ICBS International Centre for Brewing Science

KU LEUVEN TECHNOLOGY CAMPUS GHENT

EJD Food Sci

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Brewing with green malt

Celina Dugulin[1], Gert De Rouck[2] & **David Cook[1]**

[1] *International Centre for Brewing Science, School of Biosciences, University of Nottingham, UK*

[2] *KU Leuven, Bioengineering Technology TC, Ghent and Aalst Technology Campuses, Gent, Belgium*

HORIZON 2020

Brewing with green malt – why?

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

- Malting and brewing involve sequential wetting and drying steps.
  - Viewed solely from an energy and water use perspective these processes make little sense.
- The pressure on companies to reduce their carbon and water footprints will increase as climate change targets are tightened.
  - What is acceptable today may no longer make sense by 2050.
  - Kilning is responsible for ~78%* of energy consumption in malt production.
- The high enzyme complement of green malt may offer significant opportunities for brewing with high quantities of unmalted adjunct without using exogenous enzymes.

ICBS

*CARBON TRUST 2011. Industrial Energy Efficiency Accelerator - Guide to the maltings sector. Malting Sector Guide, CTG053.

Brewing with green malt – pros and cons

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

- ✓ high amounts of **desired** enzymes
  - ✓ **α-/β-amylase**
  - ✓ **limit dextrinase**
  - ✓ **β-glucanase**
- ✓ no DMSO
- ✓ reduced thermal heat load = **reduced pool of Strecker aldehydes**

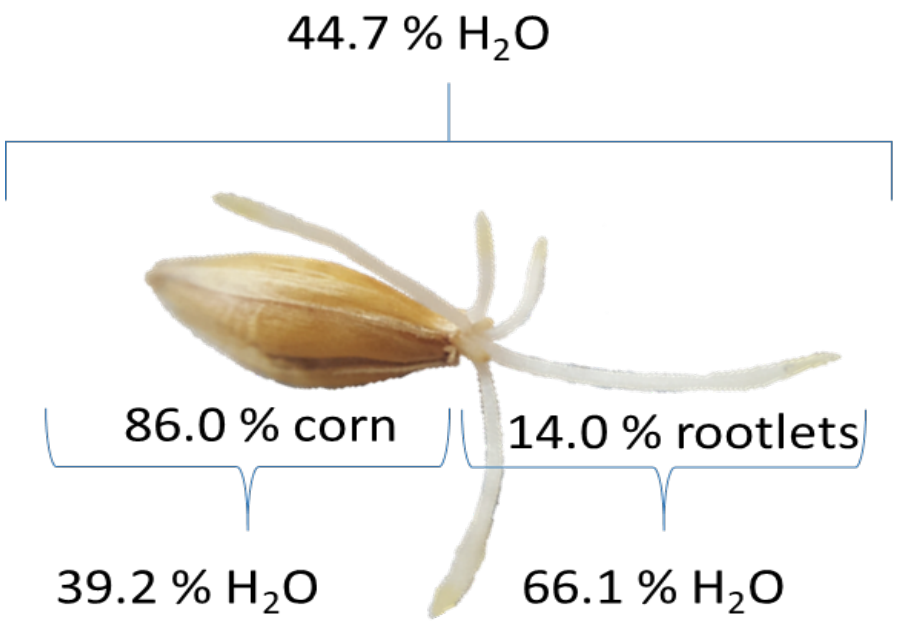
- **Perishable commodity with limited storability.**
  - 38-46% w/w moisture
  - Susceptible to microbial spoilage
  - Still respiring/ changing biochemically
- **Processing challenges – e.g. milling; rootlet separation.**
- **Loss of kilned malt colour and flavor.**

Elevated levels of quality factors usually regulated through kilning:

