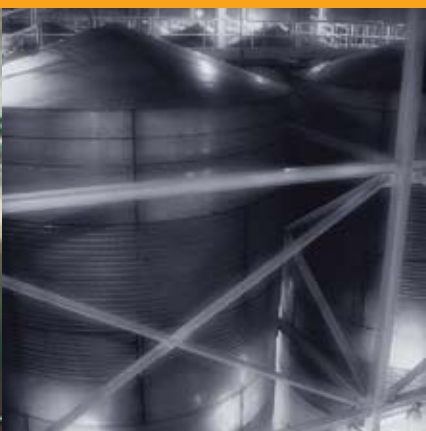
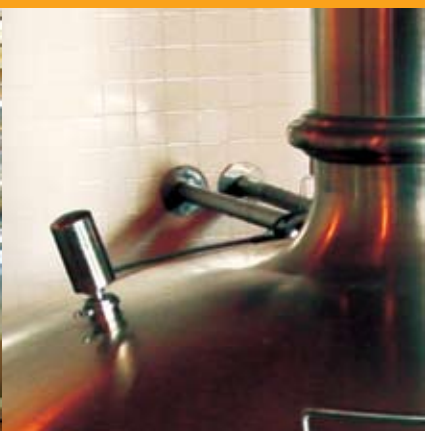


A photograph of brewing equipment. In the foreground, a tall glass is filled with golden beer topped with a white head of foam. To the left, a metal coil, likely a wort chiller, is visible. In the background, a thermometer shows a temperature of approximately 65 degrees. The scene is set against a light, neutral background.

VOLUME III : THE BREWING PROCESS

THE PROCESS IN BRIEF • BREWING  
FERMENTATION • LAGERING • AGING • FINISHING



## THE PROCESS IN BRIEF

Brewing truly represents a marriage of art and science. It is interesting to note that while brewers have developed a great deal of scientific knowledge during the past 100 years to help them monitor and measure components of brewing much more accurately, the essential procedures have changed very little over thousands of years.



The process can be divided into four basic steps:

- 1 Brewing
- 2 Fermenting
- 3 Lagering
- 4 Finishing

Each of these steps will be discussed in detail throughout this volume of *Beer: A Reference Guide to Ingredients, Brewing Science and Styles*. But before that, consider how the basic steps must be adjusted for each brew.

Mother Nature, after all, is not known for her consistency. For each crop and each individual harvest, brewmasters must taste, test and assess the ingredients to determine how those materials will perform during the brewing process.

A brewmaster's job is to control and to influence every step of the process to achieve a beer's desired taste and quality. Consistent results depend upon careful handling.

Three steps of the brewing process,

# THE PROCESS IN BRIEF

in particular, focus heavily on nature's methods of creating and changing food substances:

## MALTING: ENZYME FORMATION

Grains are predominantly composed of starch, intended by nature to serve as a food source for the growth of a new plant. When the grain is planted into the soil and watered, a plant begins to grow. Nature has provided each kernel of grain with an enzyme system that allows it to convert starches to sugars, needed for the natural growth process by the new plant.

This same natural enzyme system is used in brewing to provide sugar as food for the yeast that will convert the malted grain into alcohol and carbon dioxide.

In the malting process — which takes place before the grain reaches the brewhouse — the maltster germinates each barley kernel in a controlled growing environment, without soil, enabling the grain's natural enzyme system to completely develop. (*See also* VOLUME II: INGREDIENTS.)

The germinated grain is then dried, or “kilned,” to remove unwanted moisture and stop the kernel's growth without destroying the fragile enzyme system. The length of time the grain remains in the kiln as well as the temperature at which it is dried determines the resulting color of the malt. It also influences the flavor of the malt by driving off grassy and green characteristics and developing toasted, nutty

and “malty” flavors.

This “malted” grain now possesses a complete starch conversion system. Most of the starch reserves remain, but the cell walls around the starch have been broken down by the enzyme system. The barley kernel's remaining starch and enzymes will be used in the brewhouse to produce wort.

## MASHING: WORT PRODUCTION

In the brewhouse, when ground malt combines with a large quantity of water at the proper temperature, the enzymes in the “malt mash” are activated, and the rapid conversion of starches to sugars, which began in the malt plant, continues.

The production of wort in the brewhouse serves as a key element in the brewing process. The grains used and the time and temperature schedules followed determine the composition of the wort sugars. This process directly impacts the way the yeast performs during fermentation, which also will affect the flavor of the finished beer.

