



Water, Malt, Mash

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HHC Club Meeting
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BREWING WATER'S SCHIZOPHRENIC NATURE



impact vs no impact - e.g. soft/light no adjustments required
chemistry vs perception - e.g. mash efficiency vs personal taste
complexity vs simplicity - e.g. hard to understand, simple to practice
variability & leeway - e.g. published profiles, forgiving biochemistry, change over time, etc.

WHY CARE ABOUT WATER CHEMISTRY?

Because it impacts –

- the chemical and biochemical processes during mashing, fermentation, & maturation
(e.g. starch conversion, yeast health, hop utilisation, & clarity)
- the perceivable taste of the final beer
(pH & seasoning)



WATER



BREWING WATER QUALITY MANAGEMENT: THREE STEPS

1. Remove free Cl_2 (if present)
2. Match water's residual alkalinity (RA) to the colour of the beer to manage pH
3. Adjust ion concentrations and ratios to manage biochemistry and taste

STEP 1: DECHLORINATION

- Chlorine (Cl_2) disinfected municipal water + malt → chlorophenols (band-aid/plastic off-taste)
- Remove before brewing
 - an activated charcoal filter*
 - boiling for 15min*
 - standing overnight in an open container*
 - **potassium (or sodium) metabisulfite** (3mg/L [0.1g/20L batch])^{*#}
- Effective against chlorine* and chloramine[#] (latter not used by COCT or Stellenbosch)
- Commercial RO water may still contain some Cl_2 , depending on the filters used



STEP 2: MANAGE RA TO ENSURE CORRECT MASH (& beer) pH

- Alkalinity = water's capacity to resist a reduction in pH when (**dark**) malt is added
- **RA** used in brewing & primarily a function of Ca^{2+} and HCO_3^- concentrations (↓ & ↑ RA respectively)
- Helderberg & RO water have low RA (~12 & 0 mg/L CaCO_3 respectively; compare to London @ 196 & Pilsen @ 5 mg/L CaCO_3)
- Use a water calculator to manage

BREWING WATER vs GRAIN BILL

Low RA water (Lw)
(incl. Helderberg & RO water)

High RA water (Hw)
(much of what you'll read online)

Light grain bill (Lg)

Dark grain bill (Dg)

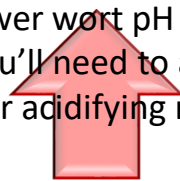
LwLg-Wort

- Can probably use as is



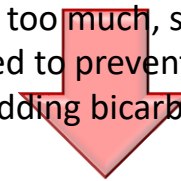
HwLg-Wort

- Light grain will not be able to lower wort pH enough, so you'll need to add acid or acidifying malt



LwDg-Wort

- Dark grain will lower wort pH too much, so you'll need to prevent this by adding bicarbonate



HwDg-Wort

- Can probably use as is



Note:

The exact outcome of any water vs grain bill/colour combination should be confirmed on a case-by-case basis using a water calculator.

WATER

STEP 3: MANAGE ION CONCENTRATIONS & RATIOS TO DESIRED LEVELS

- **HCO₃⁻ & CO₃²⁻** (bicarbonate & carbonate): **must be 25-50 ppm for pale beer and 100-300 ppm for darker beers.** Impacts mash pH, add as NaHCO₃ (baking soda).
- **Ca²⁺** (calcium): **must be 50-150 ppm.** Principle ion causing hardness, important biochemical co-factor, and promotes clarity, flavour, and stability. Add as CaSO₄ (gypsum) or CaCl₂ (calcium chloride).
- **Mg²⁺** (magnesium): **must be 10-30 ppm.** Important biochemical co-factor and accentuates flavour with a sour-bitterness. Add as MgSO₄ (Epsom salt / magnesium sulphate) or MgCl₂ (magnesium chloride).
- **SO₄²⁻** (sulphate): **must be 50-350 ppm.** Provides a sharper, dryer, bitter edge to hopped beers, e.g. 300:100 ppm SO₄:Cl (3:1). Add as CaSO₄ (gypsum) or MgSO₄ (Epsom salt).
- **Cl⁻** (chloride): **must be 10-100 ppm.** Accentuates fullness/body/roundness (mouthfeel) & sweetness/maltiness, e.g. 100:150 ppm SO₄:Cl (1:1.5). Add as CaCl₂, MgCl₂ or NaCl.
- **Na⁺** (sodium): **must be 10-150 ppm.** Rounds out the beer flavours, accentuating the sweetness, and contributes body and mouthfeel. Add as NaCl (only use NON-iodised table salt).



Water profiles for major brewing cities¹

City	Concentration (mg/L)						
	Ca ²⁺	Mg ²⁺	Na ⁺	SO ₄ ²⁻	Cl ⁻	HCO ₃ ⁻	RA
Burton-on-Trent	275	40	25	610	35	270	5
Dublin	120	4	12	55	19	315	170
London (Thames, IPA)	40	5	30	70	40	60	18
Londen (wells, Porter)	20	5	175	65	125	260	196
Munich	77	17	4	18	8	295	180
Vienna	75	15	10	60	15	225	125
Pilsen	7	2	2	8	6	5	5
London ²	100	5	35	60	50	265	146
Helderberg average	10	2	15	13	29	21	12
Oasis RO	2	0.1	3	2	5	3	4

Discuss:

- Hardness vs RA.
- Variability between available profiles.
- Well vs surface water (Londen).
- Evolution of styles based on water.
- Helderberg “average water”.
- RO water (RA & Cl₂)

¹Bru ‘n Water

²Brewer’s Friend

OTHER IMPORTANT DETAILS

○ Acidifying the mash

- highly unlikely to require when using the Cape's low RA (soft) water & managing water chemistry
- acidulated malt (malt infused with lactic acid, use at ~ 2-5%)
- acids like **lactic**, **phosphoric**, **citric**, **HCl**, **H₂SO₄**, etc. (**weak** vs **strong** acids, different taste thresholds & style matching)

○ Sulphate:Chloride ration ($\text{SO}_4^{2-}:\text{Cl}^-$)

- this ratio affects the balance of the beer, i.e. dryness vs. fullness
- the ratio is not absolute, i.e. 40:10 \neq 400:100
- common range is 9:1 (high) to 0.5:1 (low)
- maximum suggested sulfate concentration is 500 ppm (mg/L)
- maximum suggested chloride concentration is 200 ppm
- recommend not to exceed 100 ppm chloride for high ratios
- recommend not to exceed a combined sum of 500 ppm

WATER

IN PRACTICE



BREW WATER

Step 1	Get hold of a water report to confirm the chemical <u>profile of your SOURCE water</u>
Step 2	Decide on an <u>appropriate TARGET profile</u> for the specific beer you're brewing
Step 3	Use a <u>water calculator</u> to determine how much of which salts must be added (and possibly acids – unlikely for soft water) to your source water to end up with the target profile
Step 4	<u>Add the required salts</u> to your brewing water (strike AND sparge)

IN PRACTICE: Brewfather

Water pH **5.44** ? ⚙️ ✕

Mash Water L Sparge Water L
35 0

1. Source

Reverse Osmosis Water

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
1	0	8	4	1	16

Dilution (optional) REMOVE SELECT

2. Target Profile (optional) REMOVE

Hoppy

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
110	18	16	50	275	33

The target profile is used when using the auto-adjustment button. The target water profile is also what shows as a diff under your total water profile when adjusting.

Style (optional)

American Pale Ale ▾

Select a style to show suggested min and max values for each mineral addition. Clicking the auto button with no target-profile selected will create a target based on the average style range. The style selection is meant as an optional guideline for recommended mineral ranges.

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
50-150	0-30	0-100	0-100	100-400	40-120

3. Mash pH 5... ⚙️ RESET

4. Gypsum CaSO₄ g 12.5 Calcium Chlor... CaCl₂ g 3.3 Epsom Salt MgSO₄ g 6.4

Slaked lime Ca(OH)₂ g 0 Baking Soda NaHCO₃ g 0

Mash

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
110	18	8	49	271	16

Total 35 L

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
110	18	8	49	271	16
0	0	-8	-1	-4	-17

Sulfate/Chloride ratio: **Very dry or bitter** (5.5)

Water pH **5.57** ? ⚙️ ✕

each mineral addition. Clicking the auto button with no target-profile selected will create a target based on the average style range. The style selection is meant as an optional guideline for recommended mineral ranges.

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
50-150	0-30	0-100	0-100	100-400	40-120

Mash pH 5... ⚙️ RESET

Gypsum CaSO₄ g 2.5 Calcium Chlor... CaCl₂ g 3.3 Epsom Salt MgSO₄ g 6.4

Slaked lime Ca(OH)₂ g 0 Baking Soda NaHCO₃ g 0

Mash

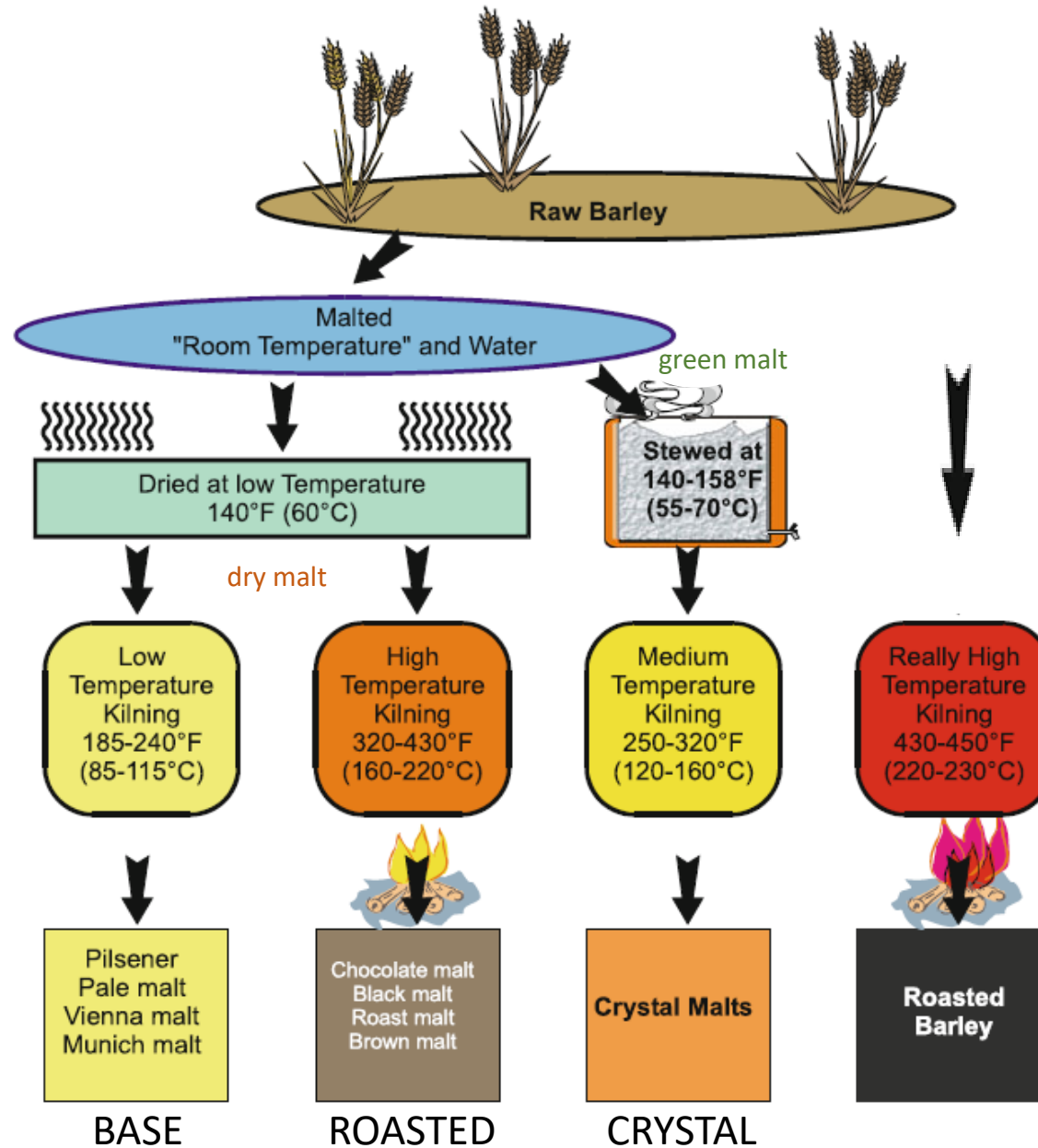
Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
43	18	8	49	112	16

