Introduction to Mashing

After you have mastered brewing beer from malt extract and specialty grains, you may wish to take the next step: brewing beer exclusively from grains (“mashing”). Many homebrewers are intimidated by the prospect of all-grain brewing; they believe that all-grain brewing is hopelessly complicated and that they are too inexperienced to undertake such a complex procedure. While it is true that mashing is a complex process, it is, in its own way, very forgiving. It is not that difficult to produce good beer from grains. It is, however, more difficult to produce a replicable, consistent beer, even from identical ingredients. Everything effects the flavor. . . the pH of the mash and rinse (“sparge”), the thickness of the mash (the volume of water per weight of grain), the temperature of the mash and sparge water, the amount of time that you maintain the mash at those temperatures, all of these factors come into play. Nonetheless, you can make a very good beer, even on your first all-grain attempt, if you follow a few guidelines.

GENERAL THEORY OF MASHING

If you understand what is going on during the mashing procedure, you can “help” the process along. Briefly, the idea is to take starches (generally, but not always, in the form of barley malt) and allow the enzymes contained within the grain to convert its starches into simple sugars and dextrins (long chains of sugar molecules). Simple sugars (in the form of maltose) will readily ferment to produce alcohol and carbon dioxide, while dextrins, being largely non-fermentable, provide body and mouthfeel. Changing the mashing pH, temperature and ‘times’, and “stiffness” (thickness/consistency) can radically affect flavor and mouthfeel depending upon the percentage of maltose versus dextrins that are produced during the mash. This may initially sound more difficult than it really is. The process generally involves the following steps:

1. Cracking or crushing the barley malt
2. Steeping the cracked grain in water at elevated temperatures for a given amount of time
3. Sparging the grains with more hot water to rinse the “sugars” out of them
4. Boiling the liquid with hops to produce the “bitter wort.”

Obviously this has been oversimplified here, but it will give you the general idea.

Grinding the Grain This is best done in a mill designed for this very purpose, as opposed to making do with a blender, food processor, coffee mill, or even the common grain mill used in Central and S. America. These mills invariably pulverize and tear up the husk of the grain. Proper milling involves feeding the grain between rollers, which crack the grain, while leaving the husks virtually intact. The reason for this is that we use the husks as a filter media to help separate the “goods” from the spent grains. If the husks are pulverized, what you get is more akin to paste than unfermented beer (“wort”). This “paste-y” consistency makes it very difficult to rinse the grains and extract the goods. Our shop has a roller mill available to crush your grains, saving you the hassle of dealing with the milling process.

Mashing Now we deal with the steeping of the grain in warm water. . This is the process known as “mashing.” This is also where things get complicated! Let’s talk about some general mashing guidelines here:

1. Use between 1 - 1½ quarts of water per pound of grain to be mashed (1¼ qt/lb. is a nice compromise)
2. Heat the water to approximately 168°
3. Carefully mix the water and the cracked grain together so as to avoid dry clumps (this process is called “doughing in”),
4. If all goes well, the resulting temperature of the mixture should be about 150° - 155°F.
5. Maintain this temperature for at least an hour before proceeding to the next step (sparging). What is taking place during this steeping period is that the enzymes (alpha and beta amylase) contained within the grains will convert the starches into simple sugars and dextrins. Needless to say, this is a critical stage of all-grain brewing. Sloppy techniques can produce a beer with very low starting gravities or nasty off-flavors.

Lautering involves separating the goods (in the form of liquefied malt sugars) from the waste materials (spent grains). This is generally accomplished by first placing the mixture in a vessel with a false bottom (a strainer that holds the grains together while allowing liquids to flow through) and then slowly rinsing ("sparging") the grains with hot water. The idea here is not to simply collect a given amount of liquid but to rinse the goods from the grains without leaching undesirable flavors. The ideal temperature for this sparge water is about 168°F. Significantly lower temperatures will fail to sufficiently liquefy the sugars created within the grains during the mashing procedure and thus lower the yield from the grains, while significantly higher temperatures will leach undesirable flavors from the grains (such as tannins) in addition to the sugars that you do want. For best results, do not allow the grains to reach even a simmer (much less a boil) before straining and rinsing!