## FERMENTATION: ALCOHOL PRODUCTION

Yeast is a living organism requiring basic nutrients to sustain life and growth. An essential part of its diet is sugar, which, under certain conditions, yeast will convert to alcohol, carbon dioxide and small quantities of many other substances to ultimately determine the final beer flavor characteristics.

# BREWING

In the brewhouse, brewers combine malt and other grains (depending on the beer style) with water to prepare a liquid extract called “wort” for the fermentation process. The composition of the wort will have a significant influence on the compounds produced during fermentation and on the ultimate aroma, taste and overall flavor of the beer.



To achieve that end, four main steps occur in the brewhouse operation:

- 1 *The milling process, or ingredient preparation.*
- 2 *The mashing process, or extraction and conversion.*
- 3 *The straining operation, or clarification and filtration.*
- 4 *The kettle operation, hop addition and subsequent cooling.*

## MILLING

The milling operation has somewhat conflicting objectives that must be delicately balanced — to grind the starchy interior of the kernels finely enough to permit easy conversion to sugars, while not grinding the malt husks because they are needed later in the process to naturally strain and filter the wort.

Some unmalted grains such as rice, but unlike barley, can be ground as finely as desired, since their husks or hulls previously have been removed. Corn grits need not be ground and, as

# BREWING

a result, bypass the mills.

The malt mill uses sets of rollers and screens to separate the husks from the kernel and grind the kernels into the grist necessary for mashing.

## MASHING

Malt and water are carefully measured and mixed in the mash tank (or tun), essentially a cooking pot. This activates the natural enzymes that have remained dormant since the kilning process.

There are two major groups of enzymes of concern to a brewer: those that act on starch to break it into simple sugars; and those that act on proteins to break them into simple amino acids. The sugars are fermented into CO<sub>2</sub> and alcohol while the amino acids are essential for the health and

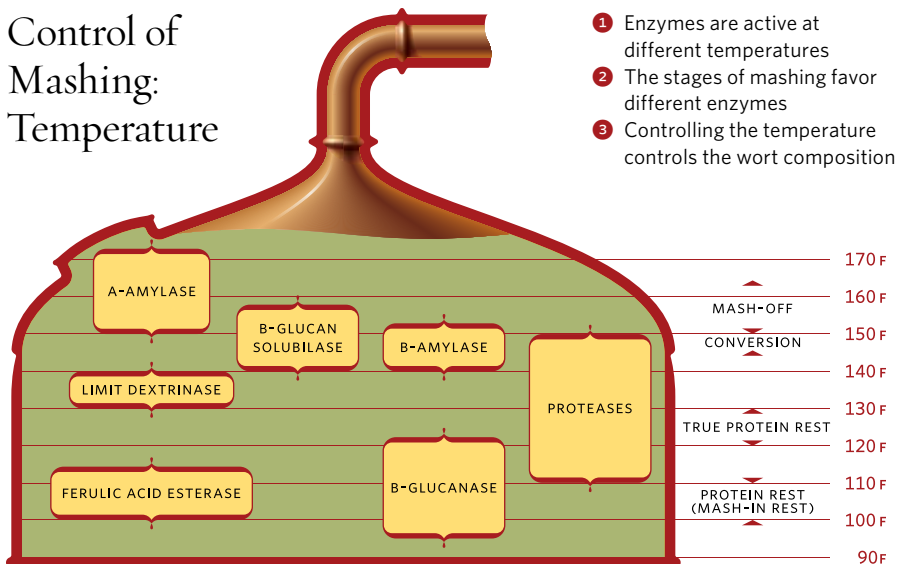
nutrition of the fermenting yeast. Each enzyme operates at different optimum temperatures, and the brewer must control the conditions carefully to harness the natural activity during the mashing process.

Mash tanks frequently are equipped with large, variable-speed agitators and steam coils for heating the mash at a controlled time and temperature cycle. For an all-malt beer, typically (except decoction mashing) only one mash vessel is required — a single-mash system.

Some all-malt beers employ a double-mash system to boil small fractions of the malt mash in steps in a process called decoction.

For brews that use both malt and an adjunct (with the exception of syrups or pre-gelatinized adjuncts), the brewer uses two mash cooker vessels

## Control of Mashing: Temperature



# BREWING

— a double-mash system. In these cases, the malt vessel is called the mash tank and the one used for the adjunct is called the cooker.