Total 35 L

Ca ²⁺	Mg ²⁺	Na ⁺	Cl ⁻	SO ₄ ²⁻	HCO ₃ ⁻
43	18	8	49	112	16
-67	0	-8	-1	-163	-17

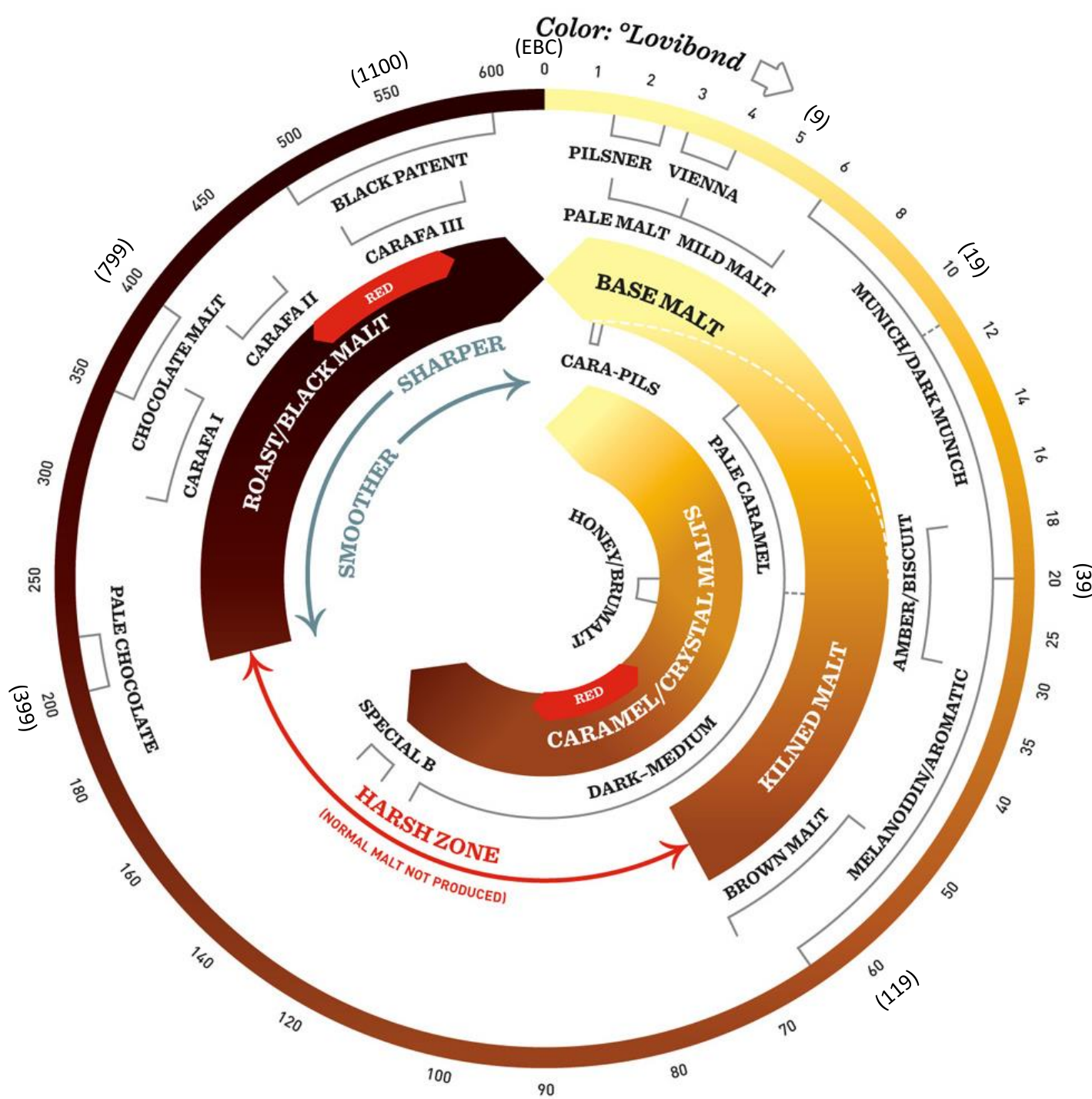
Sulfate/Chloride ratio: **Dry or bitter** (2.3)

BASE, CRYSTAL & ROASTED MALTS

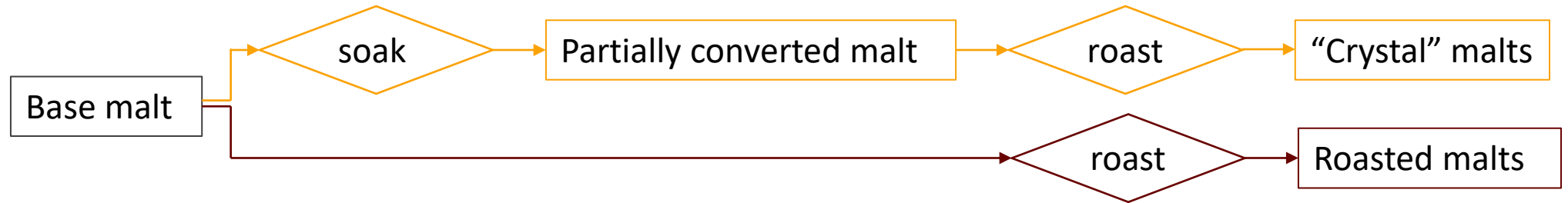




MALT WHEEL



HOME ROASTING INTRODUCTION

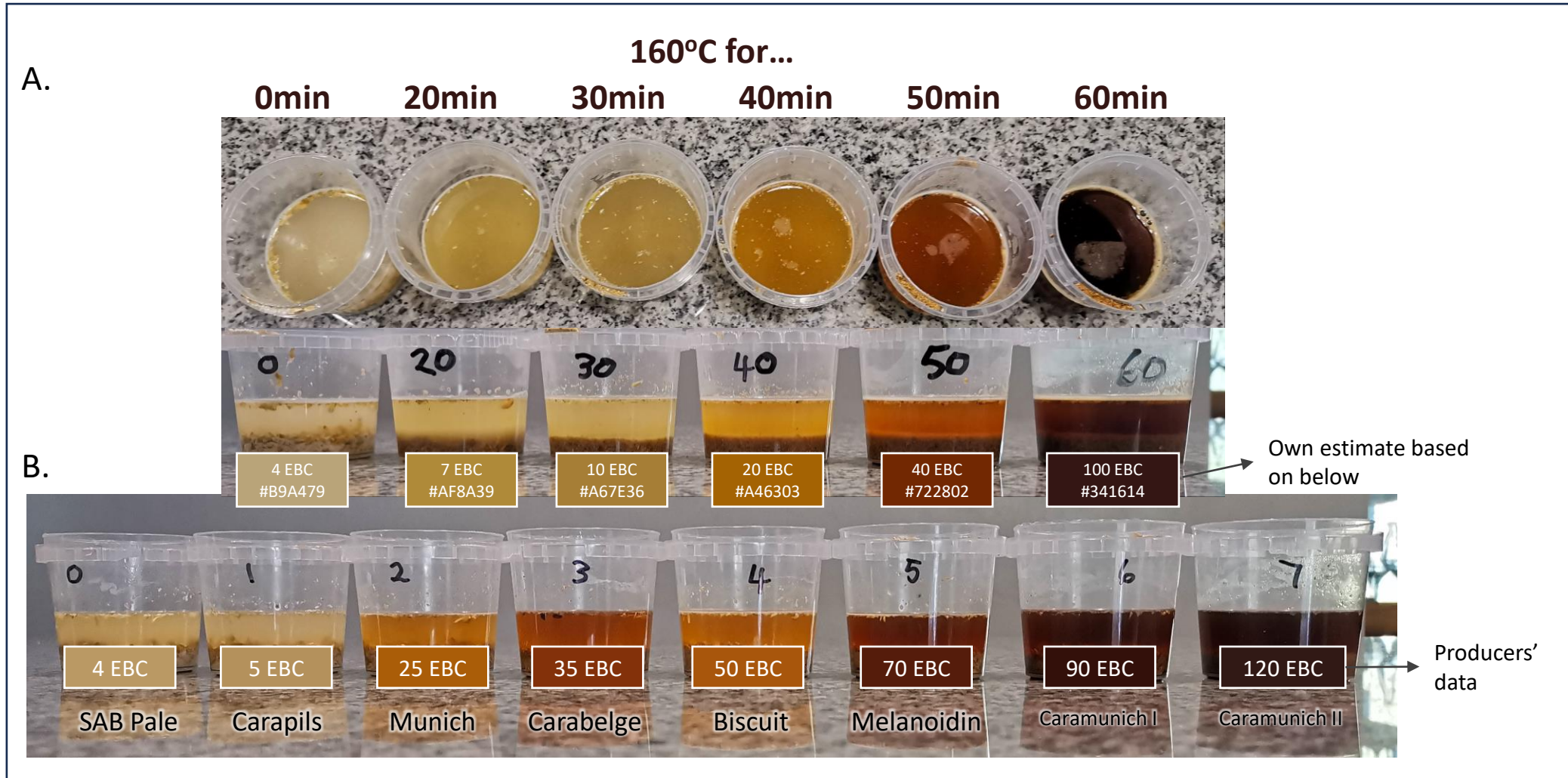


APPROXIMATE ROASTING PARAMETERS FOR HOME ROASTING

Time (min)	Temp (°C)	Colour	Flavours
20	120	Pale gold (10L, 25 EBC)	Nutty, not toasty
25	150	Gold (20L, 52 EBC)	Malty, caramelly, rich, not toasty
30	180	Amber (35L, 92 EBC)	Nutty, malty, lightly toasty
40	190	Deep amber (65L, 172 EBC)	Nutty, toffee-like, crisp toastiness
30	200	Copper (100L, 265 EBC)	Strong toasted, some nuttiness
40	200	Deep copper (125L, 332 EBC)	Roasted, not toasted, porter-like, chocolate to coffee
50	200	Brown (175L, 465 EBC)	Strong roasted flavours, coffee

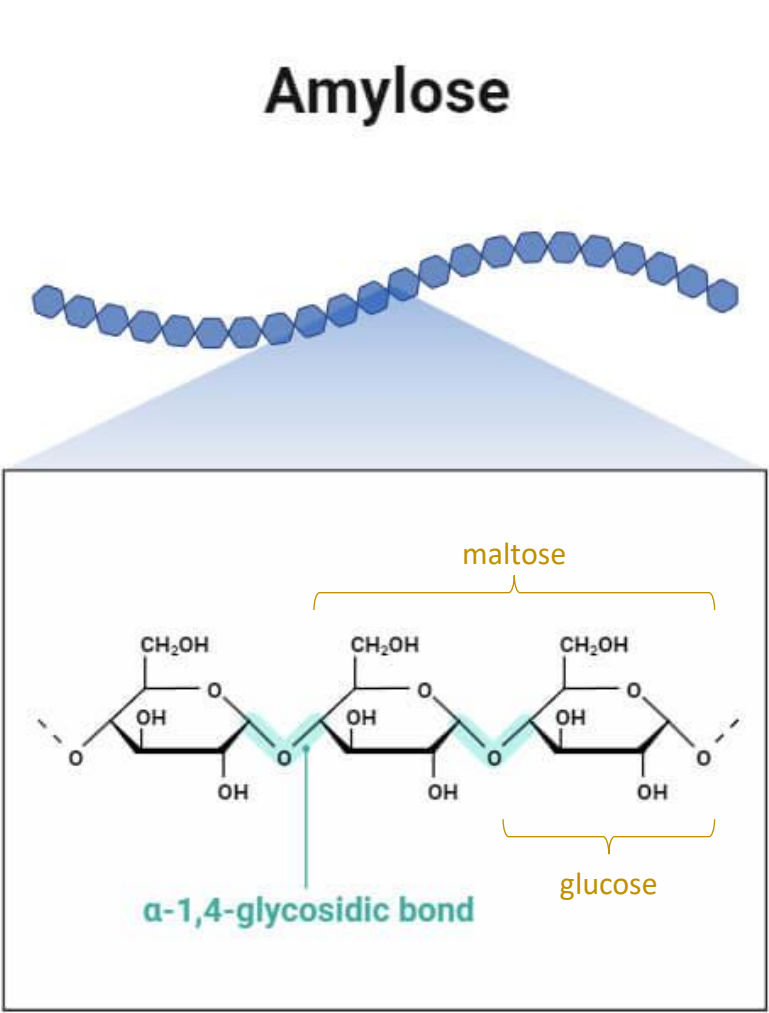
IMPORTANT! Home roasting outcomes must be determined empirically.

