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Mashing Overview

• Essentially a continuation of the malting process!!
• Crushed malt is hydrated to form a mash at temperatures that encourage starch degrading enzyme activity
• Mash tun should be preheated with hot liquor – discard this before mashing in
• Add foundation liquor to cover the plates – this will protect the mash and avoid cloudy worts
• Mashes shouldn’t be excessively mixed – fine particles will be released and β-glucans can be sheared and extracted
• Use of torrefied cereals directly in the mash can add flavour and dilute nitrogen
The Main Processes Occurring During Mashing

- Soluble sugars and proteins are leached from the grist particles
- Enzymatic degradation of some of the insoluble grist substances
- Decrease in wort pH due to the presence and interaction of Calcium ions
- Chemical interaction of other wort constituents
- Enzyme denaturation and inactivation
Malt Starch – Amylose

- 20 to 30% of starch
- Straight chain polymer of glucose units
- $\alpha$ - (1,4) linkages
- LHS non-reducing
- RHS reducing
Malt Starch - Amylopectin

- 70 to 80% of starch
- Complex branched structure, on average every 27 glucose units
- $\alpha$ - (1,6) linkages at branches
- Only have 1 reducing terminus but a non-reducing one at the end of each branch
Amylolytic Enzymes - $\alpha$ - amylase

- Endo enzyme
- Breaks any $\alpha$ - (1,4) linkage in amylose and amylopectin
- Opens up starch molecules, dramatically reducing viscosity
- After gelatinisation temperature is achieved and starch structure is un-coiled, $\alpha$ - amylase quickly reduces the polymer size
- $\alpha$ - amylase liquefies starch
- Temperature range 70 -75°C, pH 5.3 – 5.8
Amylolytic Enzymes - β - amylase

• Exo enzyme
• Breaks the chain at every second glucose at the non-reducing terminus
• Will fully reduce amylose but only 10 to 15% of amylopectin unless working with α-amylase
• Saccharifies starch producing maltose
• Temperature range 63 - 65°C, pH 5.4 – 5.6
• If the β-amylase:α-amylase ratio is low, fermentability decreases
Other Mash Enzymes

- Proteases – heat labile, destroyed during kilning – produce soluble protein in malt
- Carboxypeptidases – heat stable, cleave amino acids from carboxyl termini of peptides and polypeptides, also degrade non-starchy polysaccharides creating $\beta$-glucans which aren’t degraded during mashing and $\beta$-glucanases are inactivated during kilning – high $\beta$-glucan worts are very sticky and viscous
Critical Factors - Temperature

- Increase in mash temperature will increase:
  - speed of enzyme activity
  - rate of enzyme inactivation
  - rate of starch gelatinisation, hydrolysis and dissolution
  - mash homogeneity
  - diffusion of substances throughout the mash

- However it can:
  - reduce wort fermentability
  - reduce extract yield
Critical Factors – Temperature (cont.)

- β-amylase activity declines prior to α-amylase action
- At 63°C mash temperature:
  - β-amylase activity is high
  - low extract efficiency
  - high wort fermentability
- At 65°C mash temperature:
  - β-amylase activity begins to decline
  - α-amylase activity starting
  - medium extract efficiency
  - average wort fermentability
- At 68°C mash temperature
  - β-amylase almost inactive
  - α-amylase active
  - good extract efficiency
  - low wort fermentability
- α-amylase continues to be active during run-off
- Sparging with liquor below 78°C or sparging for too long will increase fermentability as the β-amylase will not be inactivated
Critical Factors – Mash Thickness

• Thinner mashes cause enzyme denaturation, particularly $\beta$-amylase, carboxipeptidase and protease
• Thicker mashes protect enzymes
• Thin/low temperature mashes produce lighter/crisper beers
• Thick/high temperature mashes produce heavier/fuller bodied beers
Critical Factors - pH

• The optimum pH for infusion mashes is 5.2 to 5.5 (at 20°C)
• Resulting in:
  - more rapid amylolytic starch degradation
  - enhanced carboxypeptidase activity
  - altered protein solubility and coagulability
  - minimum tannin extraction
• Alkaline worts cause:
  - poor saccharification and wort separation
  - dark worts
  - poor biological stability
  - poor protein precipitation
  - astringent beer
• Reducing mash pH:
  - Use dark malts
  - acidify with in-organic acids
  - acidify strike liquor
  - use brewing salts to increase calcium levels
Wort Composition - Carbohydrates

• 90 to 92% of total
• 50% maltose
• 13% maltotriose
• 10% glucose – some yeast are glucose repressant
• 25% dextrins – non-fermentable for most yeasts, but watch saison strains and brettanomyces
• Adding lactose, a milk sugar to the kettle will give residual sweetness to the beer as yeasts cannot metabolise it
Wort Composition - Nitrogen