- **High lipoxygenase (LOX) activity**
- **High DMS potential (SMM)**

ICBS

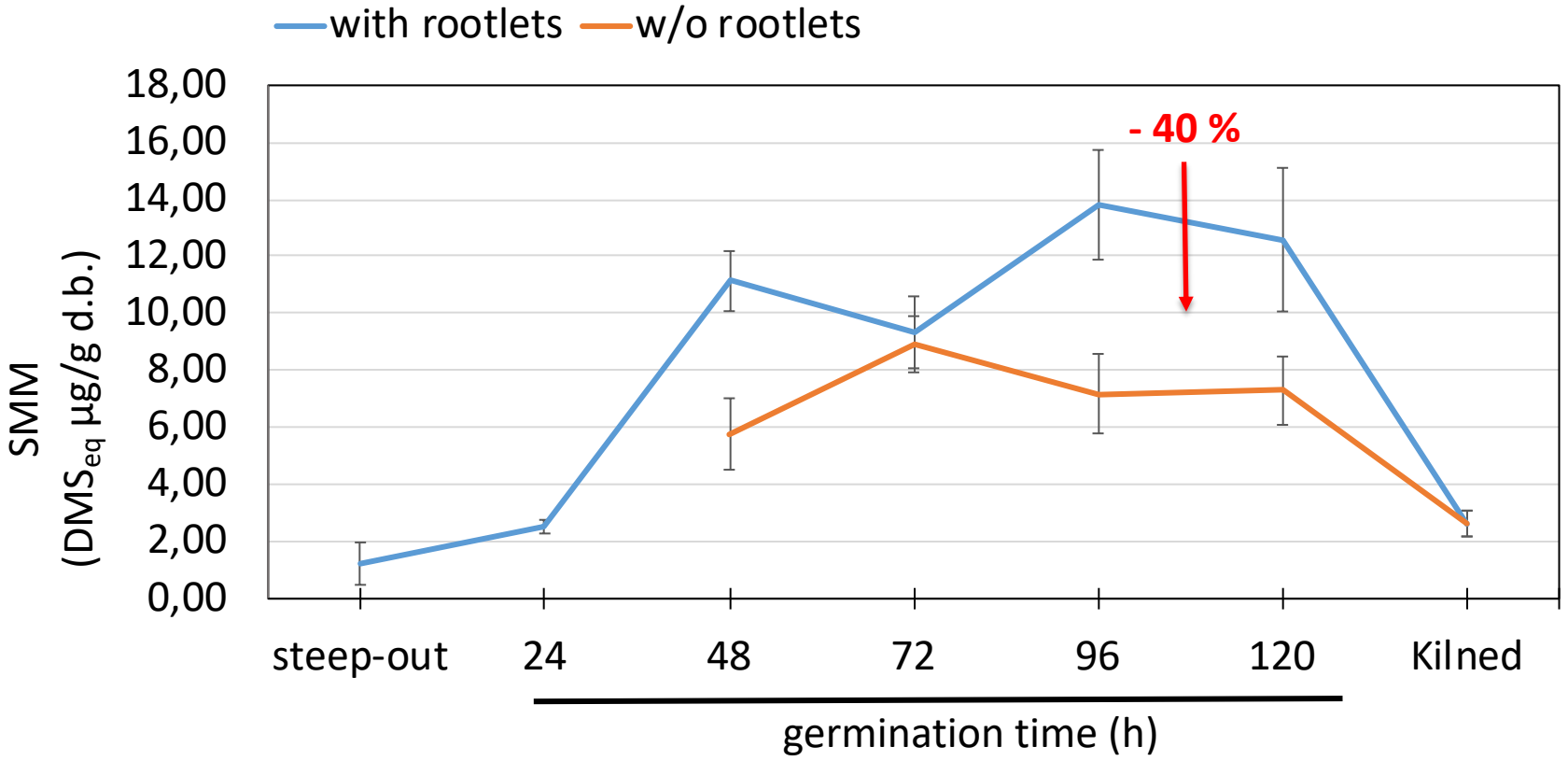
Raw material: Green malt



- What are the impacts of rootlet removal on:
  - Lipoxygenase activity?
  - DMS potential?