HOME ROASTING INTRODUCTION

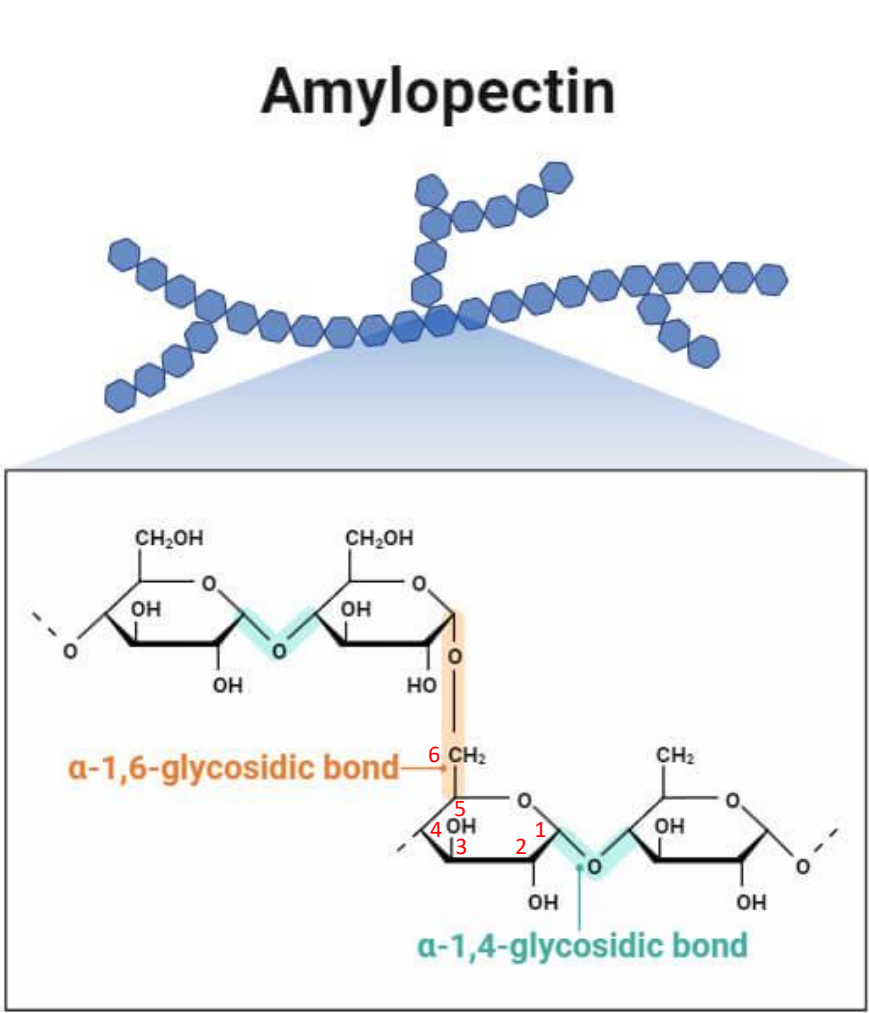


STARCH

Amylose



Amylopectin



MASHING & FERMENTATION ENZYMES



Enzyme	Temperature Range	Optimum pH	Function
Phytase	30-52°C	5.0-5.5	Also called the “Acid Rest”, it used to be used to lower the mash’s pH, but it has been discontinued with the proper use of water chemistry .
Debranching	35-45°C	5.0-5.8	Helps to increase the solubility of starches resulting in increased extraction for certain malts. This enzyme breaks down the 1-6 links in starches.
Beta Glucanase	35-45°C	4.5-5.5	Working within the same temperature range as debranching, this enzyme is best at breaking down gums.
Peptidase	45-55°C	4.6-5.3	Peptidase breaks down the smaller amino acid chains released by proteinase, but only works from the ends, releasing yeast nutrients such as Free Amino Nitrogen (FAN).
Protease	45-55°C	4.6-5.3	This is “ protein rest ” breaks up large proteins that form haze.
Beta Amylase	55-66°C	5.0-5.5	The final enzymatic process involves the conversion of starches into dextrins and fermentable sugars. The starches must be gelatinized for this to take place.
Alpha Amylase	68-72°C	5.3-5.7	Temperatures above 68°C favor this enzyme, producing a more dextrinous wort, which is less fermentable and results in a fuller body.

MASHING & FERMENTATION ENZYMES

Table I. Enzymes involved in starch/sucrose degradation during mashing and fermentation.

Enzyme name	Reaction	Substrates	Products	Optimum temperature
1. α -Amylase (EC 3.2.1.1)	<u>Endohydrolysis of 1,4-α-D-glucosidic linkages</u>	amylose, amylopectin	dextrins, maltose, limit-dextrin, glucose (low amounts)	65–75°C
2. β -Amylase (EC 3.2.1.2)	Successive <u>exohydrolysis of the penultimate 1,4-α-D-glucosidic linkage at the non-reducing end of chains</u>	dextrins, amylose, amylopectin	maltose	60–65°C
3. Glucoamylase (EC 3.2.1.20)	Successive <u>exohydrolysis of the terminal 1,4-α-D-glucosidic linkage at the non-reducing end of chains</u>	maltose, dextrins, amylose, amylopectin	glucose	35–40°C
4. Limit dextrinase (EC 3.2.1.142) (specific debranching enzyme)	Hydrolysis of 1,6- α -D-glucosidic linkages	amylopectin	dextrins, maltose (smallest sugar released)	55–60°C

^a Value for yeast invertase.

^b Value for malt invertase. Literature source^{12,26,30}.

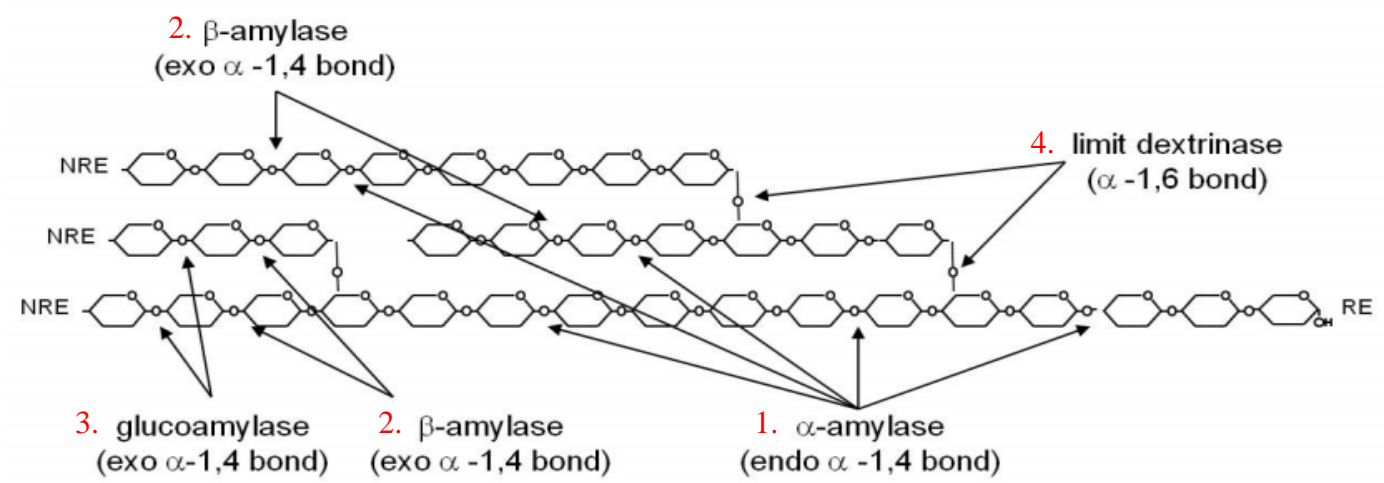


Fig. 1. Amylopectin structure and the indication of enzymatic hydrolysis points. RE = reducing end; NRE = non-reducing end. Literature source¹².

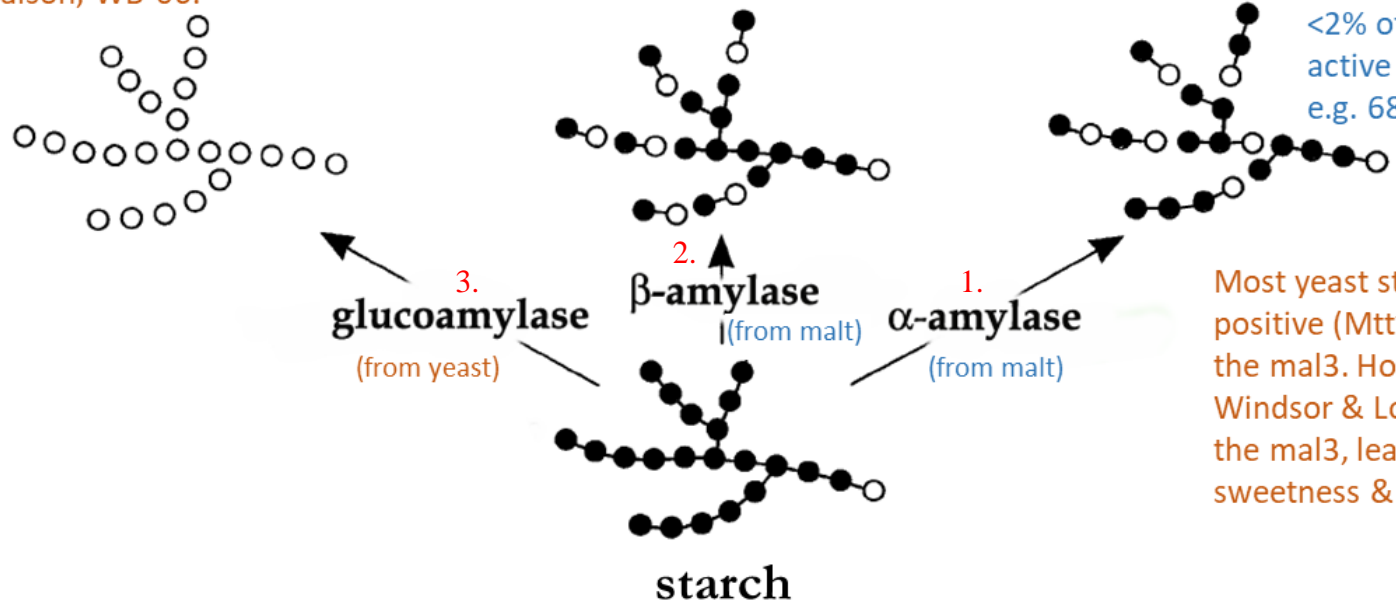
MASHING & FERMENTATION ENZYMES



Hydrolyses end 1-4 bonds & yields glucose. Only in Diastaticus yeasts (STA1+). Hyperattenuators (>90%), always POF+ e.g. Belle Saison, WB-06.

