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BREWMASTER'S ART: THE HISTORY AND SCIENCE OF BEERMAKING

COURSE GUIDE

Professor Charles W. Bamforth

UNIVERSITY OF CALIFORNIA, DAVIS

Brewmaster's Art:
The History and Science of Beermaking

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University of California, Davis

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Course Syllabus

Brewmaster's Art:
The History and Science of Beermaking

About Your Professor 4

Introduction 5

Lecture 1 The Shape of the Worldwide Brewing Industry 6

Lecture 2 The Basics of Brewing 9

Lecture 3 The History of Brewing 12

Lecture 4 Raw Materials: Barley and Malt 15

Lecture 5 Raw Materials: Water and Hops 18

Lecture 6 The Brewhouse 21

Lecture 7 Fermentation Through Packaging 24

Lecture 8 Beer Styles: Top-Fermentation Beers 27

Lecture 9 Beer Styles: Bottom-Fermentation Beers and Other Product Types 30

Lecture 10 The Quality of Beer: Flavor and Flavor Stability 33

Lecture 11 The Quality of Beer: Appearance 36

Lecture 12 Beer: Healthfulness and Perception 38

Lecture 13 Beer in the United States 41

Lecture 14 The Impact of Science on the Development of the Brewing Industry—Past, Present, and Future 45

Photograph courtesy of Charles W. Bamforth

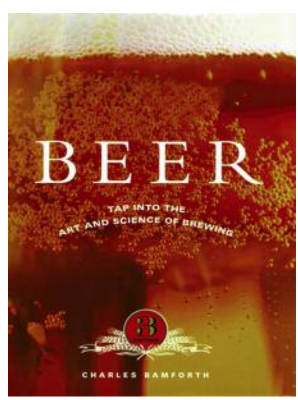
Professor Bamforth at the University of California, Davis, brewing lab.

About Your Professor

Charles W. Bamforth

Dr. Charles Bamforth is Anheuser-Busch Endowed Professor of Malting & Brewing Sciences at the University of California, Davis. He has been part of the brewing industry for more than thirty years. He is formerly Deputy Director-General of Brewing Research International and Research Manager and Quality Assurance Manager of Bass Brewers. He is a Special Professor in the School of Biosciences at the University of Nottingham, England, and was previously Visiting Professor of Brewing at Heriot-Watt University in Scotland. Professor Bamforth is a Fellow of the Institute of Brewing & Distilling, Fellow of the Institute of Biology, and Fellow of the International Academy of Food Science and Technology. He is editor in chief of the *Journal of the American Society of Brewing Chemists*, is on the editorial boards of several other journals, and has published innumerable papers, articles, and books on beer and brewing. His books include *Beer: Tap into the Art and Science of Brewing* (now into its third edition); *Standards of Brewing*; *Scientific Principles of Malting and Brewing*; *Beer: Health and Nutrition*; *Essays in Brewing Science* (coauthored with Michael Lewis); and *Grape versus Grain*. Professor Bamforth was the editor of *Brewing: New Technologies* and *Beer: A Quality Perspective*. In 1984, he was awarded the Cambridge Prize of the Institute of Brewing. He holds B.Sc. and Ph.D. degrees in biochemistry from the University of Hull (England) and was also honored by the award of a D.Sc. in applied biology from his alma mater in 1993.

You'll get the most from this course if you have Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing* (Oxford University Press, 2009).



Courtesy of Oxford University Press, 2009

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Introduction

In this lecture series we will explore the wonderful world of beer.

We will start by looking at the shape of the world's brewing industry today: how much beer is brewed, by whom and where, and who drinks the most beer. We will consider breweries large and small, and the consolidation that is occurring in the industry at the same time as the exciting growth of the craft sector.

After briefly taking an overall look at the nature of the brewing process, we will delve back in history to look at beer's origins some eight thousand years ago, how brewing moved around the world in the home and the church and how it evolved through to the advent of the scientific age.

Then we will consider in detail how beer is made. We will consider barley and malt, hops, water and yeast, and how these and other materials come together in the production of packaged beers of myriad types. And we will consider the rich diversity of beer styles (ales, lagers, and beyond) and the many factors that determine their quality: the flavor, foam, clarity, and color.

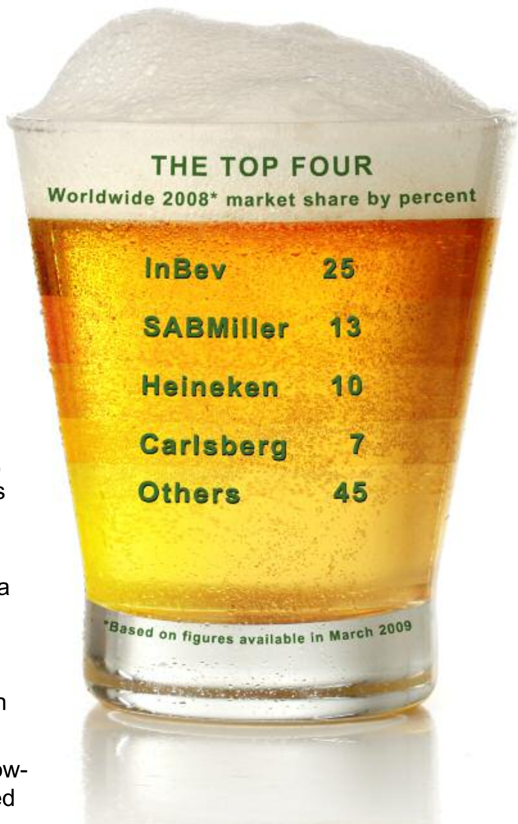
Beer in moderation can be a healthful component of the diet and this will be addressed, comparing its perception with wine on the dinner table.

Finally, we will look at how beer and brewing have evolved in the United States and beyond as science and technology have developed and as political pressures have changed.

Lecture 1:
The Shape of the Worldwide Brewing Industry

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, introduction, chapter 1, and pp. 41–42.

The volume of beer brewed has increased two-and-a-half-fold since 1970, in which time the world population has increased by 75 percent. The brewing industry is polarizing, with the growth of some mega international concerns on the one hand and the proliferation of micro-brewers on the other. More than half of the 1.78 billion hectoliters of beer worldwide in 2007 was brewed by ten companies. The biggest by far is the company formed late in 2008 by the acquisition of Anheuser-Busch by InBev. Next in size we have South African Breweries-Miller, although 2008 saw a further complication in that the Miller arm in the United States merged its brewing interests with those of Coors from within the Molson-Coors organization, to form Miller Coors. Truly the world of beer is driven by international companies, with the likes of Heineken (from Holland) and Carlsberg (from Denmark) having long had a global presence.



The biggest beer market worldwide is China, which has grown from 1.2 million hectoliters to more than 350 million hectoliters in under forty years. The per capita consumption of beer in China is relatively low (at around twenty-two liters per head). The highest per person consumption of beer is in the Czech Republic, at one hundred fifty-eight liters per head.

Beer is showing good growth in other markets, such as India and Russia. Traditional beer-drinking nations such as the United Kingdom, Germany, Denmark, and even the Czech Republic are all in decline.

One area of the business showing healthy growth in the United

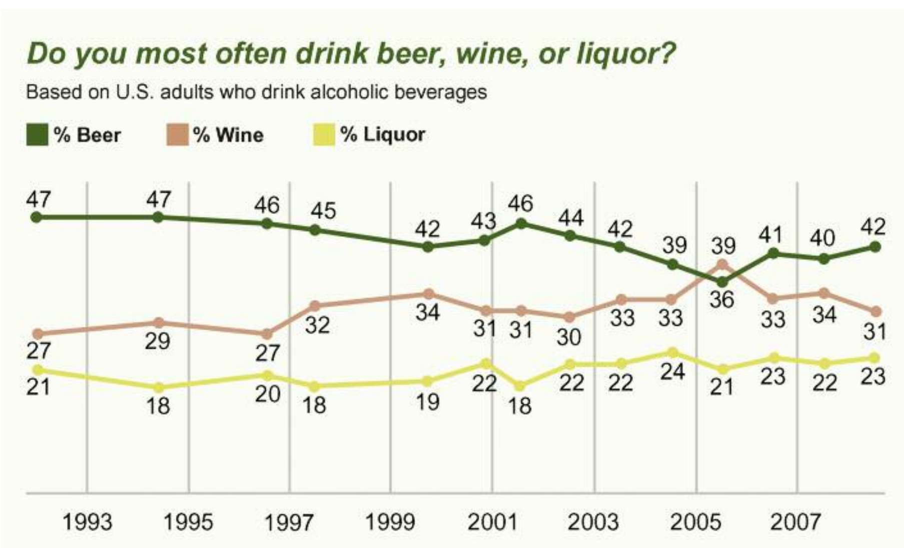
States is the craft sector. In the United States in the 1960s there were fewer than fifty breweries. Now there are more than fourteen hundred. In 2007, the craft brewing sector was the top performer in terms of growth in the United States industry, with a 12 percent volume increase over the previous year. Even then it amounts to only 3.8 percent of production and 5.9 percent of retail sales.

