

Mashing and Wort Production



Larry Horwitz

Mashing Procedures

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

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

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

Lautering

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

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

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

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

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

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

Chilling

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

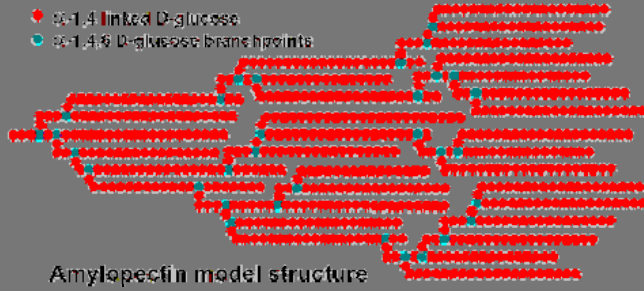
Converting Starch to Sugar (a quick review)

Starch Degredation

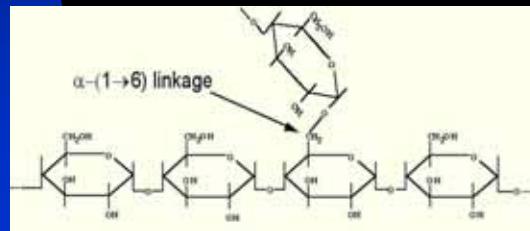
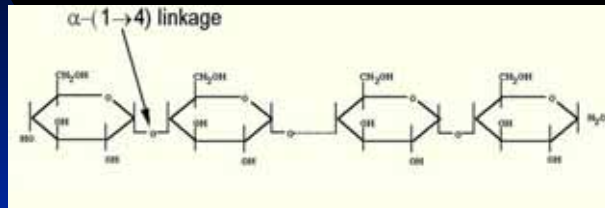
Raw Barley
(Complex Starch)

Malted Barley
(simple Starch)

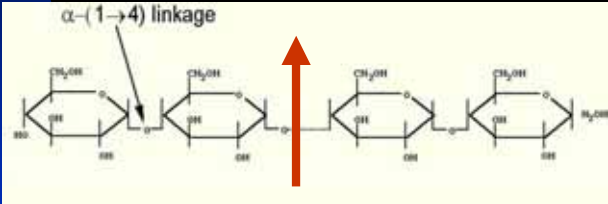
Mash
(Starch to Sugar)



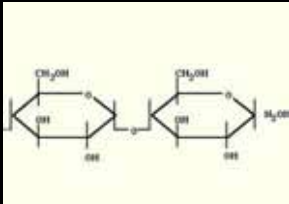
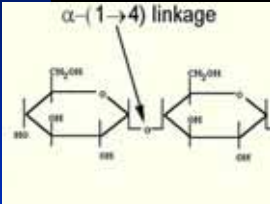
Amylose and Amylopectin



Amylase Activity



Amylase Activity



What's the Mash?



- Crushed malt mixed with water at a specific temperatures to break down starch to more simple sugars.

17.1 A Good Crush Means Good Lautering

There is a trade-off between particle size and extraction efficiency when mashing crushed grain. Fine particles are more readily converted by the enzymes and yield a better extraction. However, if all the grain were finely ground you would end up with porridge which could not be lautered. Coarse particles allow for good fluid flow and lautering but are not converted as well by the enzymes. A good crush has a range of particle sizes that allows for a compromise between extraction and lautering.

A good crush is essential for getting the best mash efficiency and extraction. There are two basic kinds of grain mill commercially available today. The Corona corn mill uses two counter-rotating disks to grind the malt. This often results in finely ground flour and shredded husks, which is not good for lautering purposes. Setting the crush too fine often leads to stuck sparges. This type of grain mill can produce a good crush without too much husk damage if the spacing is set properly (.035-.042 inch). It is the least expensive kind of grain mill, usually selling at about \$50.00.

The other type of grain mill crushes the malt between two rollers like a clothes wringer. There is much less damage to the husks this way which helps keep the grainbed from compacting during the sparge. The two roller mill is more expensive than the Corona mill, about \$100-150.00, but will give a better, more consistent crush to the grain with less husk damage. Examples of this type of mill are the MaltMill - Jack Schmidling Productions, Marengo, IL, the Valley Mill - Valley Brewing Equipment, Ottawa, ON, and the Brewtek Mill - Brewer's Resource, Camarillo, CA.

There is also a single roller mill which uses one roller against a fixed plate to crush the grain. It is called the PhilMill - Listermann Mfg. Inc, Cincinnati, OH, and also produces a good crush, like the two roller mills. It sells for about \$80.00.

The insoluble grain husks are important for a good lauter. The grainbed forms its own filter from the husk and grain material. The husks prevent the grainbed from completely settling and allow water to flow through the bed, extracting the sugar. It is important to keep the grainbed fully saturated with water so it doesn't get compacted and impermeable. The wort is drawn out through the bottom of the bed by means of a false bottom or manifold which has openings that allow the wort to be drawn off, but prevent the grain from being sucked in as well. Usually these openings are narrow slots, or holes up to an eighth of an inch in diameter.

Mashing: an overview

Mashing is really just an extension of Malting

- Crushed Grain is mixed with hot water
 - ◆ Starch is Gelatinized (Solublized)
 - ◆ Enzymes degrade Starch and Protein to simple sugars and amino acids



Mashing

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

Things we control in the mash:

- Temperature
- Thickness
- Duration
- Sometimes pH

By taking into account each of these temperature optima, and the type of beer that you want to create, you can find a single infusion mash temperature that is a compromise of the various factors.