Once you've collected the goods from the grains you will want to bring them to a boil and begin adding hops. This may not be procedurally that different from your malt extract/specialty grain brewing experiences, but you are accomplishing much more during your boil now than with extract brewing:

1. You have de-activated any enzymes that may be left from the grains. This is desirable because once you've hit the desired ratio of maltose to dextrins, you will not want continued enzymatic activity to change this delicate balance
2. You are co-agulating the extraneous proteins that form during a good, vigorous boil. Otherwise, these proteins will end up in your beer creating potential haze, flavor and other stability problems as the beer matures
3. You are, obviously, sterilizing your wort (something that many malt extract producers claim is unnecessary with their products). It's ok not to believe that and to sterilize anyway.
4. You are reducing the volume of liquid by evaporating water out of the kettle during the boil. As a rule, you will start with at least six gallons of initial "sweet wort" to yield five gallons of final product. During the hour to two-hour boil you should be able to boil off this extra gallon of volume. Yes, you could stop the sparge once you have collected a mere five gallons of wort, but then you would be wasting all of the sugars and goodies that are still left in the grain at that point, and after you finished boiling you will likely have to add water to bring the volume back up to five gallons!
5. Just as with extract/specialty grain brewing, you are extracting the bittering components from the hops during the boil. This bite from the hops helps balance out the sweetness derived from the malt and acts as a mild preservative.

The procedure described above is called "**single step infusion mashing**." This is the simplest, and most likely, the best mashing procedure for the beginning all-grain brewer. Other mashing procedures exist and can produce excellent results, but they are considerably more complicated than the single step infusion method. For this reason, we recommend them for more experienced all-grain brewers. These other procedures include

1) **Multi-step infusion**
2) **Decoction mashing**. "Multi-step infusion" is a similar process to the single step infusion with the exception that the entire mash is brought to a specified temperature, maintained, then boosted to the next temperature rest. For example, you could heat the water ("mash liquor") to 137°F, then "dough in" the crushed grain, resulting in a temperature of about 122°F. This is a good temperature to break down large protein molecules, which could, conceivably cause a chill haze (clear, room temperature beer clouds up when refrigerated). After maintaining this temperature for 20 minutes you would then boost the temperature of the wort to 140°F for 15 minutes to degrade the gums contained within the grains. This makes for a cleaner, easier run-off from the grains when you sparge them. Next you boost the wort to 155° - 158° to allow the amylase enzyme to convert the starches into sugars. After 30 - 60 minutes, you will then boost the temperature to 168°F for just a few minutes to degrade all of the enzymes. Once you've hit just the right balance on your mash, you may want to de-activate all the enzymes to prevent them from working while your sparging. Now you can move on to recirculating and sparging. "Decoction mashing" involves many of these same temperature stops or rests, but with a different kind of twist: you don't simply heat the entire batch of grain and water to the next temperature stop, but instead you remove the thickest, densest part of the grist and heat it up to a boil in a separate kettle before returning this back to the other two thirds. Naturally this raises the over-all temperature (hopefully to the next desired "stop"). After maintaining these temperature rests for a while, you remove some more grist, heat it up to a boil, and return it back to the wort to raise it to the next temperature rest, and so on and so on. This procedure originates from Central Europe (Germany, Austria, Bohemia) and has worked very well with the grains that are grown in this region. The short growing season in this climate produces noticeably different barley than, say, that grown in England. In recent years, as scientists have come to understand the intricacies of malting, there is probably less reason to use decoction mashing than in the past, except that the flavor of these beer styles is thought by traditionalists to be inextricably linked to this particular mashing procedure.

These two procedures sound complicated, don't they? Obviously, they are complicated, but they may eventually prove to be worthwhile. We recommend that you master single-step infusion first before moving on to these other, more advanced techniques. The vast majority of microbreweries and brewpubs in this country use single step infusion exclusively and with great success with a wide array of beer styles. Once you've got the basic mashing techniques down pat, moving on to the more advanced procedures is much easier, and your chances of success should be good.