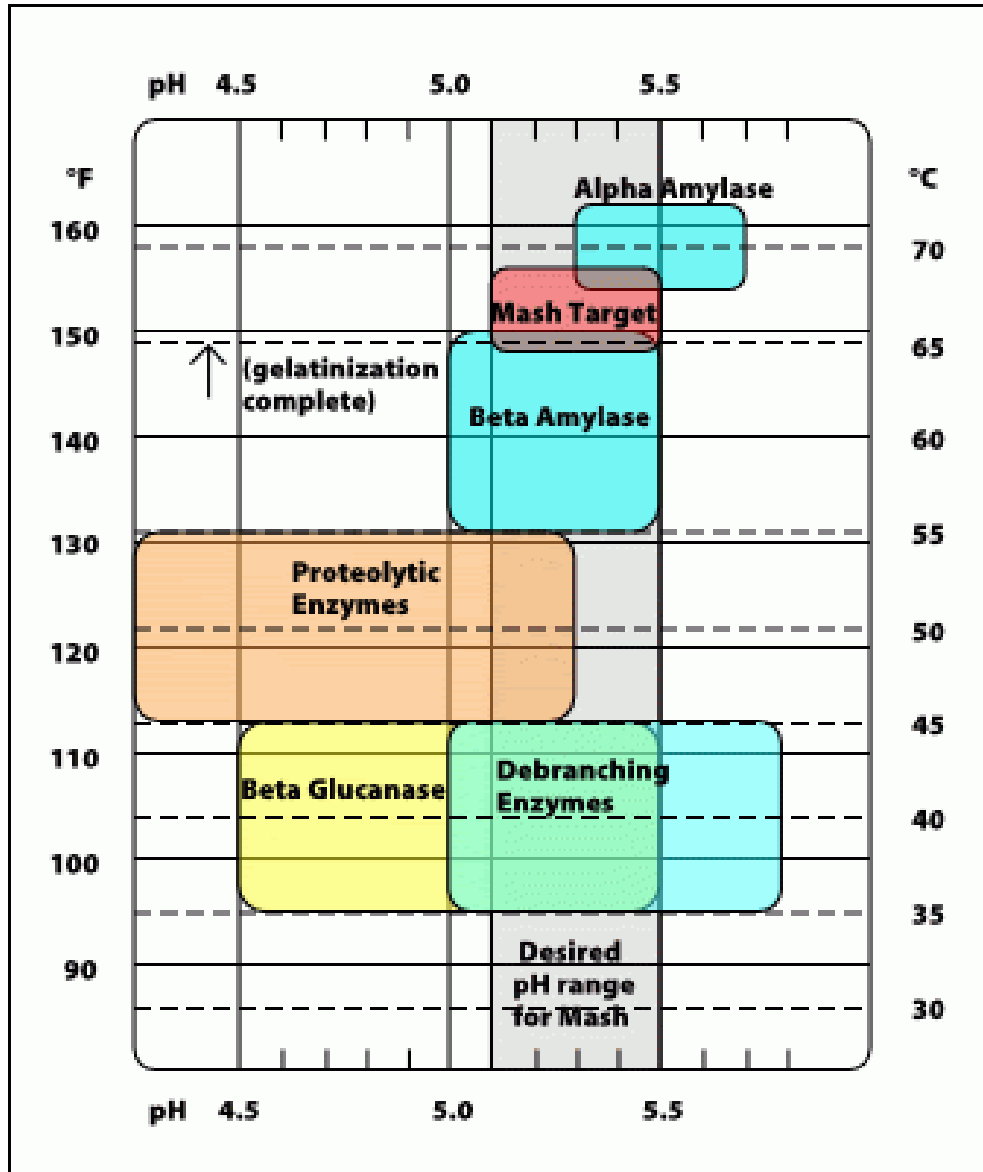
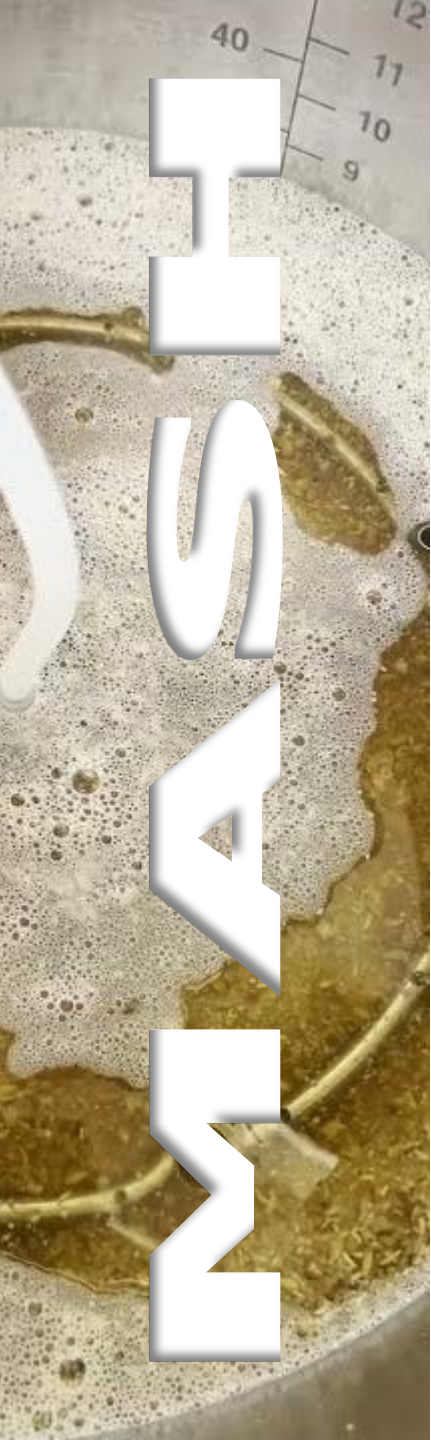
Hydrolyses end 1-4 bonds & yields maltose, i.e. highly fermentable wort. Heat labile above 60°C & more active at lower mashing temps e.g. 60-64°C.

Hydrolyses internal 1-4 bonds & yields maltotriose (mal3) & dextrins (shorter chains), i.e. less fermentable wort. <2% of β-amylase activity, more active at higher mashing temps, e.g. 68-70°C.

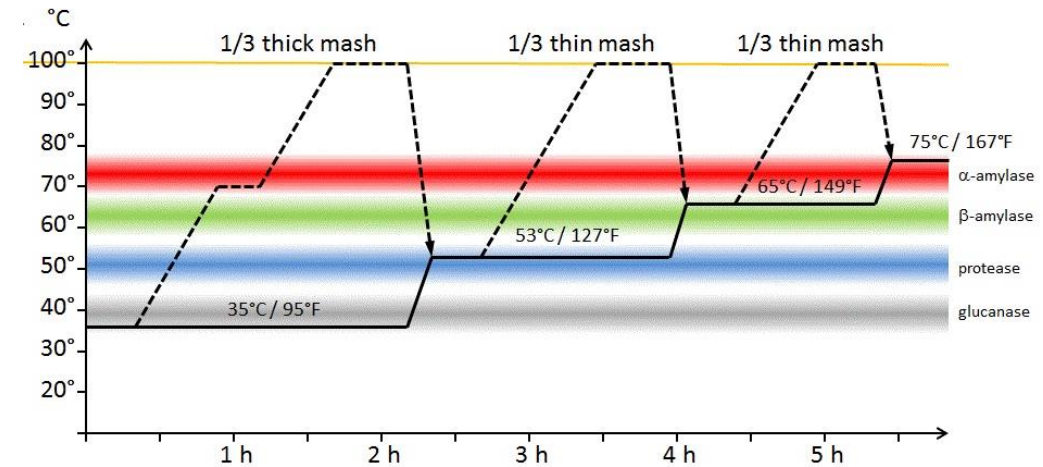


Most yeast strains are maltotriose positive (Mtt⁺) & will therefore ferment the mal3. However, some are Mtt⁻, e.g. Windsor & London, and unable to use the mal3, leaving the beer with residual sweetness & more body.

MASHING ENZYMES' OPTIMUM pH & TEMP



Decoction mashing



α -AMYLASE ACTIVITY

pH & TEMP DEPENDENCE

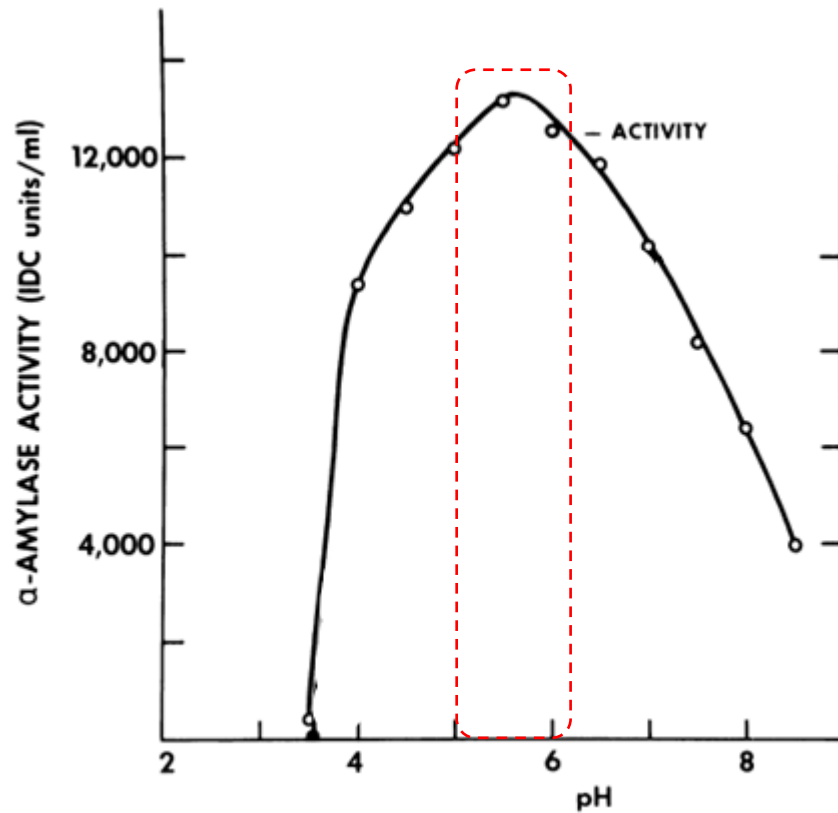


Fig. 6. Effect of pH on activity of α -amylase I.

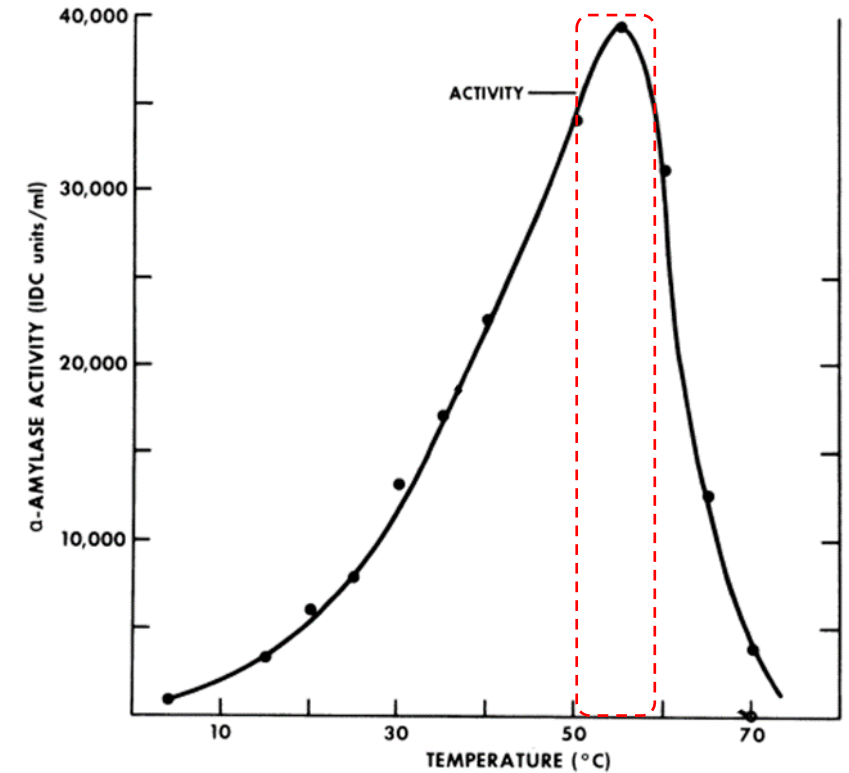


Fig. 5. Effect of temperature on activity of α -amylase I.