Why is the Mash important?

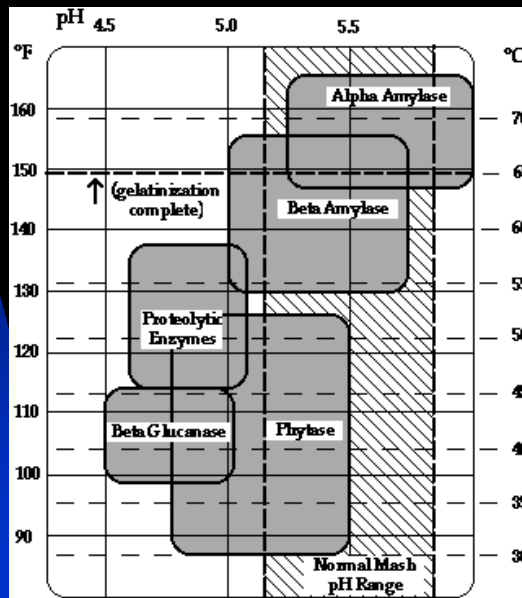
- Biggest process step to effect finished beer (other than ingredient choice)
- Items Controlled:
 - ◆ Fermentable sugars
 - ◆ Degree of Fermentability
 - ◆ Body (sometimes)
 - ◆ Protein profile (yeast nutrients and head proteins)

Mashing is one of the biggest places we effect the profile (fermentability) of the finished beer...body and flavor by controlling the carbohydrate ratio of the finished wort.

Yeast nutrients, head proteins

The starches in the mash are about 90% soluble at 130 °F and reach maximum solubility at 149°F

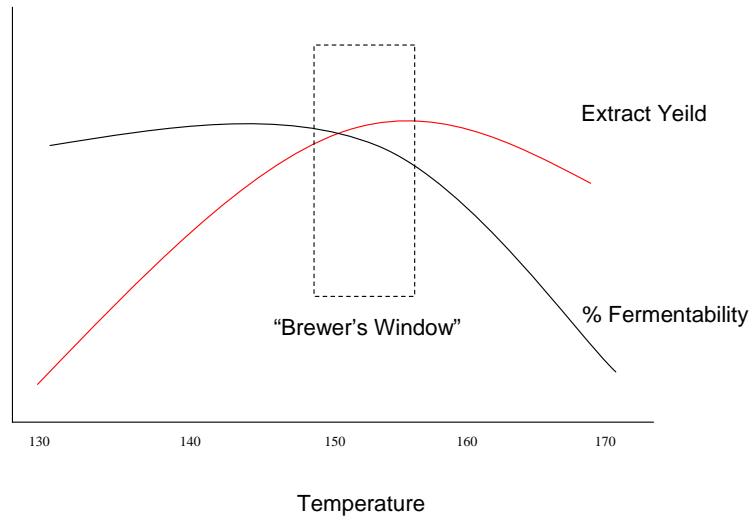
Brewer's Window



Remember b-glucan solublase works at a higher temperature than b-glucanase...

The starches in the mash are about 90% soluble at 130 °F and reach maximum solubility at 149°F

The "Brewer's Window"



By taking into account each of these temperature optima, and the type of beer that you want to create, you can find a single infusion mash temperature that is a compromise of the various factors.

A Degree Lintner

- *A malt has a diastatic power of 100 °L if 0.1cc of a clear 5% infusion of the malt, acting on 100cc of a 2% starch solution at 20°C for one hour, produces sufficient reducing sugars to reduce completely 5cc of Fehling's solution*
- *Fehling's solution reduction is a test for simple sugars*

Measurement of enzymatic power

- Windisch-Kolbach

$$^{\circ}\text{Lintner} = \frac{^{\circ}\text{WK} + 16}{3.5}$$

$$^{\circ}\text{WK} = (3.5 \times ^{\circ}\text{Lintner}) - 16$$

Note on Solubility:

- The starches in the mash are about 90% soluble at 130 °F (54C) and reach maximum solubility at 149°F (65C)

β -glucanase Rest

40-50 °C (98-113 ° F)

β -glucanases reduces beta glucan “gummy substances” and makes lautering easier.

CAUTION: β -glucan solubliase is more heat resistant than β -glucanase.

Acid Rest

50-55 °C (122-131°F)

phytase breaks down phytin into calcium- and magnesium-phosphate and phytic acid

- helps acidify the mash

Also temp for β -glucanases 40-50 °C (98-113 ° F)

Remember b-glucan solublase works at a higher temperature than b-glucanase...

The starches in the mash are about 90% soluble at 130 °F and reach maximum solubility at 149°F

The starch granules take up water with the aid of liquefaction enzymes

Doughing-In/ The Acid Rest

To the best of my knowledge, this temperature rest (holding period) is no longer used by any commercial brewery. It is sometimes used by homebrewers for "Doughing In"- mixing the grist in with the water to allow time for the mash to liquify and time for the enzymes to be distributed. The use of the a 20 minute rest at temperatures near 100°F (40°C) has been shown to be beneficial to improving the yield from all enzymatic malts. This step is considered to be optional but can improve the total yield by a couple of points.