ALL GRAIN BREWING EQUIPMENT

Here are the basic items a homebrewer will need to make all-grain beer:

1. **7-10 gallon pot**
2. **thermometer**
3. **hydrometer**
4. **Mash/lauter tun**
5. **pH papers**
6. **Phosphoric acid**
7. **Wort chiller**

Brewing Pot Some of the equipment that you will need for all-grain brewing is obvious: First you will need a large (6 - 10 gallon) **kettle**. For best results, use a stainless steel or enameled steel kettle. Aluminum is not recommended. If price is a problem, procure an enameled kettle. They work fine and are relatively inexpensive (generally about $1 per quart capacity at local discount stores. You will also need at least one, if not several reasonably accurate **thermometers** to measure the temperature of the wort, water, etc. Another very important piece of equipment that you will need is a mash tun (and/or lauter tun).

Mash Tun A "**mash tun**" is the vessel in which you hold the grains and water while the enzymes do their magic. Technically you could use your kettle as your mash tun. It has one advantage: you already own it (it's the same vessel in which you will shortly be boiling the wort!). Kettles leave something to be desired as mash tuns, in that, unless you are brewing large amounts of beer at a time (10 or more gallons), they do not maintain temperatures very well. You will need to stir the grist up every 10 or 15 minutes or so and re-heat the mash back to the desired temperature. Furthermore, you now are faced with the dilemma of how to separate the goods from the spent grains. This is where the need for a lauter tun comes in.

A lauter tun is the vessel that contains the false bottom for separating the goods from the grains. The poor man's lauter tun could be as simple (and inexpensive) as two identical food service buckets that "snug" together when they are stacked. On the side of the bottom bucket, you affix a hose either by simply drilling a 1" hole and attaching a spigot and hose or drilling a 7/16" hole and cramming a 3/8" ID by ½" OD hose through the hole (yes, it really can be done) and attaching a hose clamp to regulate the flow. Next you perforate the bottom of the top bucket by drilling a billion of holes in it (use a 3/32" drill bit for this). This is very tedious, but with a few homebrews, the time passes without too much dragging. This perforated bucket snugs into the spigotted bucket. The mashed grist is gently poured into the top bucket. Now you can begin to recirculate the wort that initially flows out of the hose back onto the grains. This can be done by collecting a quart or two of this cloudy concoction and gently pouring it back onto the grain bed. Repeat this process until the liquid begins to clarify (it doesn't have to be crystal clear). This signifies that your grains are beginning to act as a filter bed for your run-off, and that it is time to begin sparging.

We prefer to combine the mash tun and the lauter tun into one vessel. For the beginner, this is best done by utilizing an insulated "picnic cooler" fitted with a false bottom or some sort of similar "strainmaster" set-up. This strainer can be a simple PVC or copper tubing manifold with hacksaw cuts on the bottom of the "limbs." Think of this manifold as a tree with branches. In this case, the wort run-off is collected through these limbs and channeled into the trunk, from which the wort is gravity fed through the cooler wall via a spigot or simple threshold. Typically the various parts (e.g. elbows, tees, crosses, straight arms) of this manifold are simply butted together for easy disassembly and cleaning. Easier, still, than fabricating your own manifold are the false bottoms that are custom fabricated for the 5 and 10-gallon cylindrical water coolers. These false bottoms are a slightly convex, perforated thick plastic disk that sets on the bottom of the cooler. There is an elbow that attaches to the center of the false bottom and is connected to a spigot on the side of the cooler (warmer?). The sparged wort travels and is filtered through the grains, through the false bottom and then up and out through the elbow, connecting tube and through the spigot.