The average strength of beer ranges from a high of 5.2 percent alcohol by volume (ABV) in Spain to a low of 4.0 percent in New Zealand and Sweden.

One significant factor influencing the respective amounts of beer and wine drunk in different countries is the relative excise tax (duty) levied on them. In the United States, matters are complicated by there being three layers of government levying taxes on beer, a relic from the days of Prohibition. The federal rate of excise tax for the large brewers has been $18 per barrel (US) since it was doubled in 1990 following strong lobbying by anti-alcohol advocates. A reduced rate of $7 per barrel for the first sixty thousand barrels of beer annually is provided for brewers who produce no more than two million barrels in a calendar year. State excise tax varies tremendously, but the current median is 18.8 cents per gallon. Sales taxes also apply in most states. Per capita consumption of beer in the United States is highest in North Dakota, and least in Utah.

America’s beer industry, from suppliers through brewers to distributors and retail sales, contributes almost $190 billion annually to the United States.

With the exception of brewpubs, where the beer is brewed on the premises, it has been illegal since the repeal of prohibition for a brewer (other than pub brewers) in the United States to sell directly to the consumer. There is a three-tier arrangement comprising the brewer (supplier), the distributor (wholesaler), and the consumer.



FOR GREATER UNDERSTANDING

Questions

1. How do taxes affect the amount of beer drunk in different countries and within the United States?
2. What are the world's biggest beer markets?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Tremblay, Victor J., and Carol Horton Tremblay. *The U.S. Brewing Industry: Data and Economic Analysis*. Cambridge, MA: The MIT Press, 2009.

Websites of Interest

The following sites are official websites of leading brewing corporations and primary companies within them. The sites provide sales, distribution, and brand information for their different subsidiaries. (Some of the sites require a date of birth to access the site.)

Anheuser-Busch/InBev — http://www.ab-inbev.com

Anheuser-Busch — http://www.anheuser-busch.com

SABMiller — http://www.sabmiller.com

MillerCoors — http://www.millercoors.com

Heineken — http://siab.heineken.com/usa

Carlsberg — http://www.carlsberg.com

Lecture 2:
The Basics of Brewing

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, chapter 2.

Fundamentally, beer is the product of the alcoholic fermentation by yeast of extracts of malted barley, "spiced" by hops. Barley starch usually supplies most of the sugars from which the alcohol is derived, although some notable beers are made from cereals such as wheat. The starch is enclosed in cell walls and proteins (Figure 1), and these wrappings are stripped away in the malting process, leaving the starch essentially preserved. This softens the grain and makes it more readily milled. Unpleasant grainy and astringent characters are removed during malting, which commences with steeping of barley in water in a three-stage process, with the steeps being interspersed with "air rests" that allow the barley to get some oxygen.

Raising the moisture content allows the grain to germinate, a process that usually takes three to five days. In germination, the enzymes break down the cell walls and some of the protein in the starchy endosperm, which is the grain's food reserve. Amylases are produced in germination and these are important for breaking down the starch in the brewery.

Increasing the temperature during kilning arrests germination, and regimes with progressively increasing temperatures are used to allow drying to a low enough moisture content without destroying heat-sensitive enzymes. The more intense the kilning process, the darker the malt and the more roasted and burnt are its flavor characteristics.

In the brewery, the malted grain (after a month of storage) must first be milled to produce relatively fine particles, which are then mixed with hot water in a process called mashing. Fine ales are produced from waters with high levels of calcium, whereas famous pilsners are from waters with low levels of calcium. Typically mashes have a thickness of three parts water to one part malt and include a stand at around 65˚C (149˚F), at which temperature the granules of starch are converted by gelatinization from an indigestible granular state into a "melted" form that is much more susceptible to enzymatic digestion. Some brewers will also add starch from

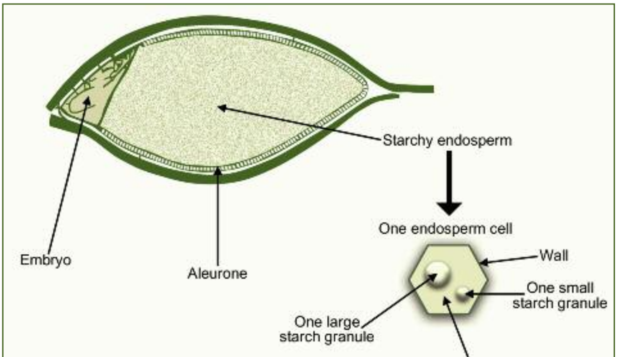


Figure 1
A cross-section through a barley kernel.

© Charles Bamforth

other sources, such as corn or rice, to supplement that from malt. These other sources are called adjuncts. Corn and rice starches demand cooking because their starches have high gelatinization temperatures.

After perhaps an hour of mashing, the liquid wort is recovered, either by straining through the residual spent grains (lautering) or by filtering through plates, and is run to the kettle where it is boiled, usually for one hour. Boiling sterilizes the wort, precipitates unwanted proteins, and drives away unpleasant grainy characters. Many brewers also add some adjunct sugars at this stage, at which most brewers introduce at least a proportion of their hops. The hops have two principal components: resins and essential oils. The resins are changed ("isomerized") during boiling to yield the forms that provide the bitterness to beer. This process is rather inefficient. The oils are responsible for the "hoppy nose" on beer. They are very volatile and if the hops are all added at the start of the boil then all of the aroma will be lost. In traditional lager brewing some of the hops are held back and only added toward the end of boiling, which allows the oils to remain in the wort ("late hopping"). In traditional ale production, a handful of hops is added to the cask at the end of the process ("dry hopping").

After the precipitate produced during boiling has been removed, the hopped wort is cooled and pitched with yeast (ale strains of *Saccharomyces cerevisiae* or lager strains of *Saccharomyces pastorianus*). Both types need a little oxygen to trigger their metabolism; otherwise the alcoholic fermentation is anaerobic. Ale fermentations are usually complete within a few days at temperatures as high as 20˚C (68˚F), whereas lager fermentations at as low as 6˚C (43˚F) can take several weeks. Fermentation is complete when the desired alcohol content has been reached and when an unpleasant butterscotch flavor (diacetyl) that develops during all fermentations has been mopped up by yeast. The yeast is harvested for use in the next fermentation.

Nowadays, the majority of beers receive a relatively short conditioning period after fermentation and before filtration. This conditioning is ideally performed at –1˚C (30˚F), under which conditions more proteins drop out of solution, making the beer less likely to appear cloudy in the package or drinking glass. The filtered beer is adjusted to the required carbonation before packaging into cans, kegs, or bottles.

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Figure 2
A beer-bottling operation.

Questions

1. What happens during the mashing process?
2. What is dry hopping?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Scientific Principles of Malting and Brewing*. St. Paul, MN: American Association of Brewing Chemists, 2006.

Lewis, Michael J., and Charles W. Bamforth. *Essays in Brewing Science*. New York: Springer, 2006.

Lewis, Michael J., and Tom W. Young. *Brewing*. 2nd ed. New York: Springer, 2002.

Websites of Interest

The Brewers' Guardian website provides brewing industry news, trends, and developments. — http://www.brewersguardian.com

Lecture 3:
The History of Brewing

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, chapter 1, pp. 22–32.

© Clipart.com/British Museum

The symbol for beer (an upright jug with a pointed base, lightened in this picture) appears three times on this Sumerian clay tablet dating from ca. 2700 BCE.

Beer probably originated accidentally approximately eight thousand years ago in Sumeria. Batches of barley must have gotten wet through inadequate storage and they started to germinate. Presumably it was found that drying stopped this sprouting with an improvement to the taste and nutritional merit of the grain. We believe that the sprouted barley was made into dough before bread making, and then batches of the dough spontaneously fermented through the action of yeasts living in vessels. Soon the ancient brewers will have realized that the dough could be thinned with water and strained as a precursor to fermentation and that the process could be accelerated by the addition of a proportion of the previous "brew." A range of plants were used to impart flavors. It has been suggested that the Egyptian Pharaoh Rameses had a brewery that furnished ten thousand hectoliters of beer annually for those employed in the temple. Beer was a staple of the diet, alongside bread and onions. It has even been claimed that modern civilization has its origins in the brewing of beer.