Before the turn of the century, when the interaction of malt and water chemistry was not well understood, brewers in Pilsen used the temperature range of 86-126 °F to help the enzyme phytase acidify their mash when using only pale malts. The water in the area is so pure and devoid of minerals that the mash would not reach the proper pH range without this Acid Rest. Most other brewing areas of the world did not have this problem.

Pale lager malt is rich in phytin, an organic phosphate containing calcium and magnesium. Phytase breaks down phytin into insoluble calcium and magnesium phosphates and phytic acid. The process lowers the pH by removing the ion buffers and producing this weak acid. This stage is known as the Acid Rest but it is not used nowadays. It can take several hours for this enzyme to lower the mash pH to the desired 5.0 - 5.5 range. Today, through knowledge of water chemistry and appropriate mineral additions, proper mash pH ranges can be achieved from the outset without needing an acid rest.

Protein Rest

50-55 °C (122-131°F)

- Temp for Yeast usable protein
- Proteases break down high molecular weight proteins into smaller polypeptides
- peptidase further degrade to peptides and amino acids (Free Amino Nitrogen)

“Most protease and peptidase is denatured in the kiln for modern fully modified malt,” Lewis, Bamforth, et. Al.

Protein Rest

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

Starch Conversion

60-70 °C (140-158 °F)

- conversion of starches into dextrans and fermentable sugars
- Always a compromise to
- Temp impacts carbohydrate profile

1:4 bonds only, no 1:6 bonds without outside enzymes

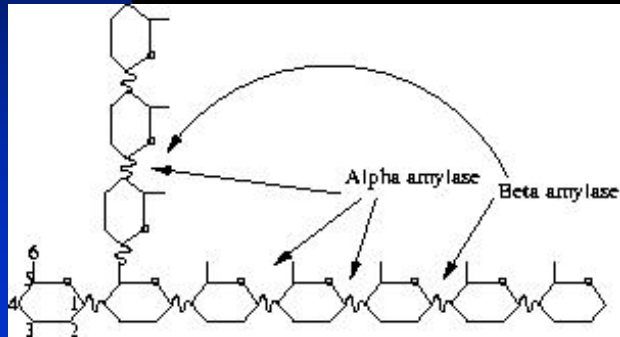
Starch Conversion

The final enzymatic process involves the conversion of starches into dextrans and fermentable sugars. The starches must be gelatinized for this to take place, and this occurs at temperatures of 130-150 F for barley malt. The gelatinization temperature is higher for raw grains, such as corn grits, so these adjuncts must be boiled or hot-flaked before adding to the mash. The breakdown of starches is carried out by the combined action of debranching (**no, no, no.....no debranching enzymes in the mash**), α -amylase and β -amylase enzymes during the saccharification rest. Debranching enzymes break the 1-6 links in starches, reducing the average length and complexity of the molecules. The diastatic, or amylase, enzymes work in tandem, with the β -fraction breaking off maltose units from reducing ends and the α -fraction breaking 1-4 links at random. Temperatures below 150 F favor β -amylase, producing a more fermentable wort, while temperatures above 155 F favor α -amylase, producing a more dextrinous wort.

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

Beta-Limit Dextrin

- Stops about 3 Gs from the 1:6 bond



Mash Out

- Up to 168F
- Denatures enzymes
- Lowers viscosity making lautering easier

Controversial necessity, but can increase efficiency

Mash-out

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

Major Enzyme Groups and Functions (old chart)

Enzyme	Optimum Temp Range	Optimum pH Range	Function
Phytase	86 - 126°F	4.4 - 5.5	Lowers the Mash pH.
Beta Glucanase	98 - 113°F 40-50C	4.5 - 5.0	Best gum breaking rest.
Peptidase	115 - 135°F	4.6 - 5.2	Produces Free Amino Nitrogen (FAN).
Protease	115 - 135°F	4.6 - 5.2	Breaks up large proteins that form haze
Beta Amylase	130 - 150°F	5.0 - 5.6	Produces small, highly fermentable sugars.
Alpha Amylase	155 - 167°F	5.3 - 5.8	Produces larger, less fermentable sugars

Optimum Temperatures for Enzyme Activity

Proteases	50-60C°	122-140°F
β Amylase	60-65C°	140-149°F
α Amylase	65-70C°	149-158°F

- Alpha: Liquifying enzyme (attacks ungelatinized starch) endo enzyme. Narrow temp range. 158 is best
- Beta: Fermentability enzyme(exo,non-red) activity slows as maltose concentration grows in thick mashes. Temperature sensitive on high end

Proteases hydrolyze peptide bonds

Beta: Fermentability enzyme(exo,non-red) activity slows as maltose concentration grows in thick mashes(1,97)

Alpha: Liquifying enzyme (attacks ungelatinized starch) endo enzyme

50mg/ltr Ca add thermal protection for enzymes (equiv to low temp sach rest) (1,97)

(Ca²⁺ is an alpha enzyme co-factor increasing temp stability of alpha above

50mg/ltr)

