THE DEFINITIVE GUIDE TO

ALL GRAIN BREWING

(PART 2)

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THE GRAINFATHER
ALL GRAIN BREWING

CONTENTS

The Brewing Process – in detail

1. MILLING P.1

The purpose of milling P.1

Husks P.1

Endosperm P.2

Milling system and results P.2

Grist assortment and fractions P.3

2. WORT BOILING P.3

Wort composition P.3

Effects of inadequate and over boiling P.4

Evaporation P.5

Distillation P.5

Sterilisation of wort P.5

Hop components & isomerisation P.5

Colour increase P.5

Kettle Additions P.6

3. WORT CLARIFICATION, COOLING & AERATION P.6

Clarification P.6

Trub removal P.6

Filtration P.7

Whirlpool P.7

Cold Trub Removal P.7

Cooling P.8

Aeration P.9

THE BREWING PROCESS – IN DETAIL

MILLING

Milling is a mechanical process that assists with both the chemical and biological conversions that occur during the mashing steps when brewing. It improves the quality of the wort by assisting with a better composition and higher extract yield. This aid through milling becomes even more apparent when the quality of the malt is of a low standard.

The mechanical destruction of grain (milling) is not always as simple as we think, there is of course a level of optimisation that can occur. While as homebrewers we don't always need to take all processes to extremes, it's still great to know where we can potentially improve our brews as we get more competent and interested in the finer details.

THE PURPOSE OF MILLING:

The purpose of milling is not simply about increasing the surface area of the grain. Ideally, we want to also;

- Crack the outer husk and separate it from the endosperm. If possible it's best to split the husk longitudinally).
- Crush and disintegrate the endosperm so that the enzymatic degradation is quick.
- Create the correct assortment of materials for the lautering (sparging) process to be optimised.

Milling as close to brewing as possible, minimising oxygen pickup in the grains.

HUSKS

Husks should be milled as little as possible. They are mostly composed of cellulose, which is not water soluble and only minimally affected by enzymes.

The husks are slightly 'elastic' which makes it difficult to mill and pulverize. Because of this, it may be tempting to tighten up the mill, but if the husks are too finely milled the extract run-off during lautering (sparging) will slow down.

ENDOSPERM

The endosperm is mostly water soluble or made so during the mashing process. It is the primary extract source of starch and proteins. It is here you will notice that enzymes from highly modified malt sections (from modified qualities) are much easier solubilised than the 'hard' ends that provide less extract.

MILLING SYSTEM AND RESULTS:

The different types of milling and machines used can affect the outcome of the products that we purchase as homebrewers. They can be simplified into a few distinct categories;

Dry Mills

- These types of mills are the simplest and least expensive. They are often the basis of the homebrew mill products found on the market.
- They are found generally as 2, 4 and 6 row/rolls mills, where the latter is generally reserved as the standard for large breweries.
- They are best used with well modified malt but as their scale grows, so does their level of control and ability to be used with varying modification levels.

Wet Mills

- These systems combine milling and mashing, where some enzymes are already active during the milling process.
- Their benefits are that no dust is created during milling and extract/brewhouse efficiency are increased.
- However, they have high maintenance costs and oxygen pickup is increased due to pumping.
- They went through a period of unpopularity but are making somewhat of a comeback with commercial breweries.

Rotary Disc Mills

- The grist created is very fine, but as these are used in conjunction with mash filters, the husk does not need to be intact.
- They are relatively inexpensive and have very high extract efficiencies when in combination with mash filters.

A good quality milling system is important when trying to achieve the best possible results and create the most ideally crushed malt. There are some great milling machines on the market for homebrewers, but still a good majority of us purchase pre-milled malt from our local homebrew stores.

When reviewing a milling system or pre-milled grain bought from a store we are looking for:

No uncrushed malts.

- This may indicate the malt was fed too fast or the rollers are worn.

The majority of the husks split longitudinally, with no endosperm attached still.

- This helps with act as a good filtration medium.

A uniform endosperm particle size after milling.

- This is important for hydrolysis and maximum yield.

As less white 'snowy-tan-coloured' powder as possible

- This can bind the lauter bed.
- If this flour is noticeably less white than you're used to, it means some of the husks were being ground which is not desirable.