β -AMYLASE ACTIVITY pH & TEMP DEPENDENCE

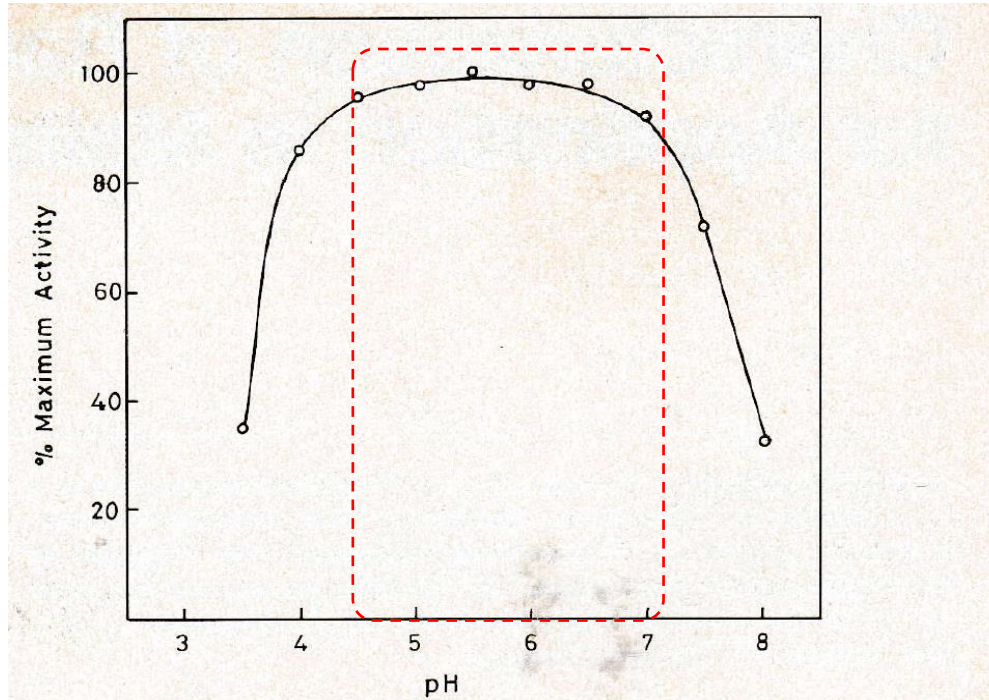


Figure 2. β -Amylase activity profile at different pH. β -Amylase was extracted from 4 day germinated barley, diluted in buffers at the indicated pH and its activity determined at 50°C.

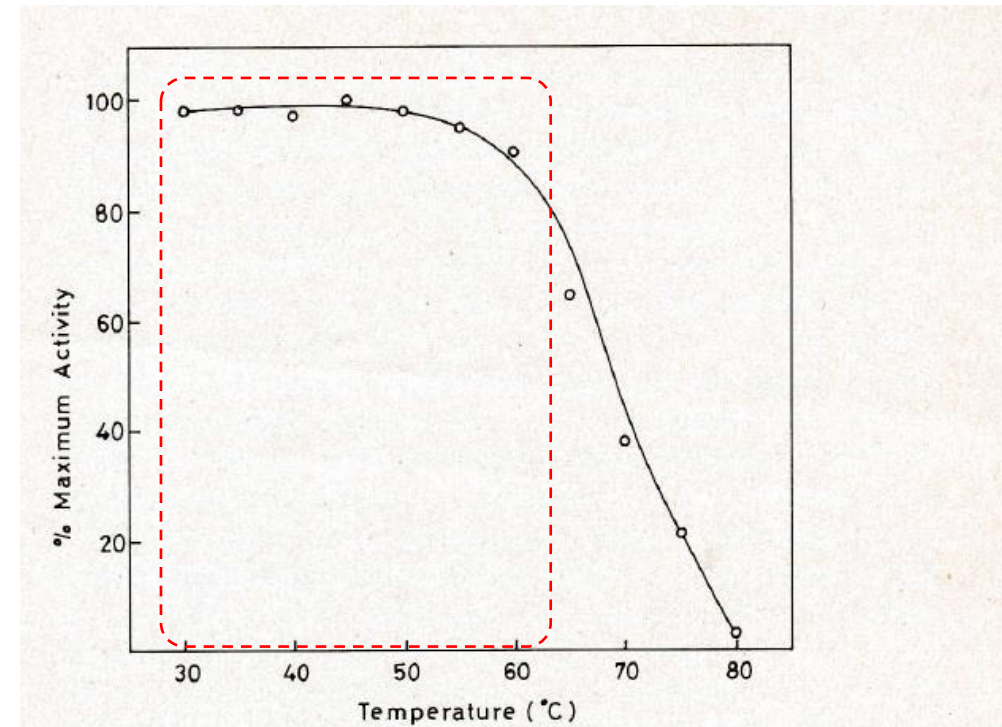
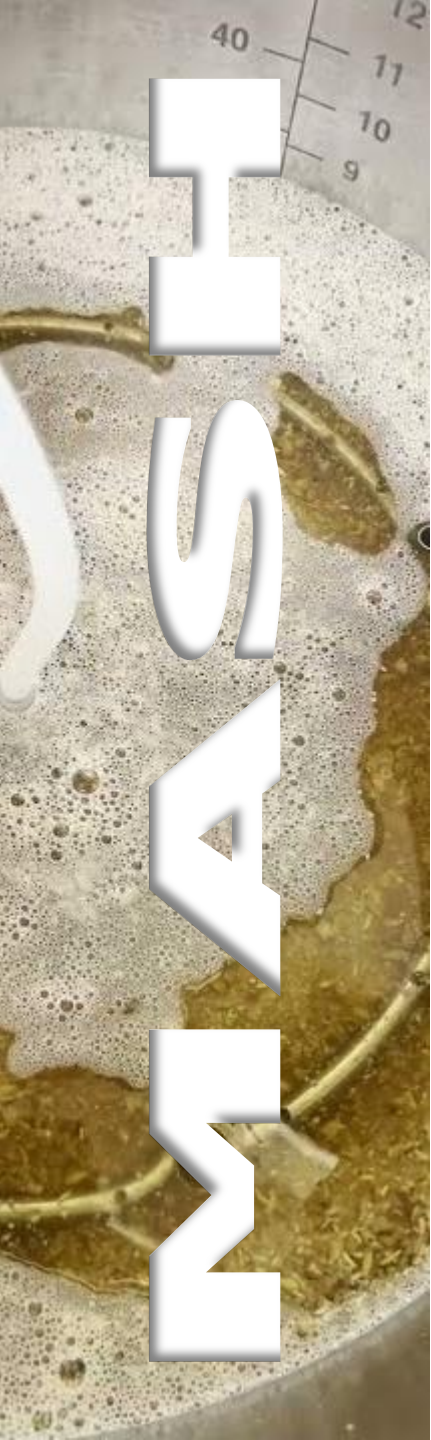


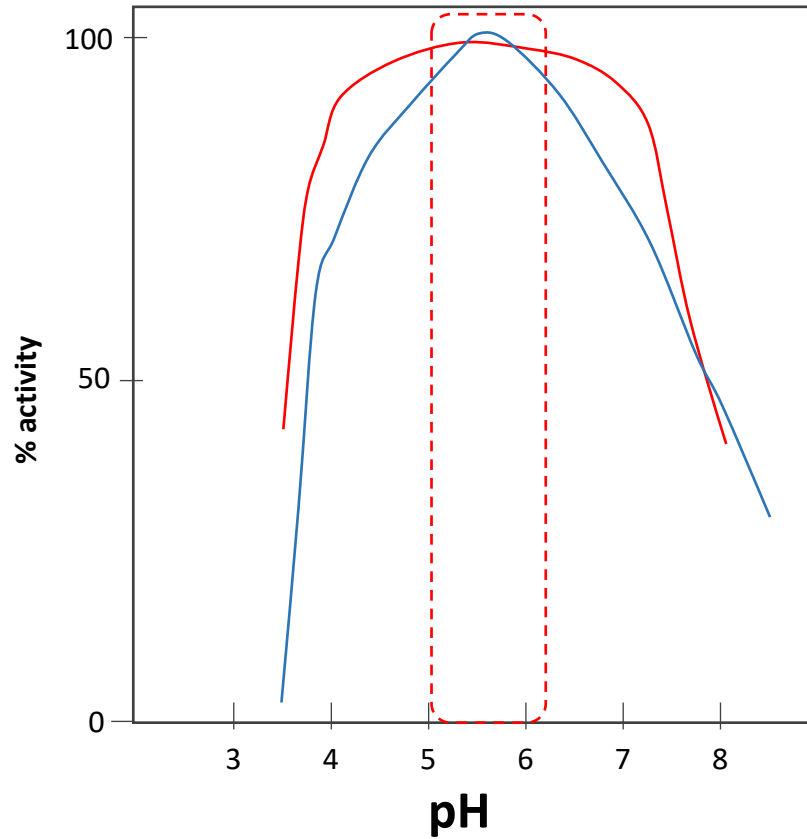
Figure 3. β -Amylase activity profile at different temperatures. β -Amylase was extracted from 4 day germinated barley and was estimated at pH 5.5 at the indicated temperatures.