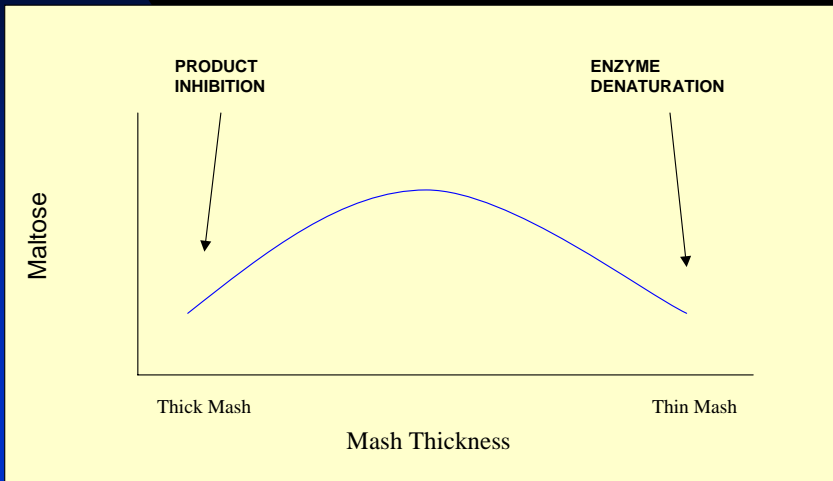
Characteristic	°C	°F
Highest extract (starch conversion)	65-68	149-155
Highest yield of reducing sugars	60-62	140-144
Highest yield of fermentable extract	65	~149
Highest yield of permanently soluble nitroge	50-55	122-131
<i>in a 1-3 hr mash (higher temperature optima for more concer</i>		
Highest yield of formol N	50-55	122-131
Highest yield of (PSN) (formol N)	55-60	131-140
Highest yield of 'acid buffers'	50-55	122-131
Maximal activity of a-amylase	70	~ 158
Maximal activity of b-amylase	60-65	140-149

Yeah Calcium !

50mg/ltr Calcium adds thermal protection for enzymes (equivalent to low temp sach rest)

Ca²⁺ is an alpha enzyme co-factor increasing temp stability of alpha above 50 mg/l

Mash Thickness



Mash Thickness

2.9 kg/L	(Thin)
to	
6.7 kg/l	(Thick)

<u>Optimal Mash Thickness</u>			
KG	Liters	Pounds	Gallon
1	3.9	1	0.41
	Per 100#	BBIs	
	100	1.31	

38oz per Pound

Mash thicknesses have been reported in the common brewing literature from 29kg per HL to 67kg per HL. Almost everyone is aware of the rate of 1 quart per pound...but as we can see, that is actually really thick. Just a note at the beginning; today's malt is so hot, and so well modified that it will just about convert if you even get it near water, and near the correct temperature. That being said, lets look at what we can do to control the process.

Extract Vs. Mash Thickness

Extract vs. Mash Thickness 66C° mashing temp (2)			
	thick	ideal	thin
Carbohydrates	67kg/hl	39kg/hl	29kg/hl
Maltose	38.8%	43.9%	42.8%
dextrins	24.2%	21.2%	22.3%
Trisaccharid	12.6%	13.6%	15.0%
Monosaccha	11.9%	9.5%	8.1%
Sucrose	4.1%	4.2%	3.8%
%extract	73.4%	75.3%	74.2%
fermentabil	67.4%	71.2%	69.7%

What's it all mean?

- Practical lower such limit of about 63C (145F)
- Start at 65C (149F) for highest fermentable extract
- Use 70C (158F) as upper limit
 - ◆ Alpha optima...you could go higher

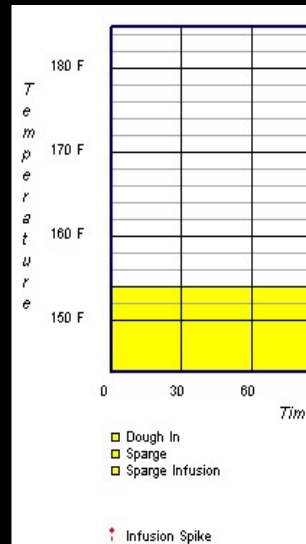
Mashing Protocols



- Single Step Infusion Mash
- Step Infusion (Profile) Mash
- Decoction
- Double Mash

Single Step Infusion Mash

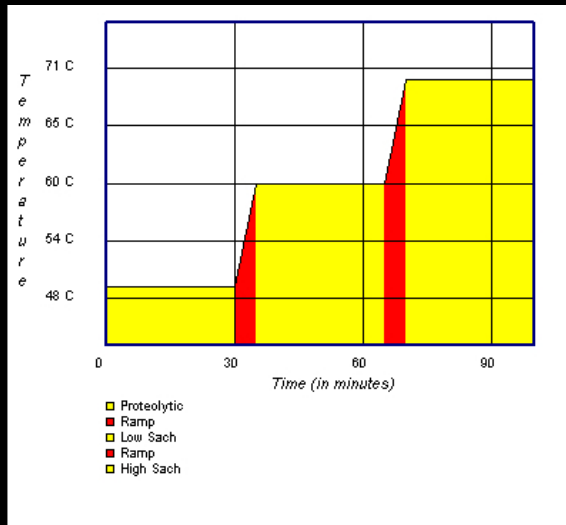
- Ground Malt Mixed with water to reach on Sacch temp
 - ◆ Fully Modified malts
 - ◆ Requires a minimum of labor, equipment, energy, and time
 - ◆ Undermodified malts would be problematic



The simplest mashing method is the single-step infusion, where the malt is combined with hot water to reach a temperature appropriate for starch conversion. This is the method of choice for fully-modified malts such as those used to brew British ales. It has the advantage of requiring a minimum of labor, equipment, energy and time, but prohibits the use of undermodified malt or adjuncts