This is not always as easy as possible, because as we see above the husk and endosperm require slightly different milling objectives. Generally speaking because of this, the quality of malt provided by larger manufacturers using a 6-roll mill should be higher than that produced at home with a homebrewer's level mill. However, having a system at our fingertips provides a high level of control, to determine the exact grist fractions needed.

GRIST ASSORTMENT AND FRACTIONS:

Below are some example grist fractions for lauter tuns and mash filters, these are just a guide and there are varying judgements on these. Mill a small amount as a sample to test and be sure to note that mechanical equipment is prone to changes after operation, so check the mills settings before each use.

WORT BOILING

All homebrewers are familiar with the basic process of brewing a beer. While mashing and fermentation usually get most of the headlines due to the variation available for brewers to experiment with and discuss, the importance of boiling is often over looked as merely "a step that happens after mashing, before I can start fermentation". While many homebrewers don't exactly think that, boiling of the wort is not held up as an equally significant contributing stage to the final result of a brew.

WORT COMPOSITION:

It's important to understand what exactly your wort is made up of as a mixture. Water is the solvent and contributes mostly to the wort with some visible organic material (from malt husks and hops), plus other minerals and salts. But the highest contribution to the wort extract comes from carbohydrates which make up around 90% of the total extract. Of this, about three quarters are fermentable sugars like;

- Fructose
- Glucose
- Sucrose
- Maltose
- Maltotriose

The nitrogenous components make up around 5% of the total extract, these are mostly;

- Amino acids
- Peptides
- Polypeptides
- Proteins
- Nucleic acids

EFFECTS OF INADEQUATE AND OVER BOILING:

When boiling the wort, you may think that so long as the liquid gets really hot for some time then the boiling stage has been taken care of and all is well is for the rest of your brew. But as with all stages in home brewing, a slight lack in judiciousness can cause an inferior result in the end.

When the boil has been inadequate a number of problems may become present, such as;

- Lower gravity
- Poor separation of trub from the wort
- Poor fermentation and filtration difficulties
- Higher than acceptable DMS levels
- Poor hop utilisation
- Susceptibility to contamination

When boiling for too long or even sometimes overheating, there are also other negative effects that may occur such as;

- Higher gravity, lower volume of wort
- Trub breakup causing haze and flavour problems
- Harsh bitterness
- Increased wort/end beer colour

Boiling contributes significantly to the final wort composition, which in turn controls many of the factors in flavour, body and palate fullness of the final beer.

As a simple break down, the main reason the wort needs to be boiled are;

EVAPORATION

The wort is diluted through the lautering (sparging) process when used to wash the grain bed, it now has to be concentrated again and this is where we need to 'evaporate' some of the solvent (water) in order to get the ideal final wort composition. A desired evaporation rate is roughly from 5 - 10% per hour, aiming for an ideal of 8% per hour.

DISTILLATION

Also during the phase of evaporation, is the process of distillation where we aim to remove volatile substances that are derived from the raw materials used when brewing. Compounds such as di-methyl-sulfide (DMS) are best evaporated off from your wort, as well as other undesirable malt and hop compounds. You may be wondering though "what about the aromas I want to keep in my wort" that are carried by the hydrocarbon components of hop oils? The best way to keep these in the wort is via a late kettle additions.

STERILISATION OF WORT

Unfortunately, the temperatures achieved during mashing are not high enough to kill off the (microflora - heat resistant microorganisms) found in the raw materials such as malt, hops and adjuncts. This is where an inadequate boiling stage would definitely have a negative effect, and boiling grows another leg in terms of its importance to the overall brewing process.

Any residual enzymes that are not killed off during the mash-out and lautering (sparging) stages are taken care of through the boil. Most bacteria will be made inactive after 15-minutes of significant boiling and a lower wort pH can assist with this. It is also important to note that significant delays between run-off and boiling can lead to bacteria contamination.

HOP COMPONENTS & ISOMERISATION

During the boil stage, different hop components are made soluble and have the potential to be reduced by an ongoing boiling process through evaporation. Hop resins, oils and other bitter compounds (alpha/beta acids) can potentially contribute a harsh, undesirable bitterness to the wort, especially if they are oxidised. The boiling process changes their molecular arrangement (isomerisation) making them much more soluble and therefore able to be evaporated/removed through the process of boiling.