The Egyptians passed on their brewery techniques to the Greeks and Romans, but in those societies wine was the drink of the privileged classes. The Celts brought westward the ability to brew. Whereas the Greeks and others in the South were drinking wine from pottery, the Germanic tribes were drinking barley- or wheat-based drinks out of wood. For the Danes and the Anglo-Saxons, ale was favored, grapes not faring well in the colder northern regions.

Much of the development in brewing techniques was by monks in the Church. The monasteries passed on their skills to those brewing in their own homes, notably the women (brewsters). Out of domestic brewing developed the forerunner of the "brewpub." The two main products were those fermented from the first strainings from the mash tun (strong beer) and those derived from a second mashing ("small beer").

Through the Assize of Bread and Ale[1] in 1266, ale-conners were appointed in boroughs and cities to test the quality of the ale. Licenses to brew were needed as early as 1305. The brewer used a pole, with attached bush or ivy plant, to register that the beer was ready. Later this became a metal hoop and various things were displayed in it to differentiate breweries. Later, real objects were replaced by paintings. It was frequent practice to spice ale, by adding pepper or other stimulants, to give the product an additional bite, but for long enough these flavorants did not include hops. The cultivation of hops in the Hallertau region of Germany is first recorded in 736.

British beer was becoming popular around the world. The Trent Navigation Act of 1699 opened up transport from Burton-on-Trent through Hull to the world.

Toward the end of the eighteenth century, the impact of taxation and increasing imports of tea and coffee saw a change in domestic drinking habits—tea instead of ale for breakfast. In the late 1700s, there was a decline in beer brewed at home, reflecting the growth in industry with people now working in factories, and the development of very large "common" brewers distributing their product via the new railways.

An illustration from a German *bilderhandschrift* (image hand writing) ca. 1520 of the "Housebook of the Family Mendel" of Nürnberg depicts Hans Franck (a grandson of the family founder), who was a beer measurer and city employee. He is determining the malt and beer amounts for tax purposes. The hexagram above him is the family mark used as guild sign of their brewery.

The western brewing industry first became established in the regions of Bohemia (now part of the Czech Republic) and Bavaria. Despite the appreciation of hops coming earlier in Germany than it did in England, there were still plenty of adherents to the merits of gruit (the proprietary blend of herbs and spices used to flavor ale). Until the sixteenth century, ale was the major beer type in Germany. Bottom fermentation probably started in Bavarian monasteries in the early fifteenth century. Prince Maximilian I, in 1533, banned brewing in the summer so the emphasis shifted to the bottom fermentation practices used in the winter, producing beer in sufficient quantities to store (*lager* is from German *Lager*, "storehouse") until the subsequent fall, when brewing could start again. In 1516 came the *Reinheitsgebot*[2] as an attempt to ensure that undesirable materials did not find their way into the brew and to prevent price competition with bakers for wheat and rye. The law survives to this day.

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1. A statute (assize) in late medieval English law, which regulated the price, weight, and quality of the bread and beer manufactured and sold in towns, villages, and hamlets, thereby setting fair trade standards for bakers and brewers.
2. The Reinheitsgebot, sometimes called the "German Beer Purity Law" or the "Bavarian Purity Law," is a regulation concerning the production of beer in Germany. In the original text, the only ingredients that could be used in the production of beer were water, barley, and hops.

FOR GREATER UNDERSTANDING

Questions

1. How was beer "invented" in Sumeria?
2. What is gruit?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bennett, Judith M. *Ale, Beer, and Brewsters in England: Women's Work in a Changing World*. New York: Oxford University Press, USA, 1999.

Hornsey, Ian S. *A History of Beer and Brewing*. London: Royal Society of Chemistry, 2006.

Lecture 4:
Raw Materials: Barley and Malt

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 103–120.

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Two-row barley growing in a Kansas field.

Barley is part of the grass family. The major types are two-row and six-row, differing in how many grains (corns, kernels) are squeezed onto the ear. There are fewer in two-row barley, so they can grow bigger and contain more starch, which translates to more useful material for the brewer.

The best climatic conditions for cultivating barley are wet growing seasons (or high irrigation) and then dry, warm conditions at the end for ripening. The maltster and brewer want only the best barleys, in terms of malting grade (high yields of extractable material). They can identify these by visual appearance and by protein or DNA fingerprinting. The barley must be alive, not dormant, infection-free (the fungus *Fusarium* causes gushing in beer), and of relatively low protein content.

On arrival at the malt house, the barley will be screened for its quality and then transferred through a cleaning process into storage. At the required time it is steeped, germinated, and kilned. For the main malt destined for the mash, the kilning is relatively gentle so that the enzymes are preserved, but sufficiently intense to remove water, which if excessive will lead to deterioration of the malt. During kilning there is also the development of color and flavor: the more intense the roasting, the more of each (see Figure 3). This is the source of the intense flavors and color in darker beers.

© Leslie Brown/shutterstock.com

Germinated barley ready for kilning.

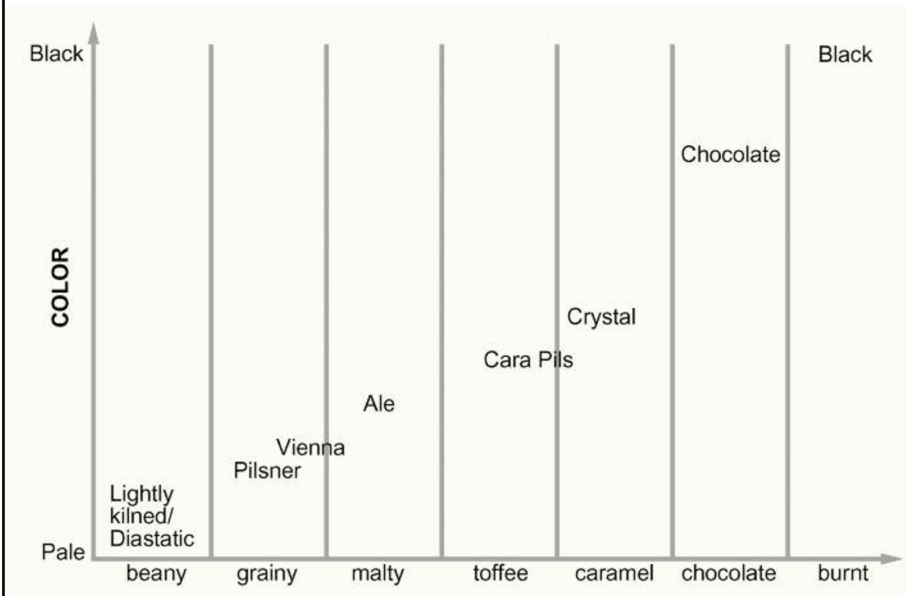


Figure 3
Types of malt: increasing heating leads successively to increased color and intensity of flavor.

Various types of malt (from top left to bottom): Pale malt, crystal malt, chocolate malt, and wheat malt; and aromatic hops (left and top right).

Questions

1. What are the two major types of barley?
2. What is the source of flavor in dark beers?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

MacGregor, Alexander W., and Rattan S. Bhatty, eds. *Barley: Chemistry and Technology*. St. Paul, MN: American Association of Cereal Chemists, 1993.

Other Books of Interest

The American Malting Barley Association was founded to encourage and support production of an adequate supply of high-quality malting barley for the malting and brewing industry. — http://www.ambainc.org

Lecture 5:
Raw Materials: Water and Hops

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 121–135.

Water

Most beers contain more than 90 percent water and brewers actually use a lot more than ends up in the glass: it is needed for cleaning, raising steam, and much more. Whether the water is from a brewer's own well or from a municipal supply, it must conform to prevailing water regulations (that is, avoidance of microbiological and chemical problems).

Classic water for ales (for instance, Burton-on-Trent) is hard (high in calcium) whereas that for lagers (for instance, Pilsen) is soft. The water composition influences pH and therefore impacts the extraction of malt, quality of bitterness, yeast behavior, and more besides. The water composition can be adjusted to match exactly that of a supply anywhere in the world.

Hops

The flowering cones from the female plant are the source of the resins that provide beer bitterness (they are also foam-stabilizing and antimicrobial) and the oils that provide aroma. Their closest relative is cannabis. There are many hop varieties, prized either for resin content or aroma or both. They are grown in the same latitudes as the great wine grapes.

To increase the efficiency with which hops are used, many brewers use hop products such as pellets or extracts (made with liquid carbon dioxide). Some of the latter are modified to make the bitter compounds less susceptible to the light damage that causes skunking.