Multi-Step Mash

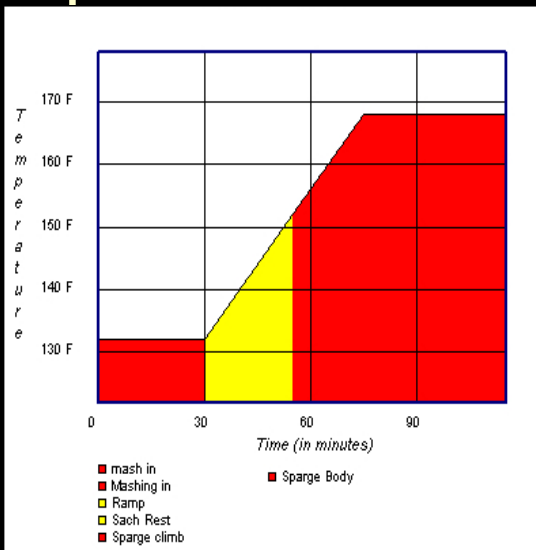
- Direct Heat or Infusion
- Activates enzymes in sequence



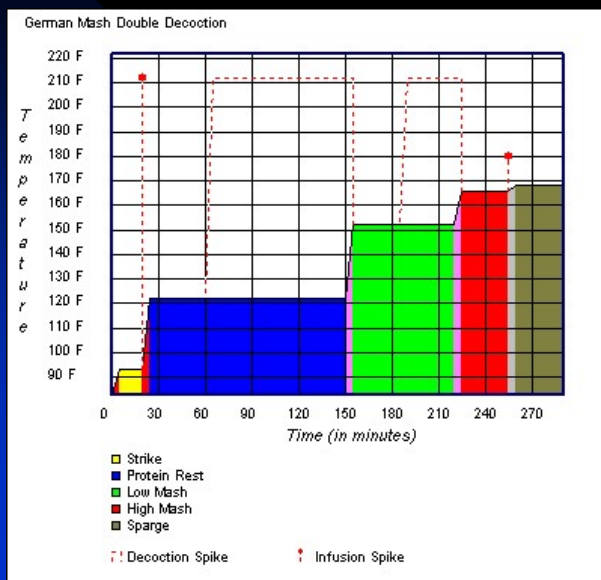
A step-infusion mash allows a little more flexibility by moving the mash through a series of temperature rests. The temperature is increased by external heat or the addition of boiling water. This requires more resources than a simple infusion mash, but undermodified malts may be used.

Ramp Mash

- Direct heat or Infusion
- Modern method



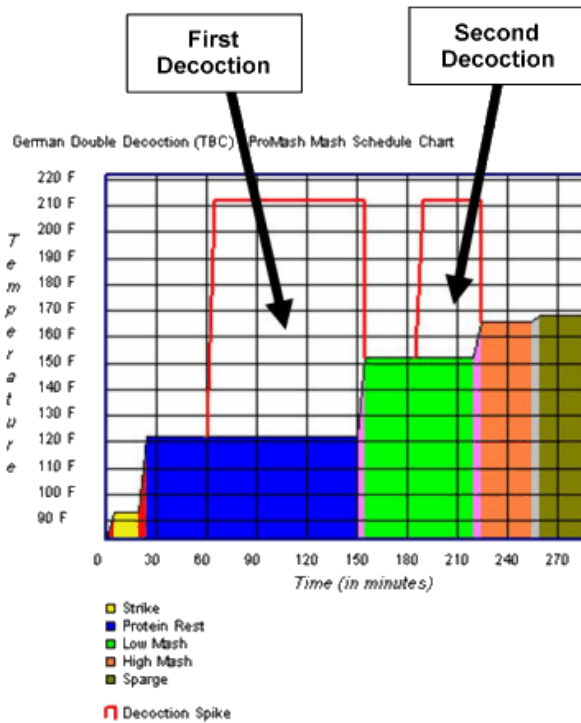
Decoction Mash



- One Third of mash removed, boiled and returned.
- Traditional for under modified malt

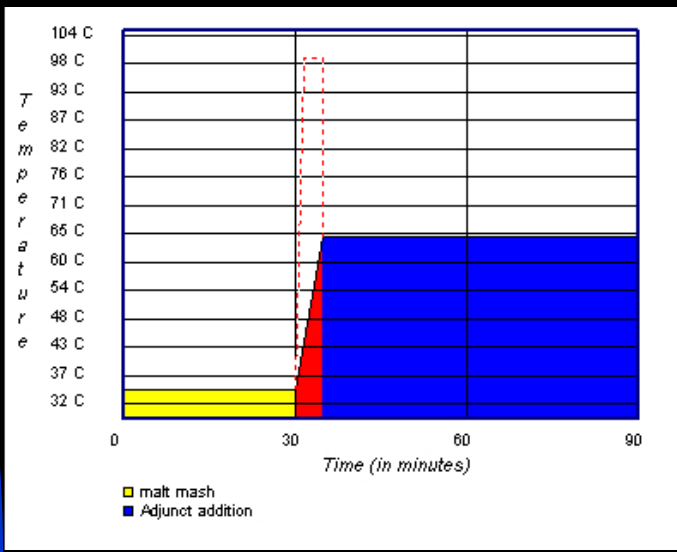
Decoction mashing involves the removal of a thick fraction of the mash (usually one-third) and running it through a brief saccharification rest at a relatively high temperature. It is then boiled it for 15-30 minutes before mixing it back into the main mash. This is repeated as many as three times, depending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