α - & β -AMYLASE ACTIVITY

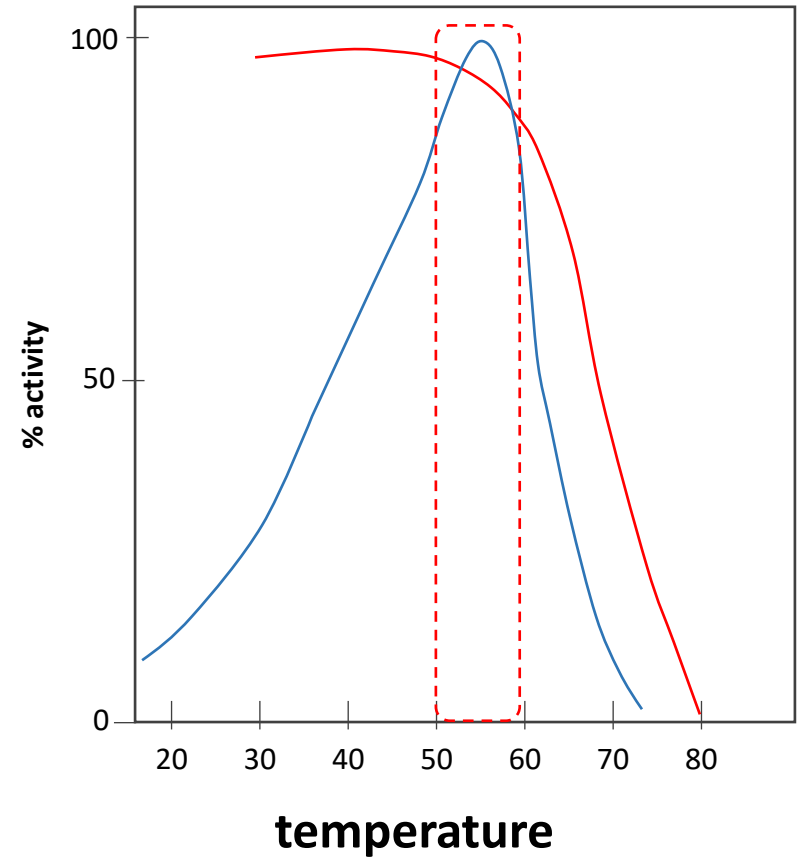
pH & TEMP DEPENDENCE



α -amylase vs β -amylase



α -amylase vs β -amylase



α - & β -AMYLASE STABILITY AT DIFFERENT TEMPERATURES & OVER TIME

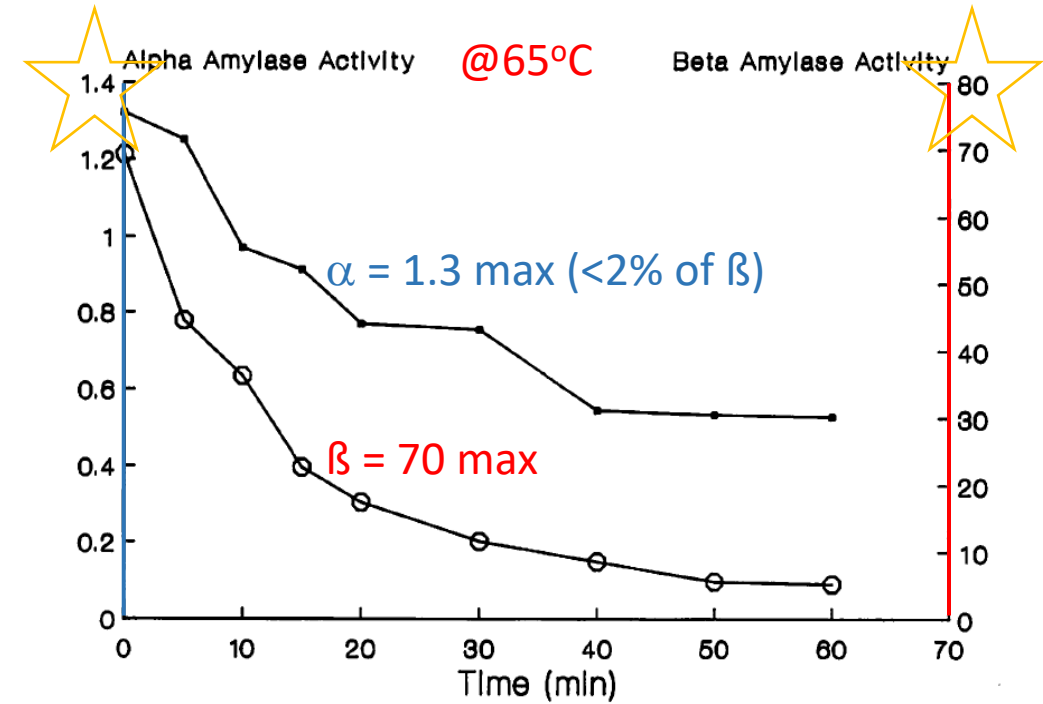
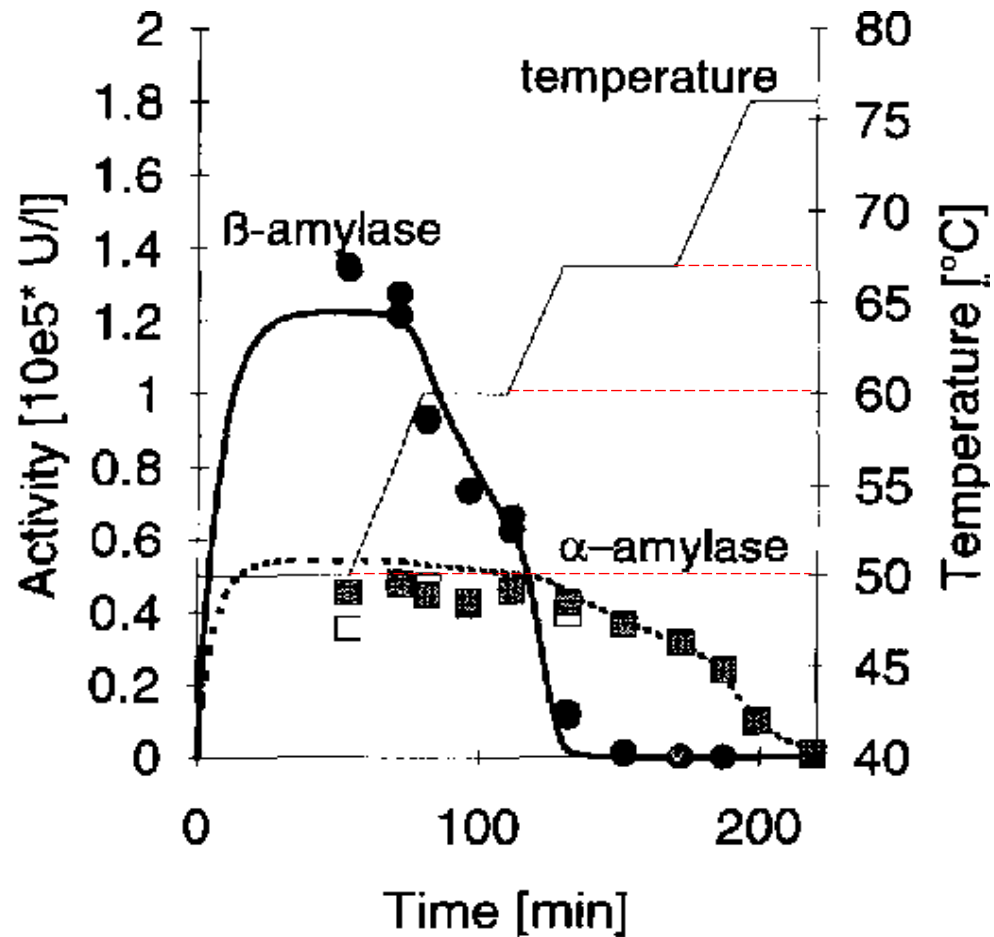
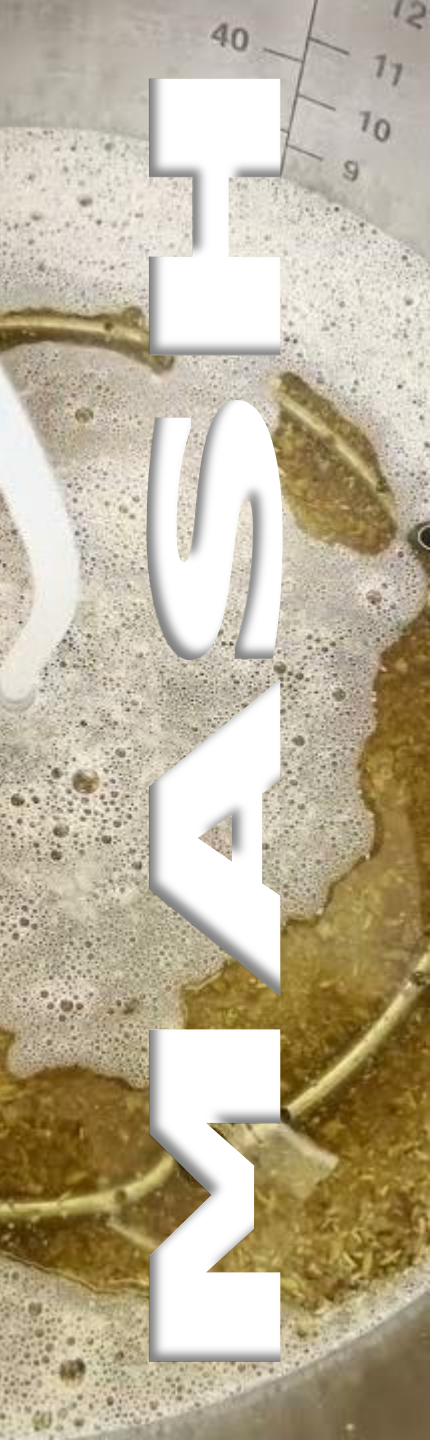
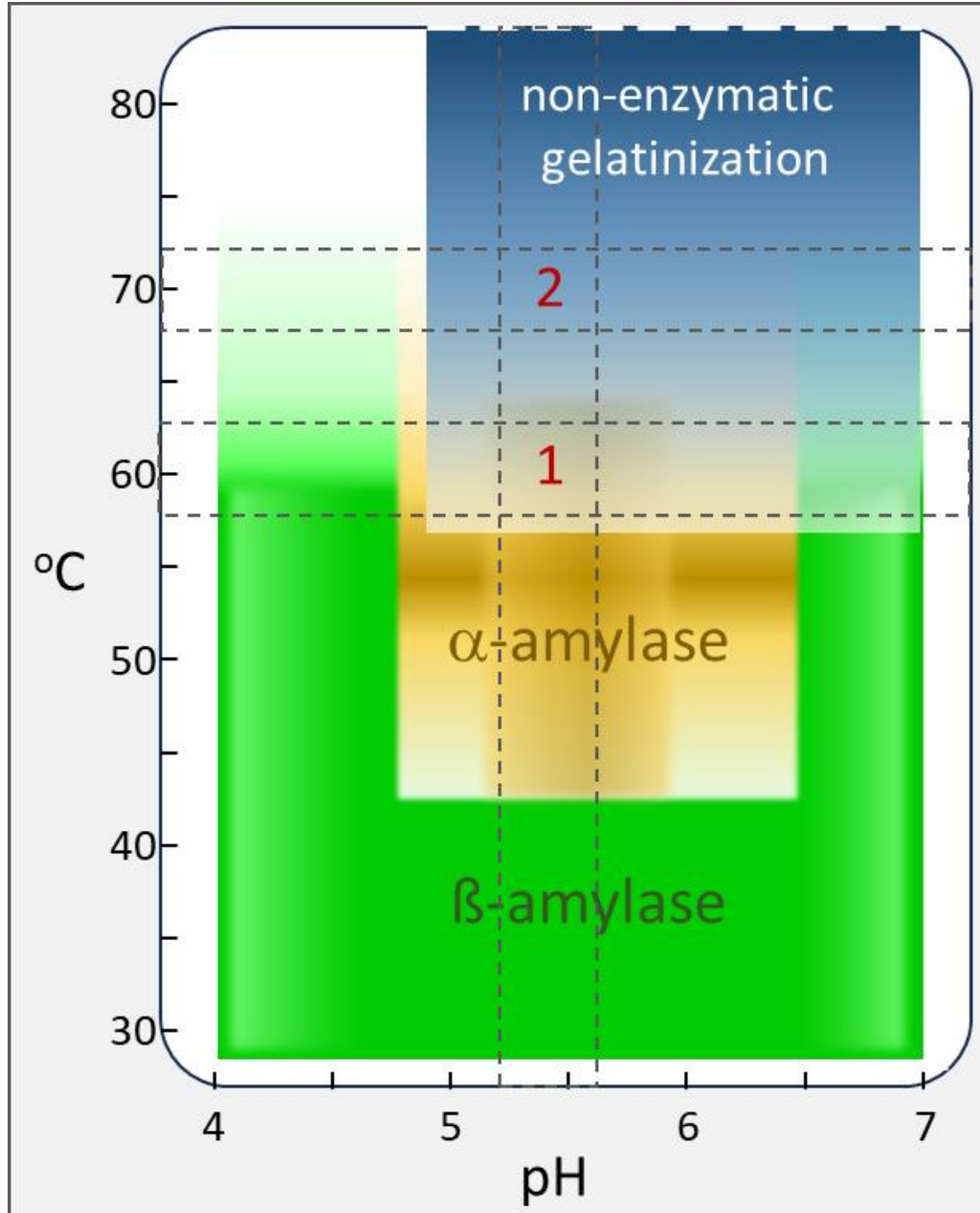


FIG. 1. Inactivation of malt amylase mashed at 65°C. Samples of mash were taken from a standard run on the BRF Mashing column using 1.5 kg malt mashed with 3.75 litres of water (liquor to grist ratio 2.5:1). Alpha and beta amylases were extracted and their activity determined at a standard temperature. This activity was corrected to 65°C by extrapolation. Alpha amylase (■—■) activity is presented as grams of limit dextrin hydrolysed per minute per gram of malt. Beta amylase (○—○) activity is presented as grams of maltose produced per minute per gram of malt.