© Frieda Weiss

Hop producing country	Output in tons
Germany	34,438
USA	23,494
China	10,576
Czech Republic	7,831
Poland	3,414
Slovenia	2,539
United Kingdom	1,693
Spain	1,537
Ukraine	1,474
France	1,372

© Brewers Association of America

Hop	Aroma
Bramling Cross	Spicy/blackcurrant
Brewers Gold	Blackcurrant, fruity, spicy
Cascade	Flowery, citrus, grapefruit
Chinook	Spicy, piney, grapefruit
Fuggle	Delicate, minty, grassy, slightly floral
Hallertau	Mild and pleasant
Hersbrucker	Mild to semi-strong, pleasant and hoppy
Millennium	Mild, herbal
Saaz	Very mild with pleasant earthy hoppy notes
Tettnang	Mild and pleasant, slightly spicy
Willamette	Mild and pleasant, slightly spicy; delicate estery/blackcurrant/herbal

From Bamforth, Charles. *Grape versus Grain*. Cambridge: Cambridge University Press, 2008.

Table 1
Some hop varieties.

A hop yard in Hallertau, Germany

Hop bines are a climbing plant, similar to beans and peas in that respect. Training (or "twiddling") the bines up strings or wires supports plants, allowing the plants significantly greater growth with the same sunlight profile.

FOR GREATER UNDERSTANDING

Questions

1. What country produces the most hops?
2. How does water influence the final beer product?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Brewing: New Technologies*. Cambridge: Woodhead, 2006.

Neve, Raymond A. *Hops*. Boca Raton, FL: Chapman & Hall, 1991.

Lecture 6:
The Brewhouse

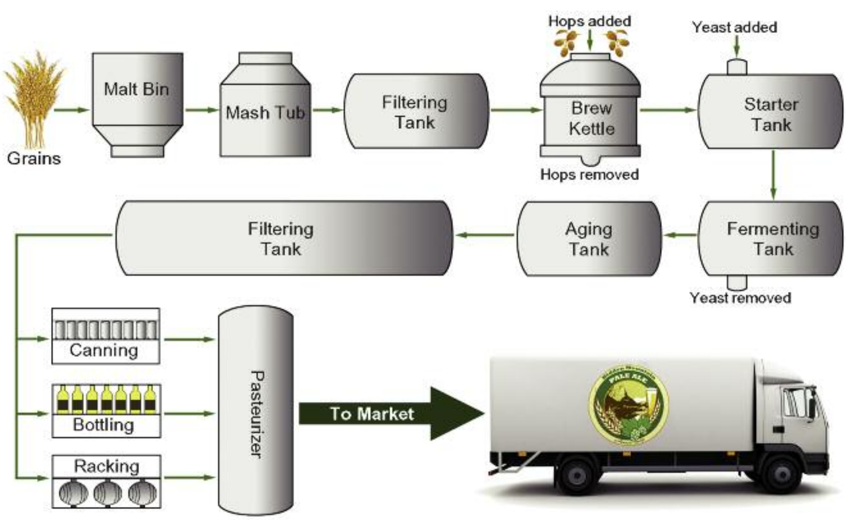
The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 136–150.

The whole of brewing is a remarkable exercise in logistics: raw materials in and waste materials out (brewers prefer to call the latter "co-products"), all in the pursuit of a stream of consistently excellent packaged beer.

The brewhouse is often called "the hot side" of the process. (We will come to the cold side in the next lecture.)

The incoming malt needs to be stored, usually for around one month; otherwise it does not "perform" well in the brewery. The incoming water is generally filtered through carbon (to remove any undesirable materials) and then is adjusted to the desired salt composition. The hops are brought into cold storage to preserve them, for they are prone to deterioration to cheesy flavors.

The malt is milled to produce small particles that are more readily extracted. These are mixed with warm water at the start of mashing, to complete the degradation of problematic polysaccharides, before the temperature is raised to around 65˚C (149˚F) to gelatinize the starch, rendering it in a form that is susceptible to the action of enzymes developed during the germination of the grain. Adjuncts may be used—the most common ones being corn or rice grits. This is to allow the production of lighter, cleaner products rather than being from a cost perspective, for they need to be cooked in an extra stage,



A simplified schematic of the beer-brewing process.

as their starches have a higher gelatinization temperature than that of barley starch. Some brewers instead add liquid sugars to the later boiling stage.

Once the starch has been degraded, the resultant liquid wort is separated from unconverted solids in either a lauter tun or a mash filter, and the spent grains for the most part are sold off as cattle food.

The sweet wort is now boiled to arrest enzyme action, precipitate out unwanted material, sterilize the liquid, drive off unwanted aromatic material, concentrate the sugars, and (if hops are added at this stage) convert hop resins to a more soluble and bitter form (this process is called isomerization).

The solid product ("hot break") is removed, generally by swirling the boiled wort in a large tank called a whirlpool according to a principle first articulated by Albert Einstein.

Finally, the wort is cooled. In traditional Germanic practice this was in a huge shallow vessel called a "coolship" located at the top of a brewery in which the vapors could evaporate and the wort gradually cool, as it did so relinquishing another precipitate ("cold break"), which would collect at one end of the gently sloping tank. Not very hygienic, so most brewers use a heat exchanger that operates a little like a car radiator, with very thin metal plates, on one side of which is the hot wort and on the other the cooling liquid (water and, often, ancillary coolant such as ammonia or glycol). The heat passes across the surface and the wort is cooled.

© Mark Renfrew

Still in use on the highest floor of the Cantillon Brewery in Brussels, Belgium, is this copper-lined coolship that began service in 1901.

FOR GREATER UNDERSTANDING

Questions

1. What is the “hot side” of the brewing process?
2. What happens when the wort is boiled?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Ockert, Karl. *Raw Materials and Brewhouse Operations: Practical Handbook for the Specialty Brewer*. St. Paul, MN: Master Brewers Association of the Americas, 2006.

Lecture 7:
Fermentation Through Packaging

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 151–183.

The production of alcohol and carbon dioxide is effected by brewing strains of the unicellular fungus *Saccharomyces*. They can be broadly categorized into ale strains and lager strains, the former traditionally being harvested after they have migrated to the top of the fermenting wort, the latter after they sink to the bottom. Most brewers insist on using their own tried-and-trusted strains.

Wort of the desired strength (measured either as specific gravity or degrees Plato, the latter approximating to percentage sugar by weight) is cooled to the correct temperature for fermentation, which may be as high as 25˚C (77˚F) for ales or as low as 6˚C (43˚F) for lagers, meaning that ales tend to ferment rather faster than do lagers. The amount of viable yeast is also very important if a controlled fermentation is to be achieved (control is important for consistent beer quality): a typical "pitching rate" is one million living cells for every milliliter of wort for every degree Plato. The yeast also needs a little oxygen (it uses it to make its membranes) and some zinc (needed by the enzyme that makes the alcohol).

Many fermentations on a large scale these days are performed in huge cylindrical vessels with conical bottoms, and these may hold as much as seven million liters of fermenting beer. As the yeast consumes the starch-derived sugars and produces alcohol and carbon dioxide, it also multiplies by budding. Approximately three times more yeast is present at the end of fermentation as at the start. Some of this can be used to pitch the next fermentation, but the surplus is used, for example, to feed to animals or to make extracts that form food spreads for use by humans (Marmite, Vegemite).

A modern beer fermentation tank.

One other product of all brewery fermentations is diacetyl, the material that gives the aroma to popcorn. The flavor of few if any beers benefits from its presence, but the good news is that it is removed again by yeast, though this takes time and this is generally the event that determines how long the fermenting wort needs to stay in the fermenter. (Like all the vessels in a brewery, the fermenters must be kept clean and this is achieved by so-called Cleaning In-Place [CIP].)

After fermentation, beer needs to be chilled to as low a temperature as possible short of freezing it, in order to remove materials that otherwise would precipitate from the beer in your refrigerator. Some brewers add isinglass finings to help this particle removal, still others centrifuge the beer. Afterwards beer is filtered, usually using diatomaceous earth as an aid. The beer may also have removed from it certain proteins and polyphenols, molecules that link together in beer to give haze. The polyphenols can bind onto a material called PVPP (polyvinylpolypyrrolidone), the proteins onto silica gels.

Microorganisms can be removed from beer either by gentle heating (pasteurization) or filtering through fine-pore membranes. Before packaging, it is also usually necessary to boost the carbon dioxide content of the product. A very few brewers do this by natural conditioning in the bottle or cask, in which residual yeast converts residual sugars into carbon dioxide.

Finally, beer is packaged into kegs or casks for draft dispense, bottles (at the rate of approximately 1,500 bottles every minute), or cans (at the rate of approximately 2,500 cans per minute).

Brewing equipment is often a part of the ambience of a brewpub or microbrewery.

Questions

1. How are alcohol and carbon dioxide produced from wort?
2. Why is beer chilled after fermentation?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Boulton, Chris, and David Quain. *Brewing Yeast and Fermentation*. Oxford: Blackwell Science, Ltd., 2001.