The mashing process is about controlling conditions for malt's natural enzyme systems to act on the ingredients to create food and nutrition for yeast; to set the body, balance and nutritional profile of the finished beer; and to extract or develop flavor for the beer's final profile. These conditions include thickness of the mash, pH and, most importantly, temperature.

Temperature of mashing typically goes from low to high, with stepwise heating and rests at points where certain enzymes are active. The final, hottest stage is often hot enough to deactivate enzymes completely, stopping their activity and permanently setting the profile of the wort.

There are three main temperature rests in mashing (*illustration at left*):

- ❶ Protein rest
- ❷ Conversion rest
- ❸ Mashing off (deactivation)

## PROTEIN REST

During this period, larger protein molecules in the malt break down into smaller, amino acid fractions used by the yeast later in the brewing process. In addition to providing nourishment for the yeast, this protein is important to beer flavor and foam. Brewers often call this phase of the process the protein rest.

## CONVERSION REST

The mash temperature is raised to the ideal temperature for natural enzymes to act on the starch from malt and other grains, and converts it into fermentable sugars. The brewmaster decides the degree to which this conversion will take place — lower temperatures for longer times for more conversion; higher temperatures for shorter times for less.

Controlling the conversion temperature of the mash is critical, because the process is extremely temperature sensitive. Small temperature variations can result in significant changes in wort composition and, ultimately, the flavor of beer.

More conversion means higher levels of fermentable sugars and lower levels of unfermentable “dextrins” (short sugar chains that are too large for yeast to metabolize), which add body to beer. A greater degree of conversion means:

- ❶ Lighter, less sweet and full body
- ❷ Higher potential alcohol in the wort
- ❸ Lower calories and carbohydrates for a given alcohol level

Therefore, the degree conversion is critical to the profile of the beer because it sets the alcohol content, the caloric value and, in part, the relative fullness, sweetness or dryness of the beer.

## WORD PRODUCTION: LAUTERING

The next step in the brewing process involves separating the dissolved extract from the malt husks and other

# BREWING

insoluble grain particles in the mash by straining, or “lautering.”

A lauter tun, used for this straining process, contains many slotted openings to hold back the grain husks, forming a natural filter bed. The liquid draws through the grain bed into the brew kettle. This liquid, called “wort,” is clarified as it passes through the grain. As the clean, sweet wort is transferred to the brew kettle, the top of the grain bed is flooded with hot water in a process known as sparging, such that the wort running to the kettle becomes less concentrated as the kettle fills.

In some countries and certain markets, unfermented wort is filtered, carbonated and packaged for sale as a beverage known as malta, a sweet, protein-rich product that is consumed for

its nutritional benefits.

The clarified wort moves from the lauter tun to a brew kettle and is heated to boiling. This large, typically stainless steel vessel will serve as the location for the clarified wort to boil for a recipe-determined time.

Next comes the hop addition, one of the most important parts of a boil. As the wort boils, a carefully measured amount of hops is added based on the specific beer recipe. (See VOLUME II: INGREDIENTS for details on hop varieties.) Hop blossoms contain oil and resins, which are released during boiling to impart their unique taste and aroma characteristics. Specific varieties of hops in exact quantities are dropped into the brew kettle at different times during the boiling cycle. Volatile hop

Besides the addition of hops, other important reactions occur in the kettle that have a fundamental impact on beer flavor and quality:

- 1 Boiling inactivates any active enzymes left from the mashing process ensuring the fermentability of the wort is set.
- 2 The wort is concentrated through evaporation, and color develops by caramelization.
- 3 Natural volatile compounds are stripped by vigorous boiling. An example is dimethyl sulfide (DMS), which has a sweet-corn aroma when present at high levels and formed naturally from precursors in malt. The appropriate level of DMS in a beer is a matter of beer style and personal taste of the brewmaster — a hotter and more vigorous boil lowers it.
- 4 Protein from malt combines with polyphenols (tannins) from malt and hops, and forms flakes, known as trub or hot break. A clean and bright hot break ensures brightness, clarity and stability of the finished beer.

# BREWING

oils dissipate fairly quickly, and over time hop acids isomerize and add bitterness to the beer. The amount and variety are determined by a brewmaster to create the desired hop character and bitterness level of a beer.