Double Decoction

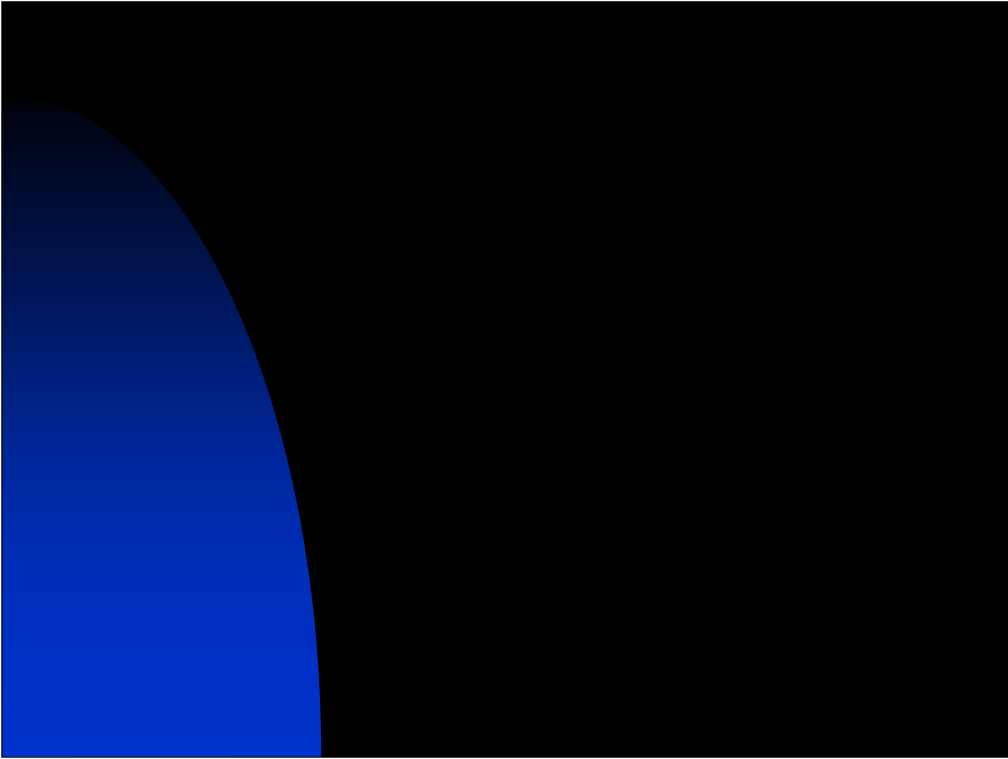


Double Mash

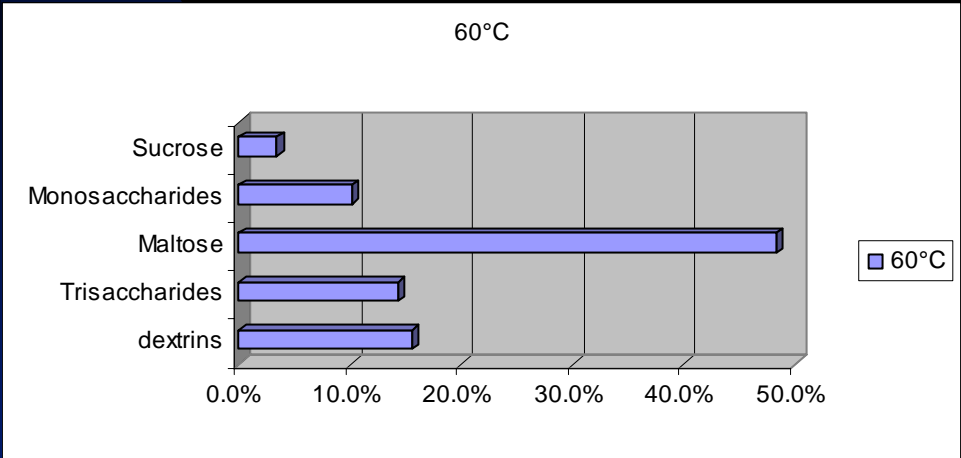
- Two Separate mashes
 - Malt
 - Adjuncts
- Combined for Sach