Lecture 8:
Beer Styles:
Top-Fermentation Beers

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 60–69.

Beers are generally classified into ales (including porters and stouts) and lagers, although some of the products nowadays seem to fall on the cusp. For example, there are brewers who use malts traditionally employed in the production of, say, lagers, to make ales and brewers who may use an ale yeast in products they label "lager." And these days much of the world's beer is made in tall cylindro-conical vessels, within which yeast behaves in a similar way whether ale or lager.

Traditionally, ales have been brewed from relatively well-modified malts that had been kilned to quite high temperatures, thereby imparting relatively high levels of color and malty flavor. They were fermented at relatively warm temperatures (15 to 25˚C; 59 to 77˚F) by yeasts that migrate to the surface of the brew in open-fermenting vessels, from which the yeast could be skimmed off for re-use. Small amounts of hop cones were added to the final beer to afford a strong "dry hop character" and the beers were dispensed at relatively warm temperatures (10 to 20˚C; 50 to 68˚F).

Lagers were historically produced from somewhat lightly kilned (and therefore low color), less extensively modified malts. Perhaps 10 percent of the hops were added late in the kettle boil to allow survival of some hop oils as "late hop character." Fermentation was at lower temperatures (6 to 15˚C; 43 to 59˚F) using yeasts that sedimented during the process and were collected from the base of the vessel. The beers were stored cold for lengthy "lagering" periods and final dispense was cool (0 to 10˚C; 32 to 50˚F).

The table on the following page lists the major ale categories and their characteristics.

A dark ale being poured.

TOP-FERMENTATION BEERS: ALES			
Type of Beer	**Origin**	**Typical range of alcoholic strength (percent alcohol by volume [ABV])**	**Characteristics**
Bitter (pale) ale	England and Wales	3.0 to 5.0	Dry hop, bitter, estery, malty, low carbonation, copper color
India Pale Ale	England	5.0 to 8.0	Hoppier than pale ales
Alt (“Alt” means “old”)	Germany	4.0+	Some esters, bitter, copper color
Mild (brown) ale	England	less than 3.5	Dark brown, sweet, mellow
Scotch ales	Scotland	3.0 to 5.0	Sweeter, maltier, darker and less hoppy than English ales
Stout	Ireland	4.0 to 7.0+	Roast, bitter, black
Porter	England	4.5 to 6.5	Similar to stout but less roast character
Sweet stout	England	3.5 to 4.0	Sweet, dark brown/black
Barley wine	England	8.0 to 10.0	Estery, copper/brown
Kölsch	Köln (Cologne) Germany	4.4 to 5.0	Pale gold, light and dry (ale-lager hybrid)
Weizenbier (wheat beer)	Germany	5.0 to 6.0	Banana, cloves, slightly cloudy, straw color
Weissbier	Germany	less than 3.0	Sour due to action of lactic acid bacteria
Trappiste	Belgium	Up to 12.5	Dark, bitter, acidic
Lambic	Belgium	5.0 to 7.0	Amber, often cloudy, fruity, sour

Three types of top-fermenting beer are shown at the right; a German weizenbier (wheat beer), an Irish stout, and an English “pint o’ bitter” ale.

FOR GREATER UNDERSTANDING

Questions

1. What differences are there in the brewing of ales and lagers?
2. What styles of beer have the highest alcohol content?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

The Brewers Association of Boulder, Colorado, publishes the *Classic Beer Styles* series of books through their publishing company, Brewers Publications. As of September 2009, there were eighteen titles in this series, including Terry Foster's *Pale Ale* (1990), David Miller's *Continental Pilsener* (1991), Eric Warner's *German Wheat Beer* (1992), Jim Parker's *Brown Ale: History, Brewing Techniques, Recipes* (1998), and Eric Warner's *Kölsch: History, Brewing Techniques, Recipes* (1998). These books are available through the Brewers Association website (http://www.beertown.org) or through Amazon.com.

Websites of Interest

The Beer Judge Certification Program was founded in 1985 to promote beer literacy and the appreciation of real beer, and to recognize beer tasting and evaluation skills. The program has administered the Beer Judge Examination to 5,184 individuals worldwide. There are 2,997 active judges currently in the program, with 450 holding the rank of National or higher. Since they started keeping detailed records, the BJCP members have judged nearly 500,000 beers and have sanctioned over 3,760 competitions worldwide — http://www.bjcp.org/styles04

Lecture 9:
Beer Styles:
Bottom-Fermentation Beers and Other Product Types

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 69–77.

It is increasingly difficult to categorize beers as being ales or lagers. Indeed, these products are best discussed for their individuality separate from any consideration within the classic ale/lager divide. The table on the following page lists the major lager-style products of the world.

For many years, then, beers have been mixed with other beverages to produce refreshing easy-to-drink products, often with a citrus character. Such products include *shandy* (in the United Kingdom), *radler* (in Germany), and *panache* (in France). It is interesting that one major recent brand extension in the United States has been a lime-flavored variant of the top-selling beer.

In recent years we have encountered chocolate stouts. All manner of other materials continue to be experimented with as the portfolio of beers is expanded: coriander, chilies, pumpkins, ginseng, caffeine, guarana, and more besides. For many years, Mexicans have delighted in *Michelada*, in which lager is mixed with tomato juice and salt and often Worcestershire sauce or even soy or teriyaki sauce.

The advent of *ice beer* was a brewery-based variant on the time-honored habit of Canadians to put beer out into the snow, freezing ice out from it, thereby increasing the alcohol content. *Dry beer* was a marketing triumph coming out of Japan, nothing more than a fully fermented beer low in residual sweetness (compare to dry wine).

By far the biggest beer sector in the United States is *light beer*, in which all of the starch from the grist is converted into a fully fermentable form such that no residual carbohydrate calories survive into the beer. The alcohol strength is adjusted downwards, so that these beers also tend to be slightly lower in the major source of calories in beer, namely ethyl alcohol.

An inviting light lager.

There continues to be some interest in *non- and low-alcohol beers* (NAB/LABs), which truly should be the lowest calorie products because of their very low alcohol content. They can be made by limiting alcohol formation in fermentation or by stripping out the alcohol from a conventionally fermented beer.

At the other extreme we have the "big beers" with huge alcohol levels. As I write, the record holder is Utopias, containing 25.5 percent ABV and aged in wood.

BOTTOM-FERMENTATION BEERS

Type of Beer	Origin	Typical range of alcoholic strength (percent alcohol by volume [ABV])	Characteristics
Pilsner/Pils	Czech Republic	5.0 to 5.5	Late hop, full-bodied, malty, pale amber/gold
Bock	Germany	6.0 to 8.0	Sulfur, malty, colors ranging from straw (Pale Bock) to dark brown (Doppelbock)
Helles	Germany	4.5 to 5.5	Pale amber/gold, very malty, low bitter/hop character
Märzen	Germany	4.5 to 6.5	Medium bitter/hop; toasted character; amber through reddish brown. The Vienna style is very similar.
Dunkel	Germany	4.5 to 5.0	Copper-brown, malt/toast
Schwarzbier	Germany	3.8 to 5.0	Toast, caramel, dry, black
Malt liquor*	United States	6.25 to 7.5	Malt/sweet, little hop, alcoholic, pale
Rauchbier	Germany	4.3 to 4.8	Smoked malt, amber/brown

**Many states decree that any beer containing more than 5.5 percent ABV must be declared as a malt liquor.*

Three types of bottom fermenting beer are shown at the right; a German bock, a German rauchbier, and a typical Czech pilsner.

FOR GREATER UNDERSTANDING

Questions

1. What is the origin of ice beer?
2. How is light beer made?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

The Brewers Association of Boulder, Colorado, publishes the *Classic Beer Styles* series of books through their publishing company, Brewers Publications. As of September 2009, there were eighteen titles in this series, including Terry Foster's *Pale Ale* (1990), David Miller's *Continental Pilsener* (1991), Eric Warner's *German Wheat Beer* (1992), Jim Parker's *Brown Ale: History, Brewing Techniques, Recipes* (1998), and Eric Warner's *Kölsch: History, Brewing Techniques, Recipes* (1998). These books are available through the Brewers Association website (http://www.beertown.org) or through Amazon.com.

Lecture 10: The Quality of Beer: Flavor and Flavor Stability

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 84–92.

The ultimate gauge of whether a beer is acceptable or not to the drinker is how it tastes. However, many factors will influence the customer's judgment of what the flavor is likely to be, before he or she has raised the glass.

The package: Is the labeling attractive and not damaged? What color is the bottle? Is it scuffed? Is the can dented?

How much foam is on the beer? Is it stable? Are the bubbles small and white or big and bladdery?