MASHING ENZYMES' OPTIMUM pH & TEMP

(THE HENNIE VERSION)

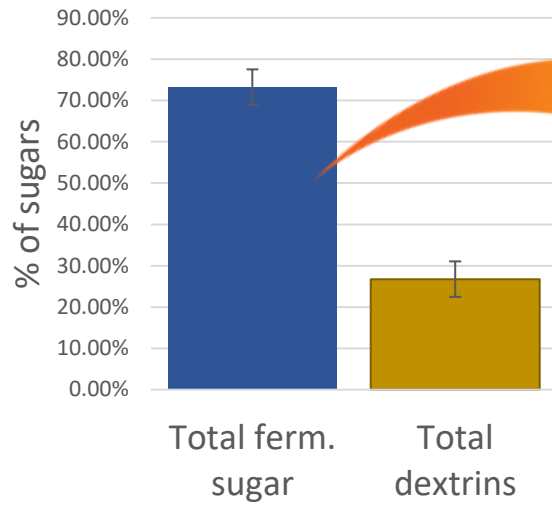


- Blocks represent >75% of max activity - always a gradient towards maximum activity.
- α -activity narrower optimum bands for both pH & temp, than β -activity.
- Total α -activity only ~2% of total β -activity.
- α -activity more stable at high temp (70°C) than β -activity, with half-life of only ~10min >60°C.
- "1" = mashing sweet spot for light-bodied, dry beers [& as 1st step for others].
- "2" = mashing sweet spot for full-bodied beers.

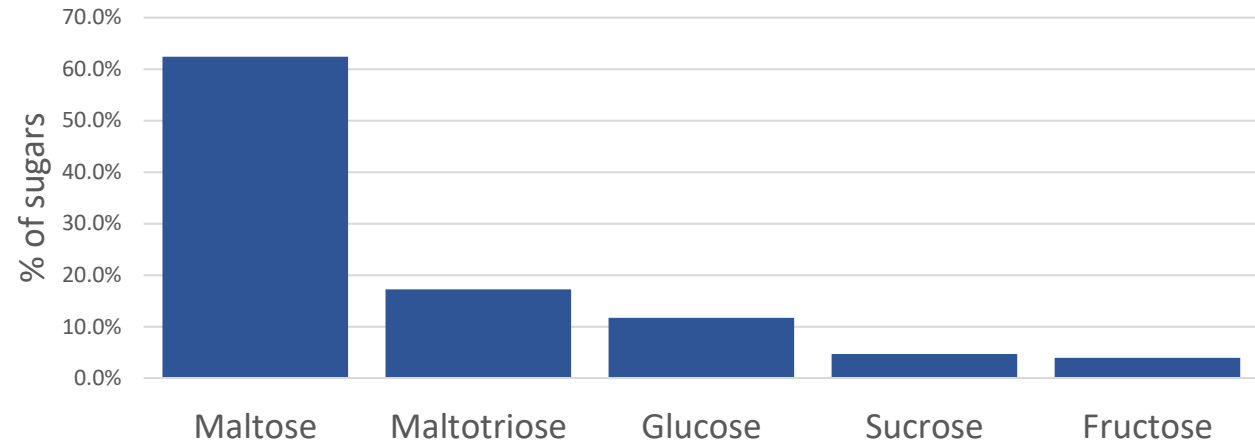


FERMENTABILITY

Fermentability*

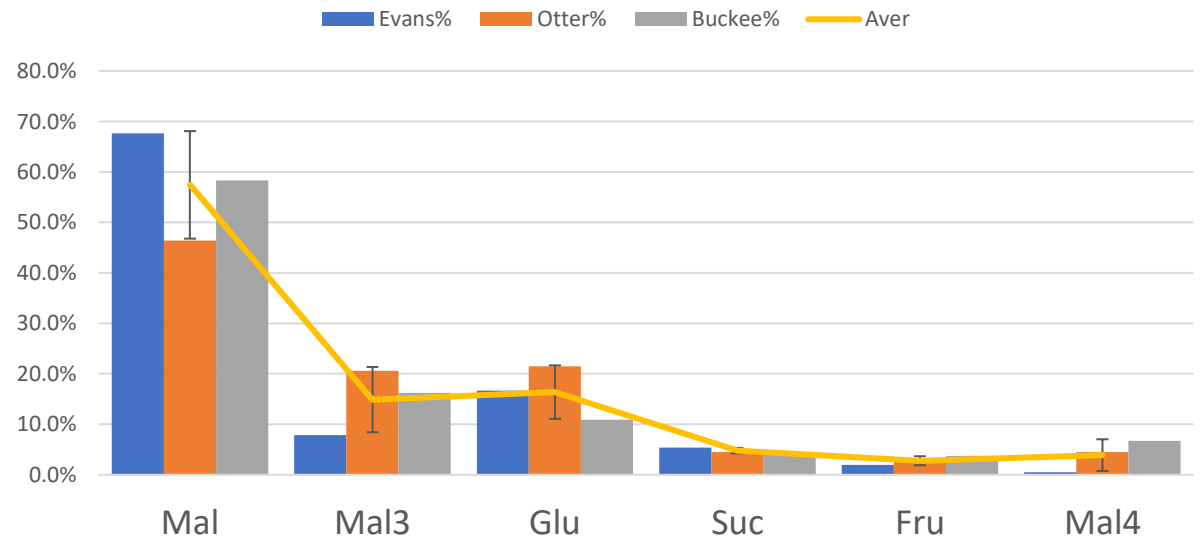


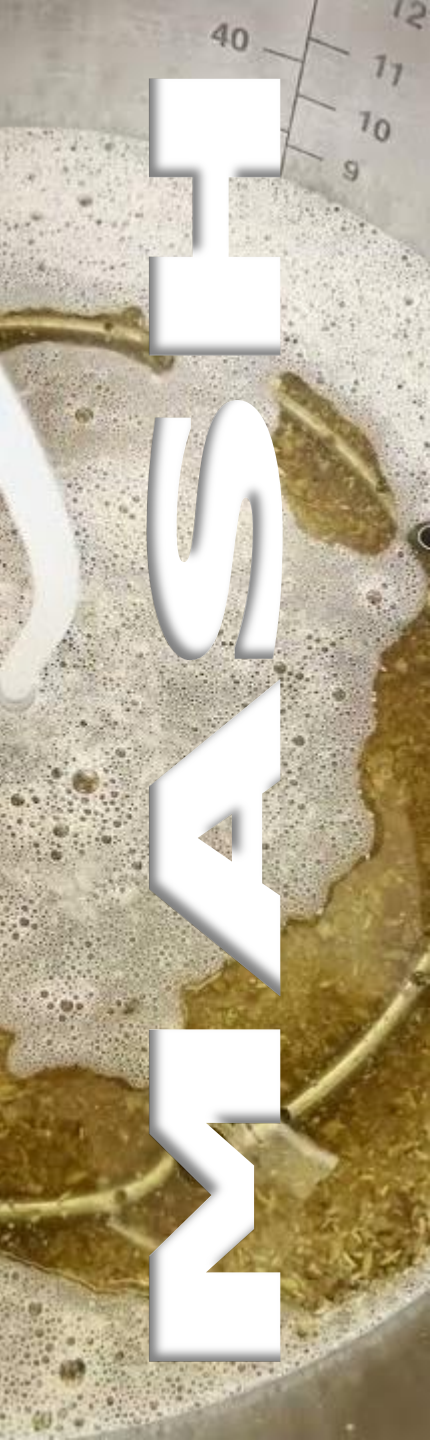
Relative amounts of fermentable sugars*



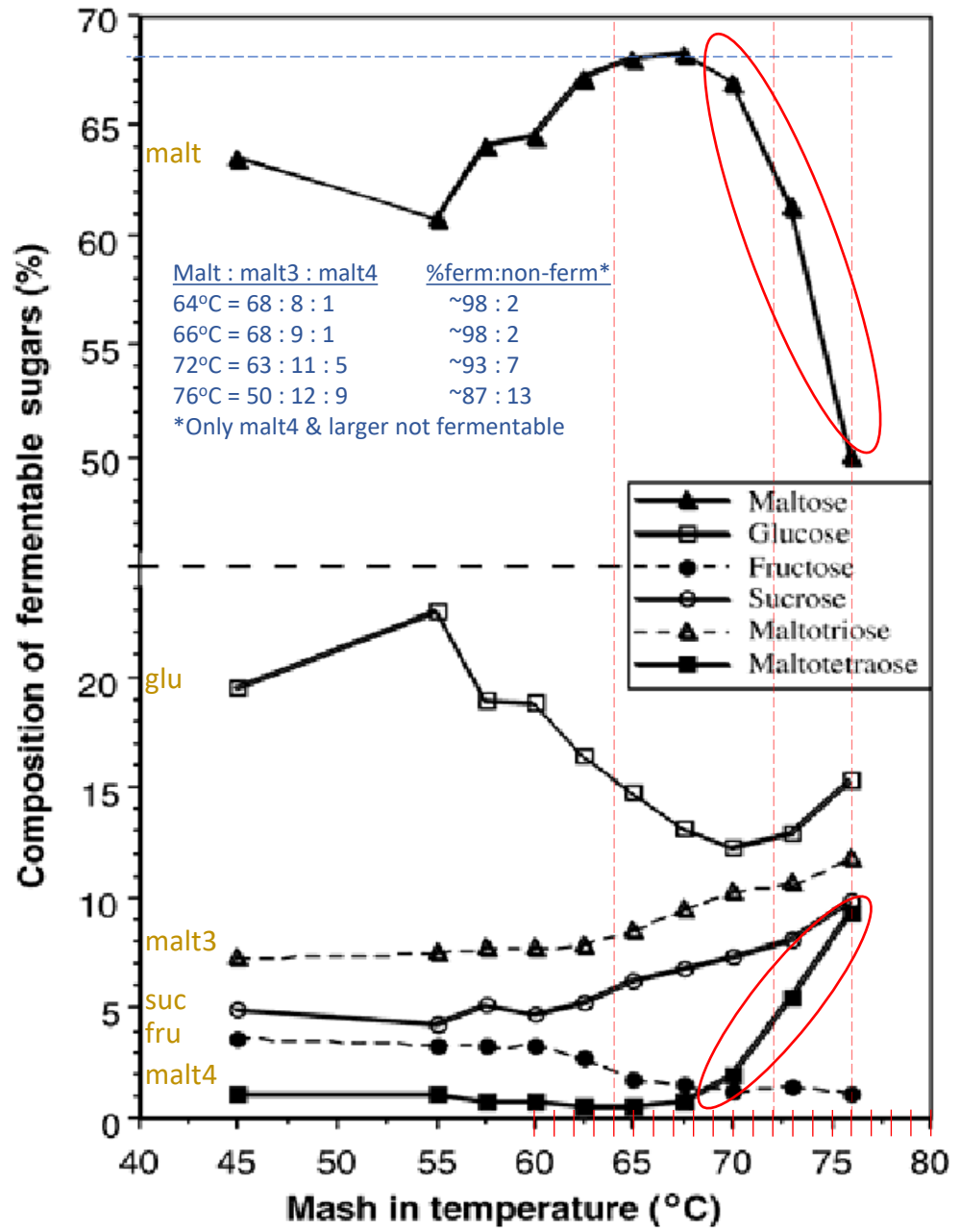
*Will depend on malt bill, mashing conditions, yeast, etc.