"**Sparging**" is the process whereby the grains are rinsed to collect the "goodies," while leaving the spent, flavorless grains behind. Traditionally this is done by maintaining an inch to two inches of hot (168°F) water above the grain bed, while draining the "sweet wort" out the spigot on the bottom. Obviously, it takes a bit of practice to keep the hot water flowing at the same rate as the wort flow at the bottom, too fast or too slow will result in not enough or too much water above the grain bed. You don't have to be a rocket scientist to figure this balance out, just a little bit of practice. Your sparger can be as simple a garden watering can with spray nozzle head. Unfortunately, this can really get to be tedious and you end up rushing through this important process, resulting in rather low yields from the grain. An alternative to this is to syphon the hot water onto the grain bed as you drain off the wort. If using this method, we recommend you find something to lay on top of the grain bed (e.g. a plastic lid) to prevent the syphon flow from digging a "trench" in the grain bed, thus disrupting the filter bed. There are even some nice 'sparge arms' available that simplifies the sparging process. They generally take the shape of a slow-flowing, micro-spraying lawn sprinkler through which the hot water is syphoned or pumped. Listermann's Manufacturing, makes several good ones which we carry and are in the $15-$20 range.

pH Papers One variable that you will likely want to control is the pH of the wort. While not terribly important for extract or even extract and grain brewing, pH plays an important role in mashing. Your yield (the amount of "sugars" that you get from a given amount of grain) is noticeably affected by the pH in the mash tun. Generally you will want the pH to be in the mid 5's (5.2-5.7) during the mash. This might be easier than you think, in that the grains, and sometimes even the water treatment, will help drop pH into range. Obviously the make-up of your water supply and the nature of your grain bill will largely determine if you need to do anything to adjust the mash pH.

In Madison and most of the Midwest well water is high in carbonates (temporary hardness) that has a tendency to keep buffering the pH thereby keeping it too high. Carbonates can be gotten rid of by boiling the water for 15 minutes, allowing it to cool, and then siphoning the now soft water from the carbonate residue. It may then be necessary to add gypsum to add permanent hardness to the brew water. In order to check the pH, you need to acquire some narrow range pH papers. We carry papers that range from pH 4.6 - 6.2. This should cover your bases. A vial of 100 of these cost only several dollars and will more than suffice for the beginning all-grain brewer. As you get more experienced, a pH meter can come in handy. These are more accurate (even the cheap ones!) than the papers, but you are now looking at $40-$100 for a hand-held pocket model to several hundred dollars for a laboratory type bench model.

One subtlety of pH control that is often over-looked by all-grain brewers is the need to adjust the pH of the sparge water, just as you adjust the mash pH. And, unlike the mash, you will not have the grains to help lower the sparge pH. Water treatment (e.g. gypsum, salt, Epsom salts, calcium chloride, etc.) may help lower pH some, but only slightly. Typically, municipal water supplies run in the pH 7 - 9 range. If you sparge with water at this high an alkaline level, you will tend to leach out nasty, husky, tannins.

Phosphoric Acid A variety of acids can be used to lower pH. Most brewers prefer lactic acid or, food grade **phosphoric acid**. We prefer **phosphoric** because it is mild in flavor (it can be found in that can of Coke you're drinking) and goes into solution as phosphate, which provides the yeast with valuable nutrients. There is no general rule of thumb as to how much you should use. Suffice to say that it will be measured in drops (or at most milli-liters) rather than ounces. Just add a little and check your pH, add and check, etc. until you've hit the right level. Do not get impatient and dump a bunch into the sparge water, as once you've neutralized all the buffers in the water, the pH will drop like a rock and you can way overshoot your mark.

Basic Rules Here is a general routine for all grain brewing:

1. Boil the brew water to remove carbonates, or treat the water with Calcium Hydroxide to remove carbonates.
2. Heat all the water (called "liquor," for both the mash and the sparge) at the beginning.
3. Add the water treatment to the entire batch of water.
4. Dough in the grains with some the water.
5. Check and adjust, if necessary, the mash pH and temperature.
6. While the grain is mashing, check and adjust pH and temperature of the sparge liquor.
7. Toward the end of the mash recirculate the run-off back through the grain bed until it begins to clarify.
8. Slowly sparge the grains until you have collected 6 - 7 gallons.
9. Bring the sweet wort to a boil.
10. Add hops in several additions, according to your recipe.
11. Turn off heat and chill the bitter wort as quickly as possible.