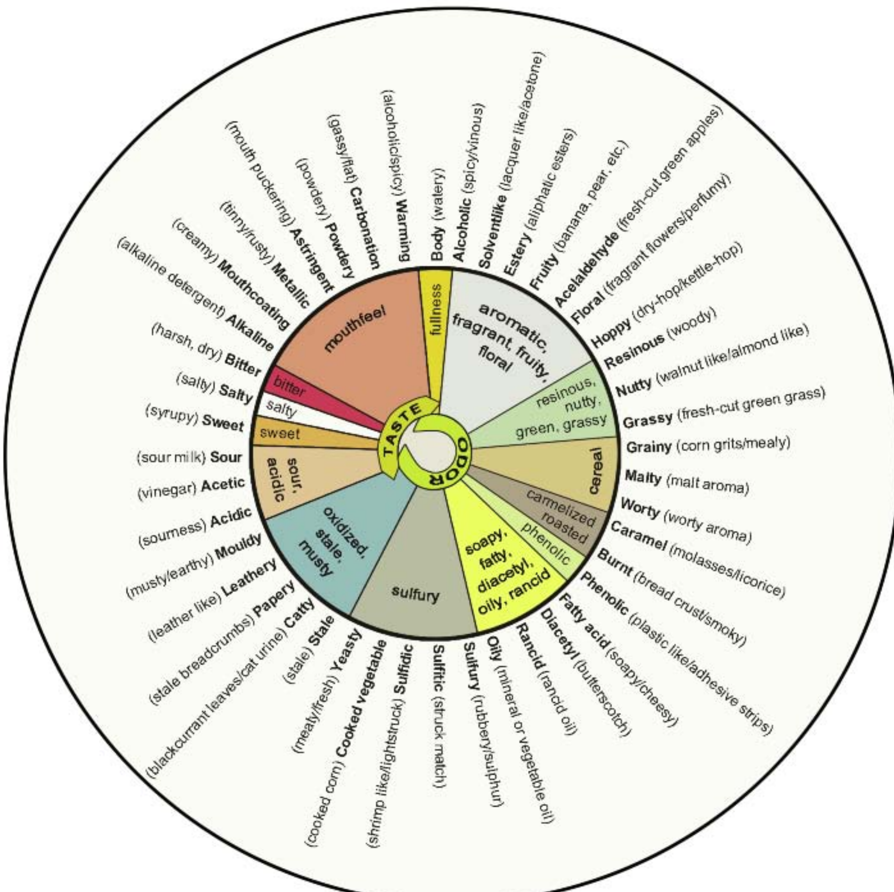
Is the beer clear or cloudy?

What is the color of the beer? Does it look like an ale or a lager?

The actual flavor of beer is due to hundreds of different substances, derived from all raw materials and during fermentation. Some develop in the finished beer. We have talked about many of them in earlier lectures. An expert taster can articulate and score the nuances of beer flavor using a flavor wheel (see page 34). The taste of beer is primarily scored as bitterness (from hops), sweetness (from the grist), sourness (from acids released by yeast), and saltiness (from the water). Brewers also talk of "mouthfeel," which is substantially impacted by carbon dioxide (it gives the "tingle") and any nitrogen gas (it gives "smoothness") that is added to some beers, including those in cans with widgets, to improve foam stability.

Most of the flavor of beer is detected by the nose as aroma, with key compounds being esters (fruitiness) and sulfur-containing substances (vegetable-like character). The aim for any beer should be a good balance of flavors, and not excessive levels of any one characteristic. This makes for good drinkability. Beer is sensitive to light, which causes the breakdown of bitter acids to give skunky flavor. This is especially a problem with beer in green or clear glass, unless specially modified hops are used.

The flavor of beer is continually changing, usually for the worse, as it becomes oxidized, giving cardboard flavors. Brewers therefore try to exclude oxygen as much as possible from the finished beer, and it is also best to store it as cold as possible (but don't freeze it).



An adaptation of Meilgaard's beer flavor wheel.

Questions

1. What “sight” factors affect the taste of beer?
2. What is the problem with green or clear glass?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Beer: A Quality Perspective*. Burlington, WA: Academic Press, 2009.

Lecture 11:
The Quality of Beer:
Appearance

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing,* pp. 78–84.

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Two pints of dark beer with excellent lacing.

Upon pouring a beer into a glass—which I strongly advocate in a civilized world—the first manifestation of quality is the foam. Beer is unusual among carbonated beverages in having a stable head. This is because beer contains proteins, originating in the grist, and bitter acids that stick together in the bubble wall and hold it together. Acting counter to this are fats (think French fries) and detergents that might linger in non-rinsed glasses. These substances kill foam. To produce the foam in the first place there is a need to pour with vigor into the center of the glass. This promotes the "nucleation" of the bubbles—you will see a nice stream of bubbles rising through the beer as you drink. Usually this is accompanied by the inclusion of a little nitrogen in the beer. Since the pioneering work of Guinness, it has become well-known that nitrogen gives much more stable foams. Stable foams will leave appealing bands or films on the side of clean glasses—this is called lacing or cling.

Occasionally foaming can be excessive—so-called "gushing"—in which the beer shoots out of the container when it is opened. This can of course be due to inappropriate agitation of a can or bottle (shaking) but it may be due to a small protein finding its way into the beer from grain infected by molds. Brewers should be fastidious in avoiding this.

Is the beer intended to be "bright" (free from turbidity), or if intentionally cloudy (for example, hefeweissens) is the degree of haziness as expected? The main cause of haze in beer is the linking together of grain-derived proteins (different from the foaming ones) and polyphenols (from grain and from hops).

The color of beer has a major impact on perceived flavor. It is possible to do experiments in which flavorless dyes are added to lagers to make them look like ales: subsequent tasting reveals that such colored beers are said to taste like ales! The color derives from the kilning stage of malting and also from the oxidation of tannin-like molecules (analogous to the browning of sliced apples).

Beer may also develop turbidity through the growth of micro-organisms in it. However, beer is relatively resistant to spoilage by micro-organisms, because it is quite acidic (pH usually 4 to 4.5) and contains substances that inhibit bacterial growth (for example, alcohol and bitter acids). However, some organisms will spoil beer, including bacteria that produce lactic acid and acetic acid.

FOR GREATER UNDERSTANDING

Questions

1. What is lacing?
2. What is the main cause of haze in beer?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Beer: A Quality Perspective*. Burlington, WA: Academic Press, 2009.

Lecture 12:
Beer: Healthfulness and Perception

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 62–65 and 93–102.


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Beer lends itself to more drinking occasions than any other alcoholic beverage. It is also less pretentious than some, yet deserves to be treated with greater reverence than is often the case. There is rather more theater possible with beer than with, say, wine: the nuances of foam, clarity, color, and flavor are surely more complex than anything that occurs in a wine pouring, and yet wine is perceived as being more refined, more challenging to make, and healthier. The reality is that beer is altogether more complex and involved production-wise, as this course has hinted. It is also at least as good for you as wine.

It would be absurd to advocate pretention in the pouring of beer such as is seen in the world of wine, and we certainly do not want those same inflated prices. However, there is more that can be done. How splendid it would be if beers were always poured into the appropriate glass for them—a necessary stage, of course, being that they should be poured in the first place and not drunk straight from the can or bottle.

Would that brewers, rather than trying to push the borders on beer hoppiness or the use of the most extreme ingredient, would celebrate the traditional raw materials that they have used for millennia. One could envisage, for example, supermarket shelves divided according to beers flavored using given varieties of hop—thus Cascade or Hersbrucker or Fuggles analogous to Chardonnay, or Gewürztraminer, or Pinot Noir.

Beer is the perfect accompaniment to so many foods: think Indian, Mexican, and Irish, for instance. We should expect it to be afforded the same menu space as wine.

Beers used to be widely advertised on a health platform, but these days that is not allowed in many parts of the world. Remarkably, though, we know more than ever that beer is far from being empty calories. It is perhaps the richest source of assimilable silicate in the diet, which is one of the reasons why moderate consumption of alcohol counters the risk of osteoporosis.

Beer is a significant source of B vitamins (though not thiamine). Take folate for example: present in beer, not in wine.

Beer contains antioxidants and likely some prebiotics. Its ratio of potassium to sodium is an appropriate one for cardiovascular health. With regard to the latter, it is now appreciated that the hype over the benefit of moderate red wine consumption in reducing the risk of atherosclerosis is just as valid for beer, because the active ingredient is the alcohol.

Other bodily problems seemingly countered by the moderate consumption of beer include kidney stones, gall stones, late onset diabetes, and even dental caries. Critical appraisal of the literature on beer and cancer reveals great inconsistency.