The boiling process is a technically complex procedure. The length of the boil also can help determine color and flavor characteristics. The boil develops important flavors and removes others by driving grainy and grassy character up the kettle stack.

## WHIRLPOOL

Wort enters the whirlpool in a tangential entry that creates the whirlpool motion. The whirlpool motion draws the trub — or kettle break — out of the wort via centrifugal motion and forms

a trub “cone” — a pile in the bottom center of the tank.

The clear wort is decanted off, leaving behind the dense trub pile.

## WORT PRODUCTION: COOLING

Before moving on to fermentation, the brew must be cooled and prepared for the addition of yeast. Cooling promotes the formation of a secondary coagulation of protein — called cold break or cold trub. It is much smaller than the hot trub particles formed in the boiling step.

Cold trub sometimes is removed with an additional settling step. A small amount of trub carryover into primary fermentation, however, often is desirable. Trub has some nutrient value and is necessary for the yeast’s proper growth.

# FERMENTING

Fermentation serves as the foundation of the brewing process — the conversion of wort into beer. Here, the yeast converts fermentable sugars created during mashing to alcohol, natural carbonation (CO<sub>2</sub>) and compounds that determine the ultimate flavor profile of the beer.

Everything that occurred in the malt-house and the brewhouse involved careful preparation of the yeast nutrients and other substances that could influence the taste of the beer. Everything that occurs after fermentation primarily preserves the beer flavor established by fermentation.

In practice, fermentation for lager beers occurs in two distinct steps:

- ① *The primary fermentation.*
- ② *The secondary fermentation, or the lagering or aging process.*

The primary fermentation takes anywhere from a few days to about two weeks, depending on the yeast strain and beer style. During this time, the yeast activity is greatest and most of the wort sugars convert to alcohol and CO<sub>2</sub>.

The secondary fermentation, or the lagering or aging process, takes several weeks at a minimum, and completes the reduction of fermentable extract and helps achieve a crisp beer profile



# FERMENTING

typical of lager styles. Ale fermentations are essentially complete after this primary fermentation, and often only have a short maturation rest or proceed directly to finishing with no aging.

## PRIMARY FERMENTATION

Yeast is blended into the wort stream in a process called pitching. Cooled wort must be injected with sterile air or oxygen after cooling to provide a proper environment for vigorous yeast growth.

Just as a beer has a recipe for ingredients — amounts of malt, varieties, rates and the timing of the hop addition — a beer also has a critical recipe for fermentation.

The most critical factor is the yeast strain itself. The fermentation is the result of the growth and natural

activity of millions of copies of itself. Yeast strains behave differently and add different flavors to beer depending on temperatures, concentrations, levels of oxygen and in different worts. The brewmaster's job is to provide the conditions for a particular strain to produce the right flavors for the beer.

Many factors can affect the rate of fermentation and, therefore, the fruity, yeasty or acidic character of the beer. A beer recipe includes oxygen addition rates, pitching rate, cooling, temperature attemperation temperature, and rate and timing of additional cooling after primary fermentation is finished.

At the completion of primary fermentation, the alpha beer is removed from the fermentor. Most of the fermentable sugars have been converted to alcohol and CO<sub>2</sub>, but the beer taste

## 2

### BASIC CATEGORIES OF YEAST

#### Lager Yeast

*Saccharomyces Uvarum* or

*Saccharomyces Carlsbergensis*

Generally prefers lower temperatures and settles to the bottom of the tank during fermentation and maturation. Produces crisp, lightly fruity and balanced flavors that are the hallmark of lager styles.

#### Ale Yeast

*Saccharomyces Cerevisiae*

Generally prefers warmer temperatures and rises to the top of the vessel during primary fermentation. Also known as top-fermenting yeast. Produces the fruity characters that often are signatures of full, round ale styles.

# FERMENTING

remains unfinished. Additional work remains for the yeast. The beer — often called green beer or ruh beer at this point — now can transfer to secondary fermentation or aging.

## WHERE THE YEAST ORIGINATES

The majority of the pitching yeast for any new fermentation came from prior fermentations. As the yeast's food supply or fermentable extract becomes depleted, however, the growth slows and the yeast begins to settle to the bottom

of the fermentor — a process referred to as flocculation.

Yeast activity can be further reduced by cooling the fermentor to increase the flocculation rate. The yeast crop is then harvested from the heavily concentrated yeast slurry, which forms on the bottom of the tank.