- 3 to 6% of total
- Polypeptides – long chain sequences of amino acids, hydrophobic ones promote beer foam, acidic ones are haze sensitive
- Peptides – 2 to 10 units long, some can be metabolised by yeast, can contribute to body and mouthfeel in beer
- Free Amino Nitrogen – 10-15% of total soluble nitrogen – minimum of 140ppm in a 1.040°sg wort
Wort Composition – Polyphenols

• 80% of wort polyphenols come from the husk of the malt grains
• Elevated pH and sparge temperatures increase polyphenol levels
• Oxidizable polys come through in beer and complex with polypeptides to form hazes
• Crisp Clear Choice malt doesn’t have any polyphenol in it
Wort Composition - Minerals

- Calcium
  - stabilises α-amylase
  - precipitates phosphate reducing pH
  - precipitates polypeptides reducing haze risk
  - precipitates oxalates reducing gushing risk
- Chlorides give perception of body and fullness
- Sulphates accentuate bitterness and are drying on the palate
- Traces of Zn, Na, PO4, Mn, Mg, K and Cu are all co-factors in yeast metabolism
Wort Boiling – Main Objectives

• Halt enzyme activity
• Sterilise the wort
• Concentrate the wort by evaporation
• Reduce pH and precipitate unwanted compounds
• Extract bitter substances and aroma from hops
• Remove unwanted volatile compounds
• Colour and flavour development
Wort Boiling - Overview

• Sweet wort is run-off from the mash tun and is heated slowly so that the temperature of the wort approaches boiling as run-off completes
• The wort is boiled vigourously for 1 to 2 hours
• Boiling effectiveness is normally measured by calculating the evaporation from the increase in gravity or alternatively the reduction in volume
• Hops are added at the start, occasionally middle and end of the boil for bitterness, flavour and aroma respectively
• 39% of the energy usage in a brewery is due to wort boiling
Enzyme De-activation and Sterilisation

• Most enzymes should have been denatured during run-off if the sparge temperature is high enough
• It is a given then, that the sugar spectrum of the wort is fixed once boiling is achieved
• Fungal β-glucanase will reduce wort viscosity and amylo-glucosidase will create a completely fermentable wort, both can be added during boiling as they are heat stable
• Bacteria, spores, yeast and mycelial fungi will be present in wort until it is boiled
Evaporation

- Normally 5 to 10% over 1 to 2 hours
- Gravity increases and volume decreases
- Either of the above can be used for calculation, but only volume if sugar has been added to the boil
- Larger kettles have a mass flow meter that measure the steam added to the boil
- Volatiles are driven up the stack and this should have a channel to catch any that condensate at try to run back into the wort
- It costs the same to boil a high gravity wort as it does a sales gravity one, so before you buy a complete bigger brewhouse consider buying a larger tun ....
Trub Formation and pH Reduction

- Formation and precipitation of protein/polyphenol complexes during boiling are essential for beer haze stability, these compounds are collectively known as trub.
- Poly’s from malt and hops are in oxidised form and will complex with protein to form hot break.
- The process is helped by the vigour of the boil, the rate of energy added to the system and the duration of the process.
- The optimum pH for trub formation is 5.2.
- Wort pH at the start of boil will be 5.8 to 5.9 and this reduces due to melanoidin formation, hop acids, precipitation of phosphates and polypeptides by calcium and release of H+ ions.
- Polyphenols also complex with other protein degradation products and these will remain in solution until after wort cooling and then precipitate as cold break aided by copper finings (electrostatic attraction).
- Acids or salts of calcium can be added to the kettle to reduce pH to the desired level.
Hops and Bitterness

- α-acids readily dissolve in wort
- Iso α-acids take longer to form and are influenced by:
  - boil temperature
  - boil time
  - form of hop used and addition time
  - wort pH
  - even hops added after flame out will isomerise to a degree
Removal of Volatiles

- The main volatile written about in the literature is Di-Methyl Sulphide which tastes and smells like sweetcorn and undesirable at high levels in lagers.
- DMS is formed from S-Methyl Methionine which is found in lager malts.
- Hop aroma compounds from the bittering hops are lost in the first 20 minutes of the boil.
- Some hop oils that lead to unpleasant vegetal and grassy aromas can take up to an hour to be driven off.
- Volatile carbonyls are also lost helping prevent formation of staling compounds.
Colour and Flavour Formation

• Colour is formed in direct fired and electrically heated kettles by caramelisation.
• Colour is also be formed through Maillard reactions between carbonyl and amino compounds.
• Wort also darkens as polyphenols oxidise and this can be minimised by avoiding oxygen in the system.
• Some of the products of these Maillard reactions add to flavour too, bringing roasted (furan), sulphurous (thiophene) and other complex aromas.
• Polyphenol oxidation.
Thanks for Listening any Questions Please?