Wort Chiller One difference between extract/specialty grain versus all-grain brewing is the cooling process. Typical extract/specialty grain brewing involves boiling a reduced volume (e.g. 2 or 3 gallons) of wort. Obviously, this will be concentrated, containing enough malt and hops for the full five gallons of finished beer. Once the boil is over, the kettle can be simply placed in the sink with several gallons of cool water to help the mix down rapidly. However, with all-grain brewing, you will very likely end up with five gallons of very hot, very sticky wort, and cooling in the sink will likely take a very long time, if your 6 to 10 gallon kettle will even fit in the sink! Moving the operation to the bathtub can help, but it leaves a lot to be desired: it still is a very slow procedure for cooling wort, even if you are constantly circulating the cool water around the kettle, and carrying five gallons of boiling hot liquid is not our idea of fun or safety! If you are going to be an all-grain brewer, you need to equip yourself to do battle. In this case, you need to purchase, scrounge or fabricate a "wort chiller." A "**wort chiller**" is simply a device used to help rapidly cool down the wort after the boil is finished. The simplest version of these is called an "**immersion chiller**" and these are very effective for small size batches (e.g. 5 gallons or so). An immersion chiller consists of a length of copper tubing coiled up and fitted with hosing on both ends.

The procedure is to immerse the coil in the wort for the final 10 minutes or so of the boil. This will sanitize the coil. As soon as the boil is completed, add your finishing/aromatic hops (if using) and immediately hook up one of the hoses to your faucet. Turn on the cold water and it will begin to cool down immediately. Be careful, as the water will begin to squirt out of the other end of the hose at close to boiling temperatures! Adjust the flow on the inlet water to produce the best cooling without squirting hot water all over your homebrewery. The length of the copper tubing depends upon the typical temperature of your tap water. In the Midwest where we are blessed with cool ground water, 25-30 feet of copper tubing is usually sufficient to cool 5 gallons of hot wort in a timely manner. This should take no more than 20-30 minutes. Commercial breweries like to have their water to yeast pitching temperatures within 1 hour.

A more efficient way to chill you wort is called a "**counterflow chiller**." These are very much like what is used in commercial breweries. They work somewhat faster than immersion chillers, but at the expense of being a bigger pain in the butt to use. If you are contemplating brewing larger than 5 gallons at a time, I would highly recommend that you use a counter-flow chiller. A counter-flow chiller consists of, again, a length of copper tubing (in this case 25 feet is about right) inserted into a garden hose. These chillers are typically coiled and a "T-type" fitting is affixed to both ends. These "T-type" fittings will consist of two large opening for the garden hose and one smaller opening for the copper tubing. The way this chiller works is that you will syphon or pump hot wort through the copper tubing at one end while running cold tap water at the other end. What happens is that the hot water exits out of the big fitting next to the "hot" wort inlet on one "T- fitting", while the cool wort exits out the small fitting on the other end, next to the large "water-in" fitting. If this sounds complicated, it is not and these "T-type" fittings are available commercially (Listermann's produces one version called the "Phil-Chiller). The hassle is that while sanitizing the copper on an immersion chiller is easy (simply place in the kettle during the last 10 minutes of the boil), sanitizing the copper tubing on a counter-flow is not so easy. Obviously you cannot immerse the copper in the boil, so what do you do?

One thing you can do is syphon or pump the same sanitizer you use on your fermentors and bottles (e.g. diluted bleach, iodophor, Star-San, Oxine, etc.). This works reasonably well. We would recommend that you run the sanitizer through the copper tubing and clamp it off for 10 - 20 minutes to allow extended contact time with the sanitizer and tubing. A thorough rinse with boiled water would hurt. One alternative you will have with you wort chiller that you probably don't have with your fermentors and bottles is to run boiling water through the chiller (Obviously, you don't want to run the cooling water through at the same time!) A combination of sanitizer followed by boiling water is a good bet to keep the "critters " out of your counter flow chiller. A good thing to do after your brewing session is to thoroughly flush the chiller with plenty of water. This will help prevent "science projects" from growing in your chiller between brewing sessions. Also, it is a good idea after flushing to blow out all the moisture from the coil. Even "plain" water will stagnate given enough time!