Evolution of S-methyl methionine through malting and its localisation in the rootlets

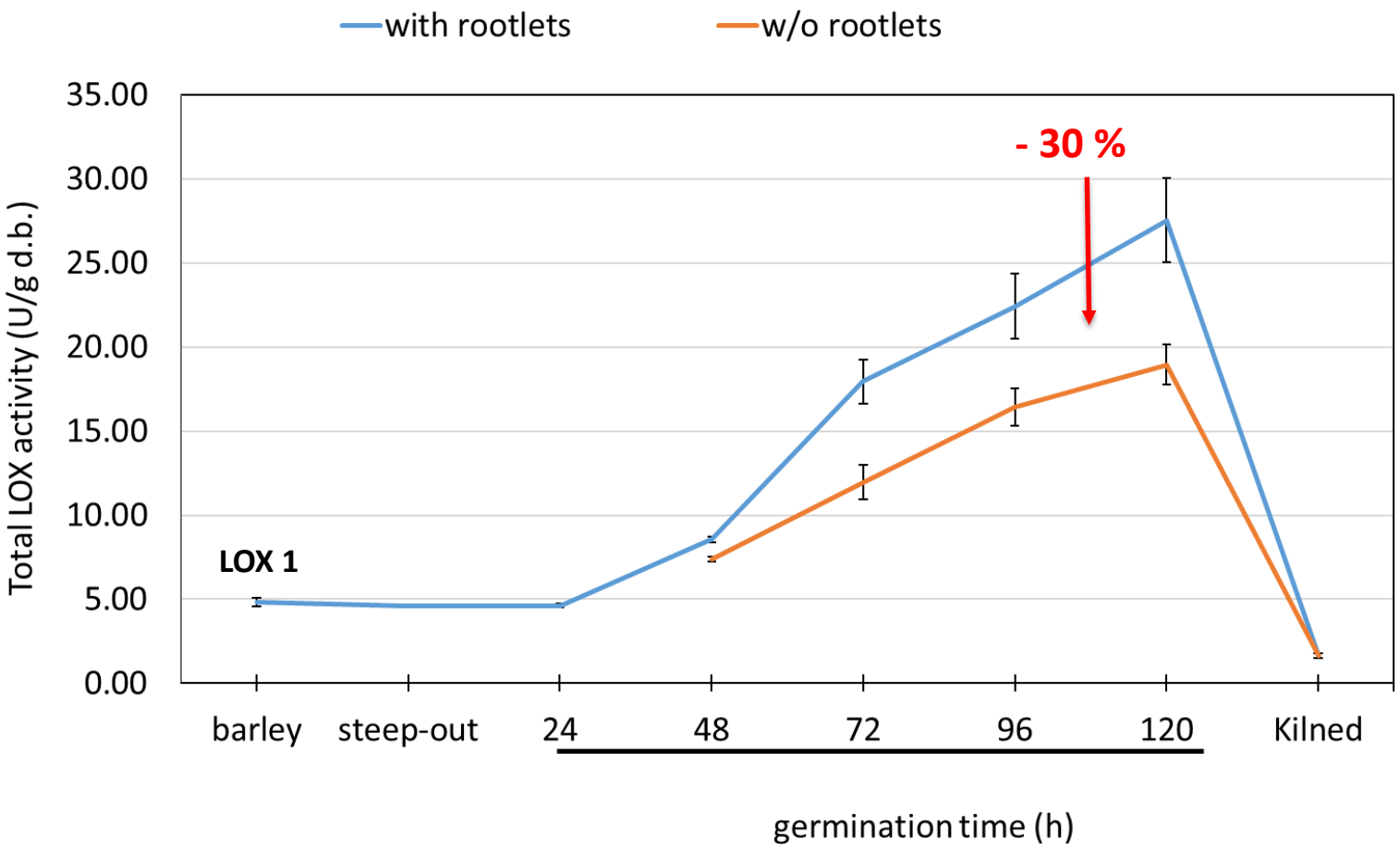
The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA



S-methyl methionine (SMM) monitored during germination in the malting barley variety *Flagon* with/without rootlets; mean values ± standard deviation (SD); n=3, tr= 3

EJD Food Sci

Evolution of total LOX activity through malting and its localisation in the rootlets



Lipoxygenase activity monitored during germination in the malting barley variety *Flagon* with/without rootlets; mean values ± SD; n=3, tr= 3