The principal source of calories in beer is alcohol. Most beers do not contain residual sugar in sizeable amounts, although they may contain some larger carbohydrates. The "beer belly" is a myth and speaks to the overall lifestyle of many beer consumers.

Beer as a source of iron is also a myth: iron damages beer quality and brewers seek to avoid its presence in beer.

Some proteins in beer, like wheat proteins, may be a risk for celiac sufferers. There are beers made from sorghum that do not present a problem.

BEER AND NUTRITION

Nutrient/ Ingredient	Regular Beer	Light Beer	"Ultra" Light Beer
Water	327.4g*	335.8g	337.7g
Calories	153*	103	96
Alcohol	13.9g*	11.0g	11.3g
Protein	1.6g*	0.9g	0.6g
Carbohydrate	12.6g*	5.8g	2.6g
Fat	0.0g	0.0g	0.0g
Cholesterol	0.0g	0.0g	0.0g
Calcium	14mg	14mg	14mg
Magnesium	21mg	18mg	14mg
Phosphorus	50mg	42mg	28mg
Potassium	96mg	74mg	60mg
Sodium	14mg	14mg	11mg
Niacin	2mg	1mg	N/A**
Folate	21mcg	21mcg	N/A**

g = gram
mg = milligram
mcg = microgram
*Includes ales, lagers, porters, premium beers and stouts. All other nutrients based on lager samples only.
**Not available.

Typical nutritional values per serving as listed on some of the most popular beer brands in the United States.

Courtesy of about.com

Questions

1. Why should beer be considered at least as complex as wine?
2. What are some possible health benefits of beer?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Grape versus Grain*. Cambridge: Cambridge University Press, 2008.

Baxter, E. Denise, and Paul S. Hughes. *Beer: Quality, Safety, and Nutritional Aspects*. London: Royal Society of Chemistry, 2001.

Websites of Interest

1. The Brewers of Europe was founded in 1958 and is based in Brussels, Belgium. They advocate for the European brewing sector to the European institutions and international organizations. Current members are the national brewers' associations from European Union member states, Norway, Switzerland, and Turkey. — http://www.brewersofeurope.org
2. The Institute of Brewing and Distilling provides the *Beer Academy* website, an educational body founded in 2003 and dedicated to helping people understand, appreciate, and enjoy beer. — http://www.beeracademy.co.uk
3. The *Here's to Beer* website is an excellent resource for learning more about beer, which type of beer goes best with different meals, how to better appreciate beer, and more. — http://www.herestobeer.com

Lecture 13:
Beer in the United States

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 5–7, 13–17, and 32–41.

© Rich Gallagher

Sir Walter Raleigh is said to have malted corn in Virginia in 1587, but it was the Pilgrim Fathers in December 1620 who shipped the first beer into the country, landing at Plymouth Rock because, according to a written account:

> We could no longer take time for further search or consideration, our victuals being much spent, especially our beer, and it being now the nineteenth of December.

Dutch explorer Adrian Block opened the first brewery (in New Amsterdam) in 1613. The Dutch West India Company opened the first public brewery in Lower Manhattan in 1632. Beer was considered a drink of moderation and a preferable alternative to the dubious alternatives made by the distillation of fermented corn.

The founding of America's longest-standing brewery occurred in Pottsville, Pennsylvania, in 1829 by David Yuengling. In 1838, Alexander Stausz and John Klein in Alexandria, Virginia, were the first to produce lager-style beer in America. In 1844, Jacob Best founded the company that would become Pabst, thanks to the wedding of Best's daughter to Frederick Pabst. Bernard Stroh opened his brewery in Detroit in 1850. Five years later, Frederick Miller bought out Jacob Best's sons' Plank Road Brewery in Milwaukee. In 1860, Eberhard Anheuser purchased a struggling St. Louis brewery and, after his daughter married a supplier named Adolphus Busch, Anheuser-Busch was born. And then, a dozen years later, another migrant from the Rhineland, Adolph Coors, set up shop in Colorado.

By 1873, there were over four thousand breweries in the United States, outputs averaging some 2,800 barrels each. Rationalization meant that by the end of World War One there were half as many breweries, each producing on average twenty-times more beer than forty-five years earlier. By the time the Second World War had run its course, there were just 465 breweries in the United States, their output averaging some 190,000 barrels.

The production of lager demanded ice. Accordingly, such beer had to be brewed in winter for storage (*lagering*) until the greater summer demand. Milwaukee rapidly emerged as a great brewing center, with Pabst and Schlitz amongst those competing with Miller. Once Carl Von Linde in 1870 showed how machines could be developed to produce ice, lager could be brewed any time and anywhere. And the application of Pasteur's proposals for heat-treating beer to kill off spoilage organisms and the advent of bottle-and-stopper technology meant that beer could be packaged for home consumption and consumed almost anyplace, after shipment nationwide on the burgeoning rail network in railcars that were developed with the latest refrigeration technology. Such developments and also the advent of cans, with their lighter weight as compared to bottles, and metal kegs, which allowed for more robust shipping of draught products, reinforced the hand of the major brewers as they took their merchandise to the great cities across the nation.

The temperance movement began in the United States in the early nineteenth century, with thirteen states becoming "dry" between 1846 and 1855. Carry Nation's prayers and lectures in Kansas developed into more physical acts of objection to drink when she and her followers started to smash beer containers with hatchets they'd hidden beneath their skirts. The Anti-Saloon League was formed in Washington, D.C., in 1895. Widespread calls for prohibition were largely precipitated by claims that extensive drunkenness severely hampered productivity during the First World War. The Volstead Act of 1920 was the basis on which the Federal Government enforced the block on all intoxicating liquor, defined as a drink containing in excess of 0.5 percent alcohol. Many breweries were rendered unable to go about their primary business. They developed alternative products that their technology might be turned to, such as ice cream, non-alcoholic malt-based beverages (including "near beer"), yeast, and syrups.

© James Dobson

Signs of the Times

An advertisement for "temperance beer" in Los Angeles and a "repeal" license plate that became popular in many cities during the late 1920s.

Unsurprisingly, the introduction of official prohibition prompted the growth in illegal homebrewing and of the "bootlegging" and "speakeasy" culture. By 1933, opinion in the United States had changed and the passing of the Cullen Bill allowed states not having local prohibition laws to sell beer containing 3.2 percent alcohol by weight. On April 7, 1933, the Twenty-First Amendment to the United States Constitution saw a repeal of the Eighteenth Amendment. Whether to enforce prohibition or not became a State issue, but it took Mississippi until 1966 to emerge from being the last dry territory.

When President Carter signed into law the freedom for home brewers to "come out of the closet," the Craft Brewing industry was launched. First off the blocks was Jack McAuliffe, with a typically home-built artisanal set up in Sonoma, California. Soon, others flocked to his location to glean ideas, amongst them Ken Grossman, who soon had to choose between buying a bicycle shop and building a brewery. He chose the latter, so now we are grateful for Sierra Nevada in Chico, producing more than 700,000 barrels every year from the most beautiful brewery in the world.

In San Francisco, a different model was at play, insofar as a long-standing brewing company very much on its uppers was rescued by a student of Japanese philosophy from Stanford, Fritz Maytag. And now he and his Anchor Brewing Company producing the legendary San Francisco are icons.

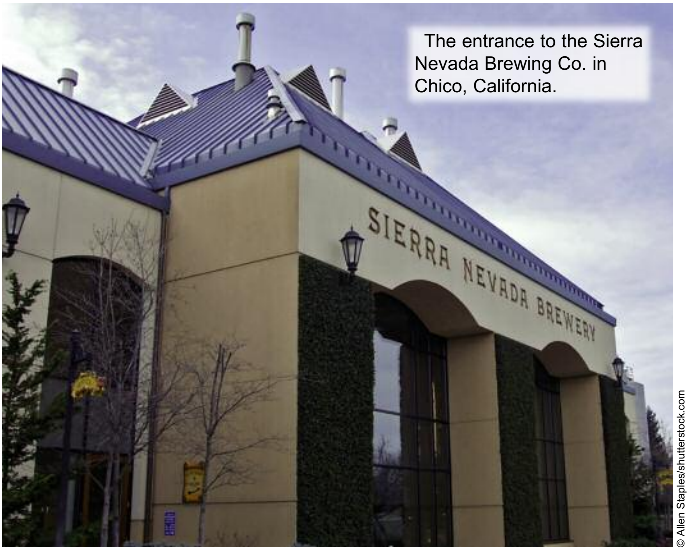
A fourth character at the forefront of the "revolution" was Charlie Papazian, a Boulder-based schoolteacher who was to become the doyen of home-brewers everywhere and who built up the Association of Brewers, a thriving meeting point for all craft brewers.