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

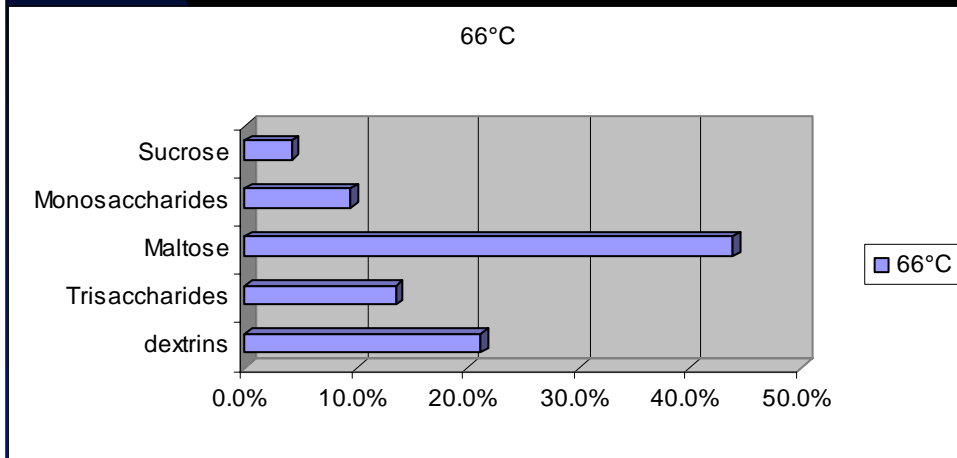


Carbohydrate Profile of Sweet Wort 60C



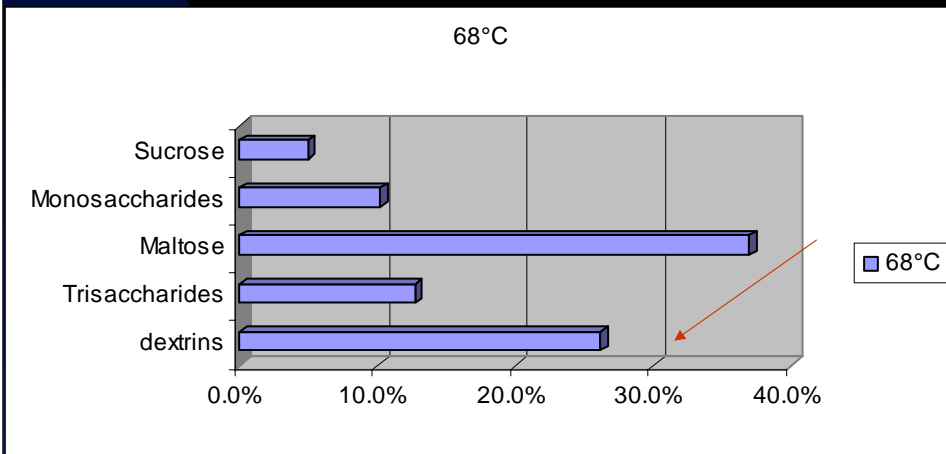
Carbohydrates
expressed as % of
wort solids

Carbohydrate Profile of Sweet Wort 66C



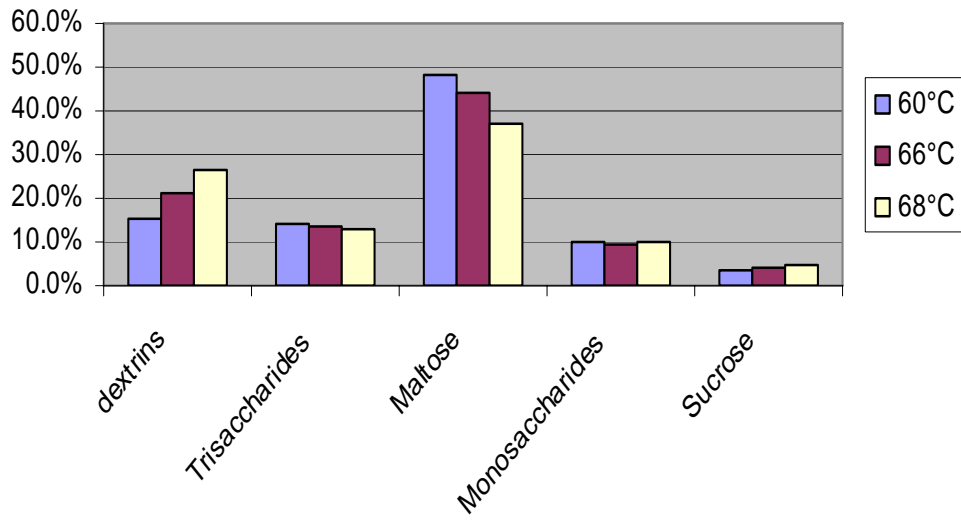
More Dextrins and Trisachcharides

Carbohydrate Profile of Sweet Wort 68C

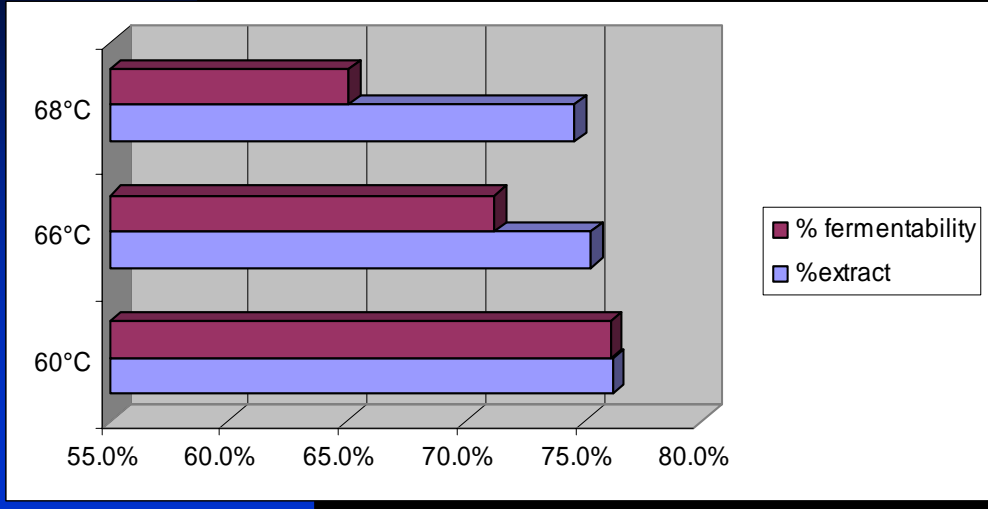


Even More Dextrins and Trisachcharides

All 3



Does Temp Matter? 140-158



Carbohydrate Profiles of Sweet Wort (2)