Brewers take great care in ensuring a pure culture yeast strain because as the yeast is so vital to the total flavor profile of the beer.

## LAGERING · AGING

**The History:** In the mid-1880s, European brewers introduced the lagering — or aging — process in the United States. The technique of using ice for cooling and the subsequent development of refrigeration made possible year-round brewing of lager beers.

Lagering is still part of fermentation and uses sufficient amounts of yeast. This “secondary fermentation” takes place either in lager tanks or in the same tank as primary fermentation after cooling and yeast removal.

### LAGER TANKS AND CARBONATION

Lager tanks usually are built to withstand higher pressures. Fermentable sugars are very low at this stage of the process, and yeast activity and heat generation are considerably less.

During the aging process, beer remains under elevated pressures for two reasons — to naturally carbonate the beer and to keep the beer under CO<sub>2</sub> pressure, free from the damaging effects of oxygen.

The most important part of the lagering process is the change in composition of the beer itself — the secondary fermentation. When the yeast had plentiful food, it took what it needed and created a wide range of fermentation products as it “hurried” through the primary fermentation. The sec-

ondary fermentation reduces certain compounds produced during primary fermentation that give beer a full, unbalanced or unfinished taste. The resultant beer is clean, crisp and fully mature.

### A BIT ABOUT BEECHWOOD AGING

Anheuser-Busch touts its beechwood aging process. Its primary purpose is improving the yeast-to-beer contact to complete the maturation process of lagering.

Through this process, the yeast settles onto an enormous surface area created by the beechwood chips, thereby keeping the yeast off the bottom of the lager tank and greatly increasing its contact with the beer. The increased surface area allows for complete maturation and slow, mellow blending. The beechwood chips add no flavor to the beer. In fact, beechwood is used because potential flavor influences are easily removed from its chips by a simple cooking procedure.

# FINISHING

To keep the lagered beer flavor and clarity intact after packaging, brewers must remove yeast and some unstable protein materials through a process called finishing. It requires two steps: *Chillproofing* and *Filtration*.

## CHILLPROOFING

Among key beer quality characteristics such as taste, color and clarity, clarity represents the most immediately observable characteristic of a beer. Following the lagering process, beer looks quite hazy because of protein particles and residual yeast suspended in the beer. Although protein particles may dissolve in the beer at room temperature, they become insoluble at the cold temperatures at which beer is served, creating a visible haze. This type of haze is known as chill haze.

Since the combination of proteins and other beer constituents called polyphenols cause chill haze, removal of either component will prevent it. Unfortunately, it is not desirable to fully remove either component. Proteins provide foam stability and flavor characteristics. Polyphenols enhance the snap and bitterness of the beer and help prevent undesirable aging effects.

Therefore, to prevent the reaction that results in chill haze, some brewers remove certain — but not all — of the proteins from the beer before the

filtration step. This process is known as chillproofing.

## FILTRATION

Through beer filtration, brewers strive to remove suspended particles of yeast, protein and silica gel, resulting in a clear, finished beer. Beer gets pumped through special filters coated with diatomaceous earth (DE) known as Kieselguhr filters in Germany. DE is the fossilized remains of single-cell organisms called diatoms.

When formed into a filter cake on the stainless steel screens inside the Kieselguhr filter, the small DE particles create a depth filter. More DE is continuously added throughout the filter run to offset the increasing amount of insoluble material coming in with the beer. The additional DE is very important to the filter performance and causes the cake to grow as more beer is filtered.

The result is bright beer with brilliant clarity at any temperature. It is worth noting some beer styles such as Bavarian- or American-style Hefeweizen

# FINISHING

zens are left unfiltered and not chill-proofed for the white, cloudy, yeasty haze typical of the style.

## PASTEURIZATION

Pasteurization is the process of gentle heating and rapid cooling of fresh packaged beer to prevent bacterial contamination.

The filled and closed packages of beer are conveyed through different sections of a “tunnel” pasteurizer and sprayed with attemperated water — increasing, holding, then decreasing the temperature. This first accomplishes

pasteurization, then rapidly recools the beer within minutes.

Every package must be sprayed with water for the necessary time and of the correct temperatures to receive the total pasteurization heat units required. Too little may result in poor flavor stability of the beer because of the remaining live microorganisms. Too much may have a cooking effect, causing accelerated staling of the beer. The balanced, tightly controlled and gentle treatment results in stable and fresh-tasting beer.