Regrettably, too many in the craft sector fire barbs at the "big guys," whereas the reality is that the major companies are champions of quality and consistent brewing. Merely because a beer is subtly flavored does not make it bad. Just because a beer is piled with hops does not necessarily make it good.

In speaking of the larger companies, then, there is almost a frightening degree of consolidation going on in the industry. Recent examples have been Anheuser-Busch's purchase by InBev and the merging of the United States interests of Miller and Coors.

This polarization will continue: the bigger will get more and more powerful while at the other extreme new ventures will come into play as others fall by the wayside.

A reality not appreciated by many is that making a living in the craft brewing sector is never easy. It is hard work, invariably for low pay. But what fun!



The entrance to the Sierra Nevada Brewing Co. in Chico, California.

© Allen Staples/shutterstock.com

FOR GREATER UNDERSTANDING

Questions

1. What effect did the world wars have on beer production in the United States?
2. What are the possible ramifications of consolidation among large beer brewers?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Smith, Gregg. *Beer in America: The Early Years—1587–1840: Beer's Role in the Settling of America and the Birth of a Nation*. Boulder, CO: Siris Books, 1998.

Yenne, Bill. *The History of Beer in America*. San Francisco: AGS Bookworks,2007.

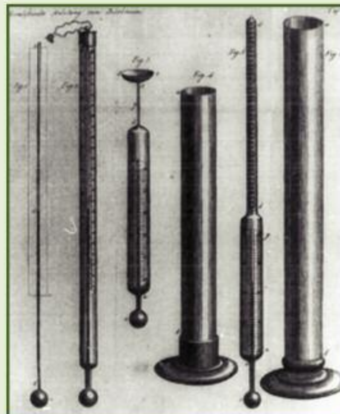
Websites of Interest

1. Association of Brewers page provides information on the modern history of craft brewing. — http://www.beertown.org/education/craft_history.html
2. BeerHistory.com website provides detailed information on the history of brewing in America. — http://www.beerhistory.com
3. *Democracy's Drink* is an online community platform where craft beer enthusiasts can discover and promote content through various online mediums. — http://www.democracysdrink.com

Lecture 14: The Impact of Science on the Development of the Brewing Industry—Past, Present, and Future

The Suggested Reading for this lecture is Charles W. Bamforth's *Beer: Tap into the Art and Science of Brewing*, pp. 42–49 and 184–205.

Brewing has always been more science than art and for the longest time brewers have used scientific tools and approaches to control their processes as they pursue consistent excellence in their beers. Michael Combrune in 1762 was the first to employ a thermometer in a brewery, while John Richardson constructed the first brewer's saccharometer in 1784.



Above: Thermometers and saccharometers in use by the end of the eighteenth century. Left: A modern combination thermometer/hydrometer used by brewers.

A saccharometer consists of a large weighted glass bulb with a thin stem rising from the top with calibrated markings. The sugar level can be determined by reading the value where the surface of the liquid crosses the scale. A solution with a higher sugar content is denser, causing the bulb to float higher. Less sugar results in a lower density and a lower floating bulb.

Images courtesy of Raudins Publishing

The first textbook on brewing was from Thomas Tryon in 1691, eleven years after Antonie van Leeuwenhoek reported to the Royal Society in London that he had developed a microscope which had enabled him to inspect a drop of fermenting beer to reveal therein something we now recognize as yeast cells. One hundred and fifty years later Charles Cagniard-Latour in France and Theodor Schwann and Friedrich Kutzing in Germany independently claimed that yeast was a living organism that could bud. They were ridiculed by the Germans Justus von Liebig and Friedrich Wöhler, who insisted (we believe with sarcasm) that yeasts comprise eggs which turned into little animals when put into sugar solution. Louis Pasteur, in sorting out the difficulties that brewers were having with beer going sour after fermentation, demonstrated that the infection was due to airborne organisms, and in 1860 Pasteur concluded that alcoholic fermentation is due to the action of yeast cells.

In 1883, Emil Christian Hansen, of the Carlsberg Laboratory in Copenhagen, proposed that many brews were unsellable because of infection by "wild yeasts." It was Hansen who perfected a system for purifying yeast into a single, desired strain, and this forms the basis for the brand-to-brand individuality of beers to this day.

In the ensuing one-hundred-plus years, the technology for the malting of barley and brewing of beer has advanced remarkably, building on the scientific explorations of many gifted scientists worldwide. The processes are enormously more efficient now than they were even fifty years ago. For instance, the malting process is now completed in less than a week, whereas it took twice as long half a century ago. Brewing can take as little as one to two weeks, although many brewers insist on longer processing times: Brewers take pride in their products and, while striving for efficiency, won't take shortcuts if quality would be jeopardized.

Brewing scientists, too, have bequeathed to society many concepts that are now accepted as commonplace. For instance, James Prescott Joule was employed in a laboratory at his family brewery in Salford, England, when he contemplated the research that led to the First Law of Thermodynamics. Dr. Søren Sørensen, working in the Carlsberg Laboratories, explained the concept of pH (the universal scale for measuring acidity and alkalinity) and its importance in determining the behavior of living systems, notably through an impact on enzymic activity. W.S. Gosset, who was breeding new varieties of barley and hops for Guinness, published under the pseudonym "Student," a name familiar to those statisticians everywhere who apply the T-test (any statistical hypothesis test). Not least, of course, the impact of Pasteur on modern society extends far beyond beer.

Brewers and brewing scientists are part of an impressive international community, in which scientific discoveries, technological developments, regularized methodology in pursuit of analytical excellence, and much more are discussed and advanced. Notable organizations are the Institute of Brewing and Distilling, the American Society of Brewing Chemists, the Master Brewers Association of the Americas, and the European Brewery Convention.

An old boss of mine, a chemical engineer, despaired of the perceived inefficiency of the brewing industry, with all the energy utilized, basically, in effecting successive addition and removal of water as barley passes through to beer. He predicted the day when beer would be made by adding flavors, foam, and color to a bland alcoholic base. There will undoubtedly come a time, perhaps sooner rather than later, when flavor technology will make this approach a reality. Indeed, there are many alcoholic beverages ("malternatives") that are made from bland beer bases by the addition of flavors. In Japan, to circumvent certain tax laws, there are new products, *happoshu* ("sparkling spirits"), categorized as a "third beer" based on the fermentation of "worts" that contain little or no malt. The driving

Asahi, a major brewer in Japan, offers regular and *happoshu* beers for consumers.

Darrell Angai, © 2008

forces for tomorrow’s beverage strategies are technical (Can it be done?), economic (Is it cheaper?), environmental (Will it be resource saving?), and attitudinal (What do customers want?).

We can envisage the brewing industry moving into two segments: (a) those making diverse alcoholic beverages by flavor technology based on high-efficiency production of a bland alcoholic base and (b) what I call the “slow beer” movement, with beers made according to traditional raw materials, processes, and values.

It is important to remember that the major cost components of a bottle of beer are the cost of the packaging process itself, marketing, production, and taxation. These are the main areas that a brewer will focus on with the aim of lowering costs. In turn, major factors are raw material supply (What is the long-term prognosis for malting barley and hops?), water availability, waste reduction, and energy saving. Political pressures will not lessen. On the other hand, consumer science will move to a status where there is a far better understanding of what consumers look for in a product and how a beer might best pair with a meal. We will also have a better handle on the benefits and risks of alcohol consumption, individual by individual.

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FOR GREATER UNDERSTANDING

Questions

1. How has science affected beer brewing?
2. What is the “slow beer” movement?

Suggested Reading

Bamforth, Charles W. *Beer: Tap into the Art and Science of Brewing*. 3rd ed. New York: Oxford University Press, USA, 2009.

Other Books of Interest

Bamforth, Charles W. *Scientific Principles of Malting and Brewing*. St. Paul, MN: American Society of Brewing Chemists, 2006.

Combrune, Michael. *The Theory and Practice of Brewing*. 1804 ed. Whitefish, MT: Kessinger Publishing, LLC, 2008.

A limited collector’s edition reprint of Combrune’s *The Theory and Practice of Brewing* (1762 ed.) is available through the Raudins Publishing (Chagrin Falls, OH) website — http://www.raudins.com/BrewBooks

Websites of Interest

1. Darrell Angai’s blog *Darrell in Japan* includes a review of Japanese beer products in the Beer Review section. — http://darrellinjapan.wordpress.com/2008/08/30/the-beer-review
2. American Society of Brewing Chemists — http://www.asbcnet.org
3. European Brewery Convention — http://www.europeanbreweryconvention.org
4. Institute of Brewing and Distilling — http://www.ibd.org.uk
5. Master Brewers Association of the Americas — http://www.mbaa.com
6. Brewing at the University of California, Davis — http://foodscience.ucdavis.edu/bamforth