Wort relative [sugar] (%)





FERMENTABILITY



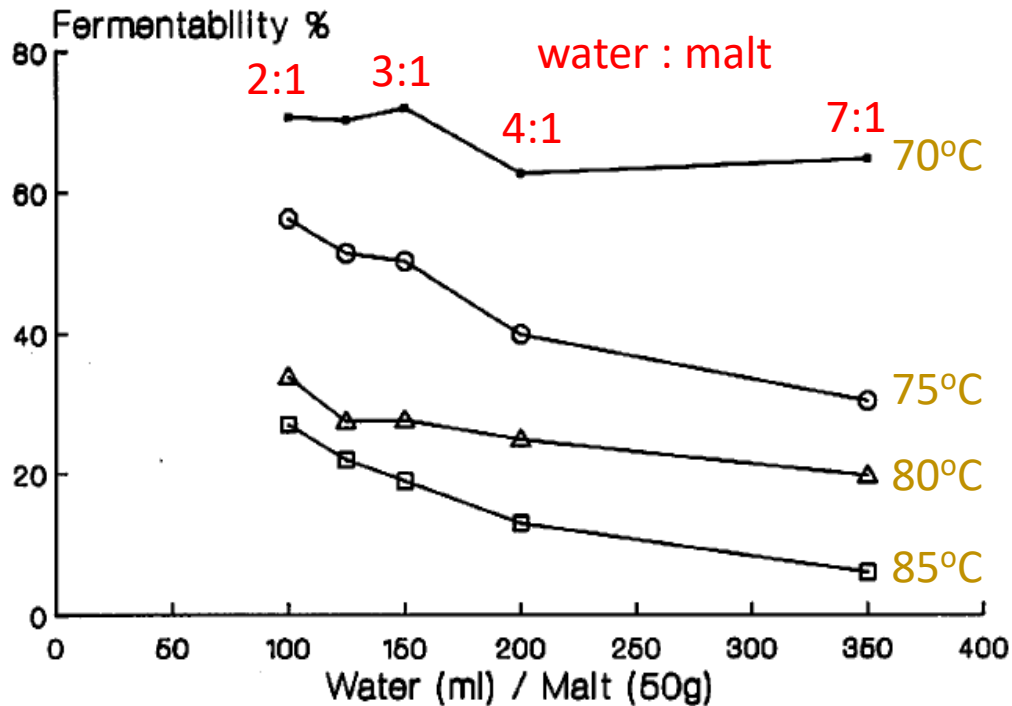
↓ β-amylase activity

↑ α-amylase activity

FERMENTABILITY

MASHING

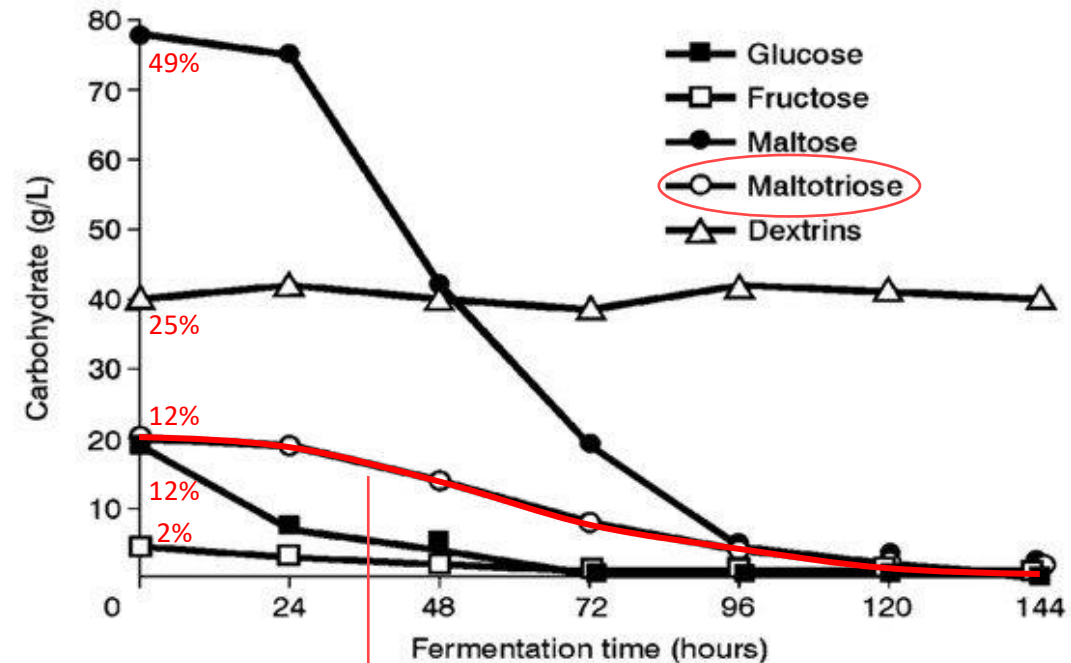
Wort fermentability at **high mashing temperatures** and different **mash thicknesses**



- Fermentability is only significantly impacted at mashing temps >70°C
- Thinner mashes reduce fermentability

FERMENTATION

Sugar utilisation during fermentation

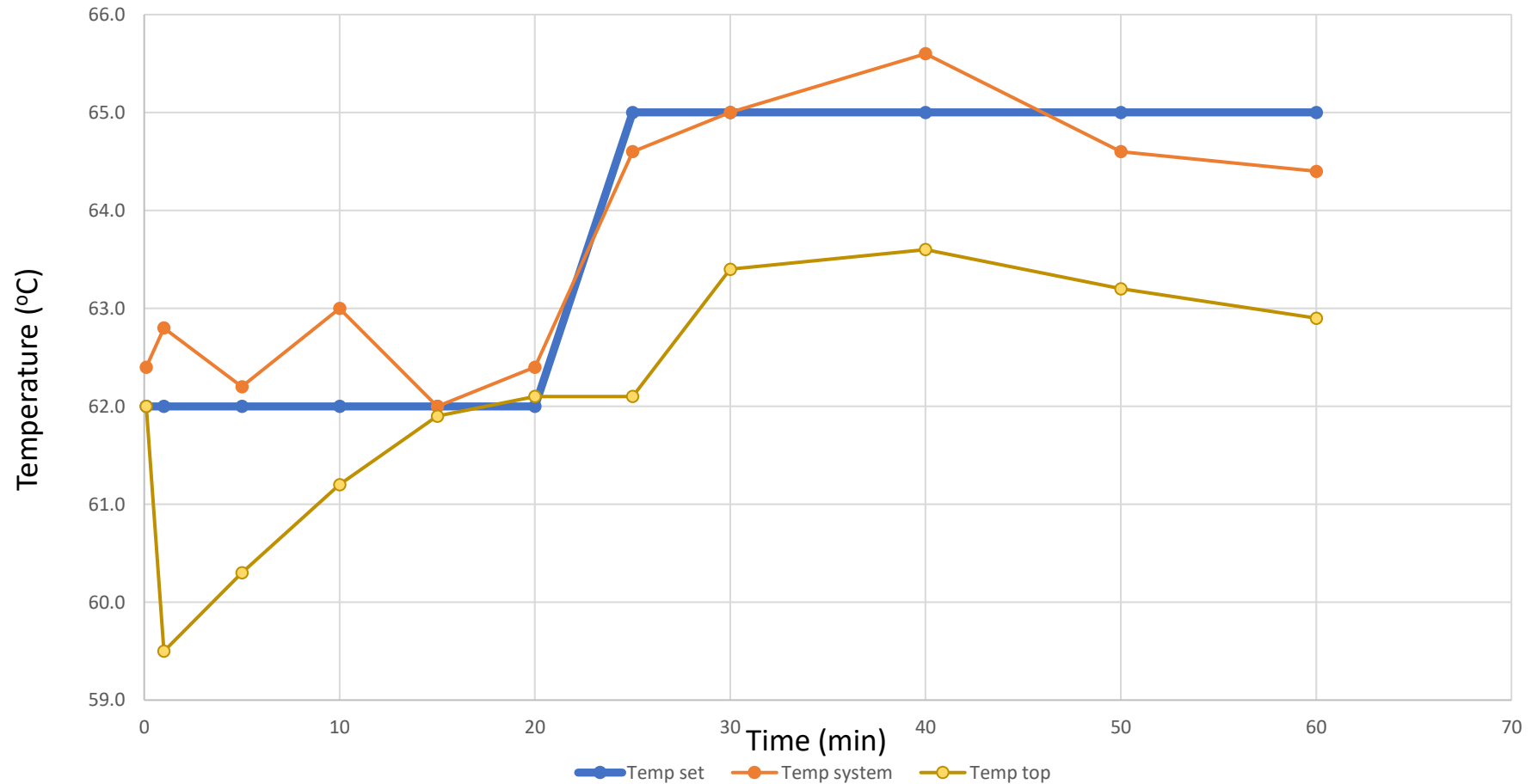


- This data for a Mtt⁺ yeast
- Yeasts like Windsor & London of Lallemand are Mtt⁻ & will NOT be able to use mal3, resulting in lower alcohol & increased mouthfeel.



MASH TUN TEMP GRADIENTS

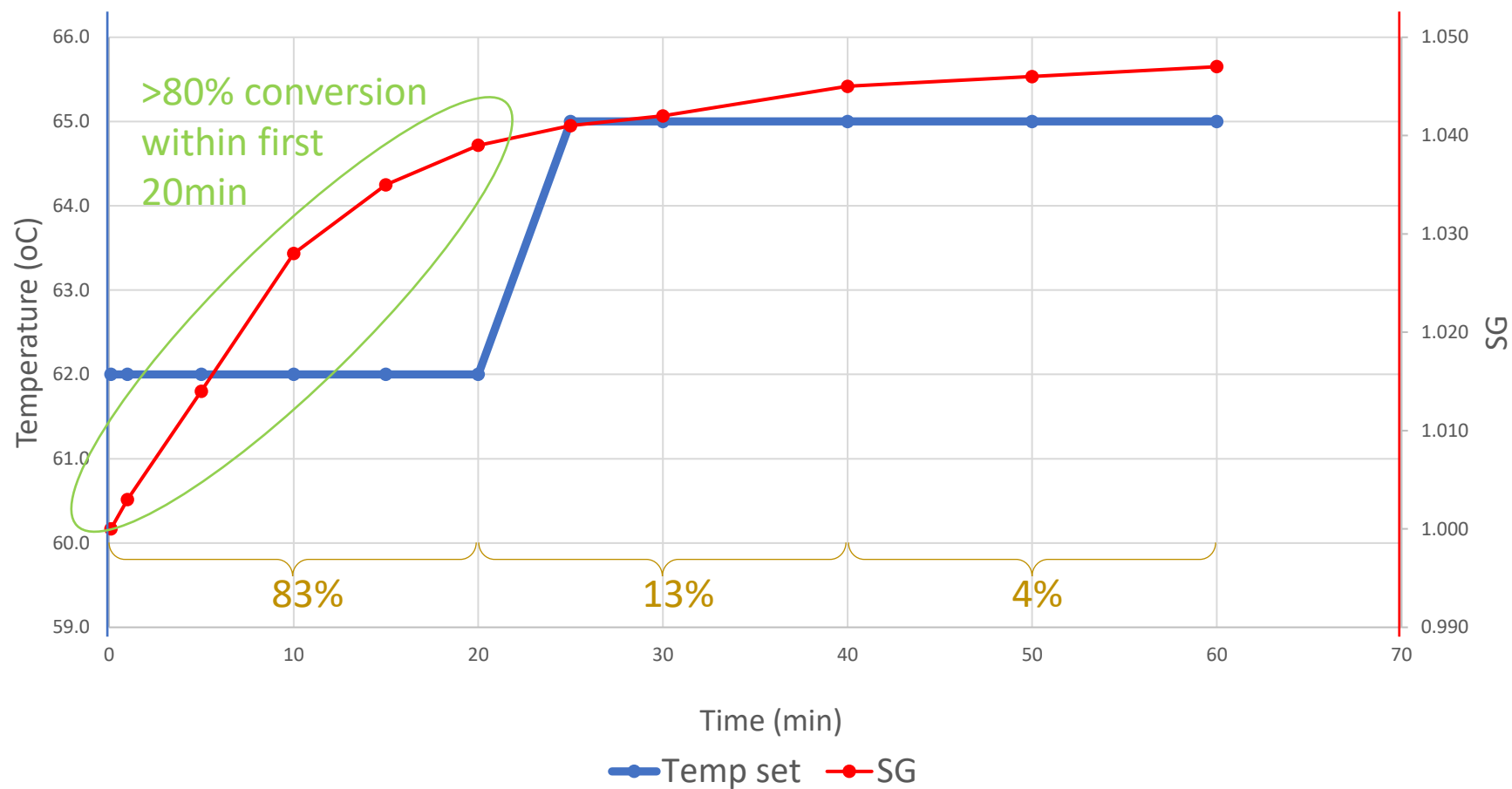
For a 60L, all-in-one, electrical brewing system



CONCLUSIONS

- System specific
- Temp gradient within mash tun/grain bed
- Temp profiles not as clean as program suggests
- Recirculation important for this system

STARCH CONVERSION RATE



- Milled malt's grit size has a big impact on this.



Thank you

Hennie Groenewald - 083 288 1271 - hesamati7@gmail.com