COLOUR INCREASE

A 'Malliard Reaction' is commonly found to take place during the boil phase of a brew where the higher temperatures favour the reaction to take place more readily. Also found in everyday cooking, a Malliard reaction is a non-enzymatic reaction of simple amines with simple sugars and leads to the formation of brown nitrogenous polymers. In short, these final products and 'caramelisation' from the reaction leads to a colour increase during the boil and also adds some flavour to the wort.

KETTLE ADDITIONS:

Additives used in the kettle during the boil phase are mostly to aid in trub formation. Some of the more common additions include;

- Irish Moss
- Tannin
- KMS (potassium metabisulfite)
- Gypsum (calcium sulphate)
- Activated carbon
- Diatomaceous earth

WORT CLARIFICATION, COOLING & AERATION

Wort forms a precipitate during both the boil stage (break) and when cooling prior to fermentation (trub). This precipitation is insoluble and consists of;

- Hardened protein
- Polyphenols (tannins)
- Carbohydrates

CLARIFICATION:

Why clarify? Trub has the ability to really affect the beer quality in a number of different ways. And while there are 'some' perceived benefits to not removing this trub, the disadvantages of not removing it really do outweigh them.

For starters, there is a direct correlation between beer flavour instability and trub reduction, where some of the trub components are substances that can induce negative flavours later in the beer. Trub has a significant concentration of bitter and polyphenolic substances which can impart on the flavour of the beer if left.

Haziness can also be introduced into the beer if trub is left in the wort.

Fermentation can also be affected by trub, where a yeasts health that gets re-pitched over time will compromised.

TRUB REMOVAL

The most common and agreed process for trub removal is during the 'hot break'. Although the negatives include a loss and time needed to do so, the benefit is a better wort clarity and avoidance of the problems that can occur listed above. It is very reasonable to try and remove as much of the hot trub as possible to a practical level. Cold trub removal is also possible but is not always as practical.

There are a few different methods that can work for hot trub removal, though as homebrewers, not all become practical to achieve. If you are using the Grainfather or similar system either 'filtration' or 'whirlpooling' become your best options.

FILTRATION:

The Grainfather system has a filter built in to assist in consistently removing the trub when used in conjunction with the magnetic drive pump. Passing the wort through this filter separates the trub particles from the wort and collects it near the filter.

WHIRLPOOL:

Considered by many brewers as the most practical method of trub removal, if done correctly it also has a minimal impact on wort quality. The basic description of this method is, a rotation of the wort leading to the trub accumulating at the bottom/ center of the vessel from the pressure and centrifugal forces of the whirlpooling effect.

This can be achieved by either pumping the wort back into the vessel, tangential to the vessel wall using a nozzle spray. The other more commonly used with the Grainfather system, is a specifically designed ‘paddle’ with four mesh fins, that is spun at high speeds to induce the whirlpooling effect of the wort. This is a far more cost effective and accessible method, available for most home brewing setups.

COLD TRUB REMOVAL:

Cold break can be much more difficult to remove, and the advantages of removal are much more controversial. There are some cases where it can reduce bitterness in the beer, while many think beer flavour benefits from cold trub remaining and can even be an advantage for mild and lighter beers. The process of cold trub removal for homebrewers also presents a potential contamination issue due to the process of using an immersion chiller cooling the wort to below Pasteurisation temperatures before transferring over to the fermenter.

When open fermenters were more common, these could be skimmed after the collapse of the high krauesen foam. The removed krauesen included the cold trub/ break. Open fermenters are not often used anymore, and this method would require more manpower than others. Following this, some fermenters included ‘foam chambers’ which sit on top of the fermenter. The cold break would stick to the roof of the fermenter, but due to the cost of additional cleaning these are also not a popular option.

If it is desired to remove the cold break, flotation tanks are the method most commonly used today. The flotation tank method is where an additional vessel is installed after wort cooling, before the fermenter. Excessive cold wort aeration causes foaming, entrapping the cold break. The clarified wort is pumped out of the flotation tank. The foam can then be discarded.

Most breweries which do not specifically reduce the cold break, tend to use the conical tanks to take out the sediment trub, together with the sediment yeast during the first few days of fermentation.

