worts, the metabolism of fatty acids in the trub, low yeast pitching rate, and low wort aeration. These flavors are desirable in most ales, particularly Belgian and British styles, and the signature banana notes in Bavarian wheat beers are primary due to the ester isoamyl acetate. Note that esters often have solvent notes at very high concentrations.

Grassy

This is the flavor and aroma of freshly cut grass or green leaves. Responsible compounds include the aldehydes hexanal and heptanal, which are produced by the oxidation of alcohols in the finished beer or the deterioration of improperly stored malt or hops. Some English and American hop varieties produce grassy notes if used in large quantities, but this flavor should not be a significant part of the profile.

Head Retention

Good head retention is measured in terms of the time required for the head to collapse to half of its initial height. This should be at least a minute in well-brewed and conditioned beers. The beading should also be uniform and tight, leaving lace on the glass as the beer is consumed. Good head retention is promoted by several factors, including isohumulones, high original gravity, alcohol content, dextrins and the levels of high- and medium- molecular weigh proteins. Adequate carbonation is also important. Most of these variables are style-dependent, but the brewer can increase the protein content by adjusting the length and temperature of the protein rest and using adjuncts such as flaked wheat and barley. Fatty acids carried over from the trub and unclean glassware are both detrimental to head stability, since they decrease the surface tension of the foam, causing the bubbles to collapse.

Husky/Grainy

This may be perceived in both the aroma and the taste and is reminiscent of the flavor of spent grains. Possible causes include overcrushing, oversparging or sparging with hot or alkaline water. Long mashes may also leach these flavors from the grain husks. Low levels are acceptable in some lagers, but are not appropriate in any ale.

Lightstruck/Skunky

This aroma and taste is due to the presence of the same mercaptans that are found in the scent glands of skunks. These compounds are formed when ultraviolet light cleaves an isohumulone molecule, and the resulting radical combines with a sulfur compound. Beer stored in clear or green glass bottles is more susceptible to this reaction, which is why brown glass offers more protection. Lightstruck flavors are not desirable in any style, but many European imports possess this quality. Note that Miller Brewing is able to use clear glass bottles because they use a chemically modified form of isohumulone that does not interact with light.

Musty

This is a stale aroma and taste associated with the oxidation of malt compounds in the melanoidin family. This oxidation can occur in the mash or boil via hot side aeration or by exposure to air when racking or bottling. The responsible compounds may be later transformed to their reduced state by oxidizing alcohols into aldehydes. Musty flavors are generally not desirable, but may be found in some cellared beer styles such as Bière de Garde.

Paper/Cardboard

These are perceived in both the aroma and flavor and are primarily due to the aldehyde, 2-trans-nonenal. This compound has an extremely low flavor threshold and is produced by the oxidation of higher alcohols. The threat of oxidation may be reduced by minimizing splashing of the hot wort or of the fermented beer while racking or bottling. This flavor is never appropriate and is rare in homebrew due to the reducing power of yeast, but it is a common flaw in many old or abused commercial beers.

Phenolic

This is an aroma and taste often compared to Band-aids (tm), medicine chest or disinfectant. Chlorophenols are particularly offensive members of this family with bleach-like flavors in addition to the ones listed above. High levels of phenols are generally produced by bacteria or wild yeast, both of which indicate a sanitation problem. Phenols may also be extracted from grain husks by overcrushing, oversparging or sparging with hot or alkaline water. Chlorinated water and sanitizer residue are possible sources of chlorophenols. Phenolic flavors are generally never desirable, the exception being the clove-like, vanilla-like or slightly smoky flavors and aromas in Bavarian wheat beers and some Belgian ales.

Sherry-like

This is the aroma and taste of dry sherry and is often accompanied by hazelnut or almond notes. The responsible compounds are oxidized members of the melanoidin family. This flavor is one of the few positive flavors attributed to oxidation and adds complexity to barleywines, old ales and Scotch ales. Sherry-like flavors are considered a defect in most other styles, particularly low-gravity ales.

Solvent-like

This describes an aroma and taste similar to turpentine or acetone that is often accompanied by a burning sensation in the back of the mouth. It is due to high concentrations of ethyl acetate and other esters, as well as fusel alcohols. Possible sources include underpitching, lack of oxygen, and fermenting on the trub, especially at elevated temperatures. Contamination by wild yeast may produce elevated levels of both esters and fusel alcohols. Solvent-like notes are generally undesirable, but perceptible levels may be encountered in old ales such as Theakston's Old Peculier.

Sour/Acidic

This is usually perceived as a taste on the sides of the tongue, towards the rear of the mouth. The two most common acids responsible for this flavor are lactic and acetic, which both have related esters that may be perceived in the aroma. Lactic acid is produced by Gram positive bacteria such as *Lactobacillus* and *Pediococcus*, which are present in dust and saliva. Acetic acid may be produced by several contaminants, including *Acetobacter*, *Zymomonas*, and yeast in the *Kloeckera* and *Brettanomyces* families. High levels of sour and acidic flavors generally indicate a sanitation problem, but they are an important part of the profile of the lambic, oud bruin and Berliner weiss styles, and to a lesser extent, Belgian white beers.

Sulfury/Yeasty

These flavors, not to be confused with DMS, have the aroma and taste of rotten eggs, shrimp or rubber. The compounds responsible for these flavors originate from sulfur-containing amino acids such as cysteine and methionine. Possible sources include yeast autolysis, bacterial spoilage and water contamination. These flavors can be quite putrid and are not desirable in any style. In the same family are sulfitic flavors, which recall the aroma of a struck match. They are usually due to the overuse of antioxidants, and while rare in beer, are quite common in wine and cider.

Sweet

Sweetness is a taste perceived primarily at the tip of the tongue and is due to the presence of reducing sugars. High levels of residual sugars can result from a flocculent or low-attenuating yeast or poor yeast health linked to low FAN levels or low levels of dissolved oxygen prior to pitching. High gravity worts, high dextrin content and the addition of lactose also play a role in determining the sweetness of the finished beer. The appropriate level is style-dependent, with high levels desirable in most strong ales and lagers, and low levels in American light lagers and lambics.

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