ALL-GRAIN FORMULATION

The following is a simple explanation for converting malt extract recipes to all-grain recipes. If you are interested in recipe design, we recommend you obtain a copy of Ray Daniels' excellent book, "Designing Great Beers." There are other good books available on the subject, but this is, in our opinion, the best specifically for recipe design. If you are ready to take the plunge into all-grain brewing, you are very likely already an intermediate brewer, i.e. you are currently brewing with malt extracts flavored with specialty grains. If this is the case, the good news is that you do not necessarily have to change up the proportions of the specialty grains in your recipe. In other words, if your pale ale recipe calls for 7 Ibs. of light malt extract, ½ lb. Carapils, ½ lb. medium crystal malt, & 1oz. chocolate malt, you are still going to use the same amount of Carapils, medium crystal, and chocolate malts. The question will be, "What do I use to replace the malt extract?"

As a general rule, 1lb. of malt extract (syrup) dissolved in one gallon water (total volume) will yield an original gravity (O.G.) of **1.036** or abbreviated 36 points. Two pounds of syrup in one gallon (total volume) will yield an O.G. of 1.072 (or 72 points). In the recipe above, we are using seven pounds of syrup in five gallons. Let's do the math: 7 x 36 = 252. Divide this number by the number of gallons: 5, and this should give you a reasonably good approximation of the expected O.G. (in this case 1.050 or slightly higher).

We need to figure out how many pounds of pale malt to substitute to yield that same 252 points to end up with a comparable O.G. Gravity yields from malt extract are, by and large, pretty cut and dried. You can count on that 36 point per pound per gallon figure. On the other hand, however, yields from all grain brewing are going to vary considerably because of all the variables involved: the type and quality of pale malt used, the pH of the mash & sparge, the amount of water used in the mash & sparge, the temperature of the mash & sparge, the quality of the crush from the mill, the quality of the false bottom used, and the patience of the brewer in the sparging process.

A good starting point is to say that in the hands of an average, beginning all-grain brewer, with average equipment, a pound of pale malt mashed, sparged and boiled back to one gallon will yield approximately an O.G. of **1.025** (or 25 points). So, in our hypothetical pale ale recipe, we will need approximately 10 pounds of pale malt to yield the equivalent of the 7 pounds of malt extract (252/25=10+). This is just a starting point, and you may find, with repeated experience that you will need more or less grain to replace the extract in your recipes. A yield of 25 points is average for the beginner, 28 points is probably closer to the average for a more experienced all-grain brewer, 30 to 32 points is theoretically possible with advanced equipment and lots of patience.

Notes

1. Dried malt extract is more concentrated than syrup, so expect a yield of about **42** points for any DME in your recipes.
2. Substituting for amber and dark malt extract will require the addition of small amounts of crystal and/or chocolate malts to maintain color and flavor. Obviously, these will vary from brand to brand, but as a rule of thumb, for amber malt extract, let's use the same amount of pale malt as we would for light malt extract (at 25 points per pound of grain versus 36 points per pound of extract), and add about 1½ ounces of crystal malt for every pound of amber extract replaced. Similarly, for dark malt extract, add an ounce of crystal malt and about a quarter ounce of chocolate malt for every pound dark extract substituted (in addition to the pale malt needed.
3. Wheat beer recipes offer a different problem. While there are a few 100% wheat malt extracts on the market (Ireks comes to mind), most wheat extracts are actually only 40 - 60% wheat, with the balance being pale (barley) malt. This is not a problem, in that most European wheat beers average close to 50% wheat content. Thus, for a good starting point, use approximately equal amounts pale malt and wheat malt in your wheat and wit recipes. Wheat malt grain should give you comparable yields to pale malt (start with 25 points per pound per gallon). For Berliner weisse recipes use only 25 - 33% wheat malt.
4. Some styles of Bavarian beers, e.g. Munich Dunkel, Munich Helles, Traditional Bock, & Double Bocks, will require some Munich malts in the mash. Munich malt (preferably German or Belgian) can be substituted for pale malt with comparable yields (25 - 32 points), but with much more robust, sweet, malty finish. Use 10 - 30% Munich malt in place of pale. This will produce a much more complex, authentic Continental flavor than simply using pale and enough crystal and chocolate malts to achieve the proper color.