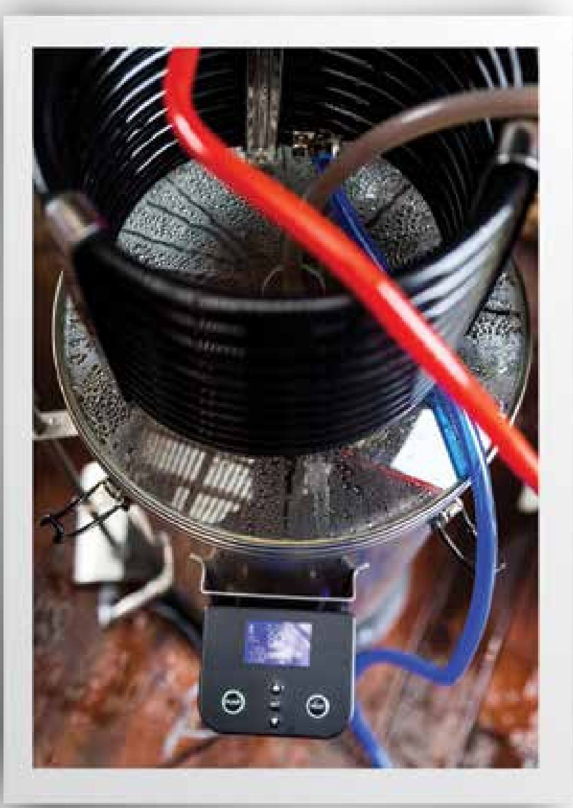
COOLING:

Wort needs to be cooled down from 95°C (203°F) to a yeast pitching temperature of 6 - 25°C (42 - 77°F) in the shortest time possible to minimize microbiological breakdown. The more efficiently the wort can be cooled, the better and cooling methods have evolved over time with technology.

There are three common tools used for chilling:

- Plate and frame heat exchanger, or plate chiller
- Shell and tube heat exchanger, commonly known as a counterflow chiller
- Immersion chiller

Any of these can be used in combination, or in multiples to create a two-stage chiller.



For the Grainfather system, a counter-flow shell and tube heat exchanger was chosen to cool the wort. It integrates and utilises the existing mechanical parts such as the magnetic drive pump and uses water as the coolant to chill the wort before it enters the fermenter.

Water is plentiful and an efficient use of utilities, that most home brewers can access easily. The downside over other coolants in more complicated systems such as brine, glycol and ammonia, are that while having a high capacity for heat removal, they require a lot more energy and maintenance for cooling maintained compared to water, which is easy to handle and use and the only limiting factor is the temperature of your ground water.

Immersion style chillers are another very popular type for use in home brewing. They most often use water as the coolant, where the water is pumped through a series of coils that are placed directly in contact with the wort. Immersion chillers are often low cost, easy to make and some home brewers find peace of mind in being able to see all sections of the chiller where they can clean and sanitise.

The Grainfather chose to develop and use a compact counter flow chiller over an immersion style, because a counter flow style chiller (especially at a home brewing level) provides greater cooling efficiency from the difference in temperature of the ground water temperature and the wort, which also results in less water use than most other style systems. The Grainfather counter flow chiller is based on a closed system that pumps the wort directly into a fermenter, resulting in a time efficient and very sanitary cooling and transfer process.

AERATION:

The stage of wort aeration is the only time in the entire brewing process where oxygen is not only desired, it is required. The level required is approximately 8-9 ppm of dissolved oxygen (D.O.).

Yeast growth, especially 'lipid synthesis' which is essentially for developing cell walls, is dependent on aeration of the wort. Yeast uses oxygen very quickly, within half an hour and up to 3 hours.

The amount of oxygen absorbed into the wort is dependent on pressure, temperature, bubble size and beer gravity. For homebrewers, the factor most controllable and measurable is temperature, whereby the lower the temperature of the wort, the more oxygen that will be absorbed. The higher the temperature of the wort, the less soluble oxygen will be.

E.g.

Temperature °C	**°F**	**Oxygen solubility in wort (mg/l)**
5	41	9.5
10	50	8.1
15	59	7.3

Tools such as the Grainfather aeration and whirlpool paddle are an effective method for home brewers to oxygenate their wort, however more complex systems are implemented for commercial breweries.

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Version 1