	140	150.8	154.4
Carbohydrates expressed as % of wort solids	60°C	66°C	68°C
dextrins	15.5%	21.2%	26.2%
Trisaccharides	14.3%	13.6%	12.7%
Maltose	48.3%	43.9%	37.0%
Monosaccharides	10.1%	9.5%	10.2%
Sucrose	3.4%	4.2%	5.0%
%extract	76.2%	75.3%	74.6%
% fermentability	76.1%	71.2%	65.1%

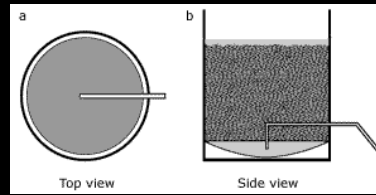
Max Extract is at 55c (131f) and 5.0ph

Max Maltose is at 49c (129f) and 5.0ph

Temperature and pH are interrelated...for a given pH there is a preferred temperature range (1,95)

Lower pH favors lower conversion temperatures

Lautering: Wort Separation



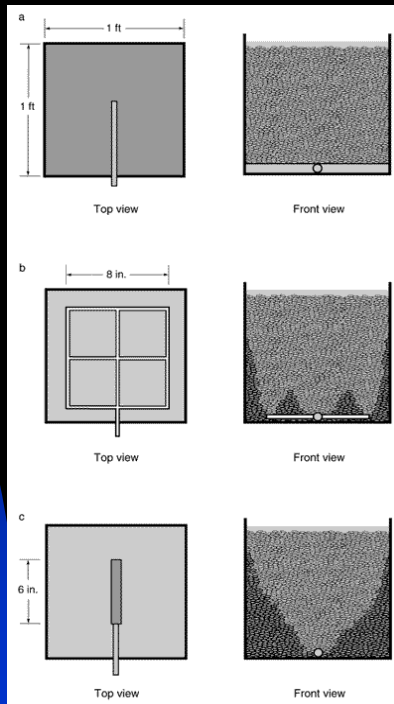
Separation of Wort from Grain:

- Usually in a “strainer”
- Recirculation (Vourlauf) for clarity
 - ◆ First runnings returned to top of mash
- Sparging
 - ◆ Water traditionally 1:1 mash to sparge
 - ◆ pH and temperature sensitive
 - ◆ Time = extract

Lipids and Hot Side Aeration

- Lipids will reduce foam in finished beer, in high enough concentrations. Extracted in High pH high temp lauters
- Sterols and Fatty acids are critical for yeast growth and fermentation. Fatty acids in beer may cause staling by creating aldehydes when oxidized, and this reaction is catalyzed by an enzyme called **lipoxygenase**.

“This would appear to be a factor in “hot side aeration” but it actually only applies to very light malts with low temperature mashing since the lipoxygenase enzyme is very unstable.” *Dr. Lewis, et. Al. 1982*



Boiling

A vigorous rolling boil of at least 60 minutes:

- 1) Extracts, isomerizes and dissolves the hop α -acids
- 2) Stops enzymatic activity
- 3) Kills bacteria, fungi, and wild yeast
- 4) Coagulates undesired proteins and polyphenols in the hot break
- 5) Stabilizes salts for correct boil pH
- 6) Evaporates undesirable harsh hop oils, sulfur compounds, ketones, and esters.
- 7) Promotes the formation of melanoidins and caramelizes some of the wort sugars
- 8) Evaporates water vapor, condensing the wort to the proper volume and gravity.

Boiling

Boiling wort is normally required for the following reasons:

- 1) Extracts, isomerizes and dissolves the hop α -acids
- 2) Stops enzymatic activity
- 3) Kills bacteria, fungi, and wild yeast
- 4) Coagulates undesired proteins and polyphenols in the hot break
- 5) Stabilizes salts for correct boil pH
- 6) Evaporates undesirable harsh hop oils, sulfur compounds, ketones, and esters.
- 7) Promotes the formation of melanoidins and caramelizes some of the wort sugars
- 8) Evaporates water vapor, condensing the wort to the proper volume and gravity.

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

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

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

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

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

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

Take Aways

- Mash thickness can have as big an impact as mash temperature
- Get it wet and it'll convert
- Lauter at or below 76 °C (169 °C)
- Boil hard
- Every mash is different, but in general
 - ◆ Lower temps favor fermentability
 - ◆ Higher temps favor residual sugar

Further reading

- 1. Dave Miller, Dave Miller's Homebrewing Guide (Garden Way Publishing, Pownal, VT 1996).
- 2. Darryl Richman, Bock (Brewers Publications, Boulder, CO, 1994).
- 3. Gregory J. Noonan, New Brewing Lager Beer (Brewers Publications, Boulder, CO, 1996).
- 4. George Fix, Principles of Brewing Science (Brewers Publications, Boulder, CO, 1989).
- 5. George and Laurie Fix, An Analysis of Brewing Techniques (Brewers Publications, Boulder, CO, 1997).