EJD Food Sci

Control of Lipoxygenase activity in green malt

- Use of Null- LOX/ Low- LOX barley varieties (e.g. Yu et al. (2014)
- Selective heating methods (e.g. electromagnetic heating, Ferrari-John et al. (2016))

OR

through its **limiting factors**:

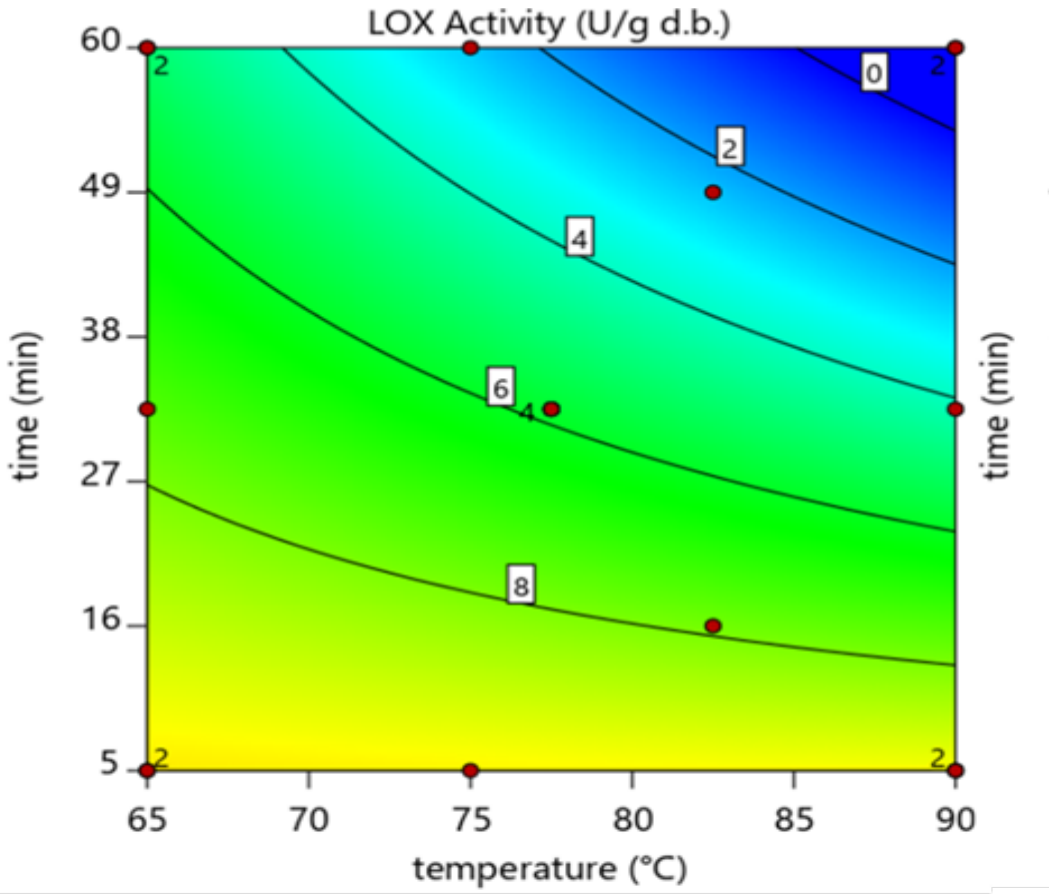
- Temperature
- pH (optimum pH: 6.5)
- access to oxygen

Yu, J., Huang, S., DONG, J., Fan, W., Huang, S., Liu, J., Chang, Z., Tian, Y., Hao, J. & Hu, S. M. 2014. The influence of LOX-less barley malt on the flavour stability of wort and beer. Journal Of The Institute Of Brewing, 120, 93-98.

Ferrari-John, R.S., Katrib, J., Zerva, E., Davies, N., Cook, D.J., Dodds, C and Kingman, S.W. (2016) *Electromagnetic heating for industrial kilning of malt: a feasibility study.* Food and Bioprocess Technology

Reduction in LOX activity in green malt following a short (5-60 min) heat treatment (65-90°C)

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA



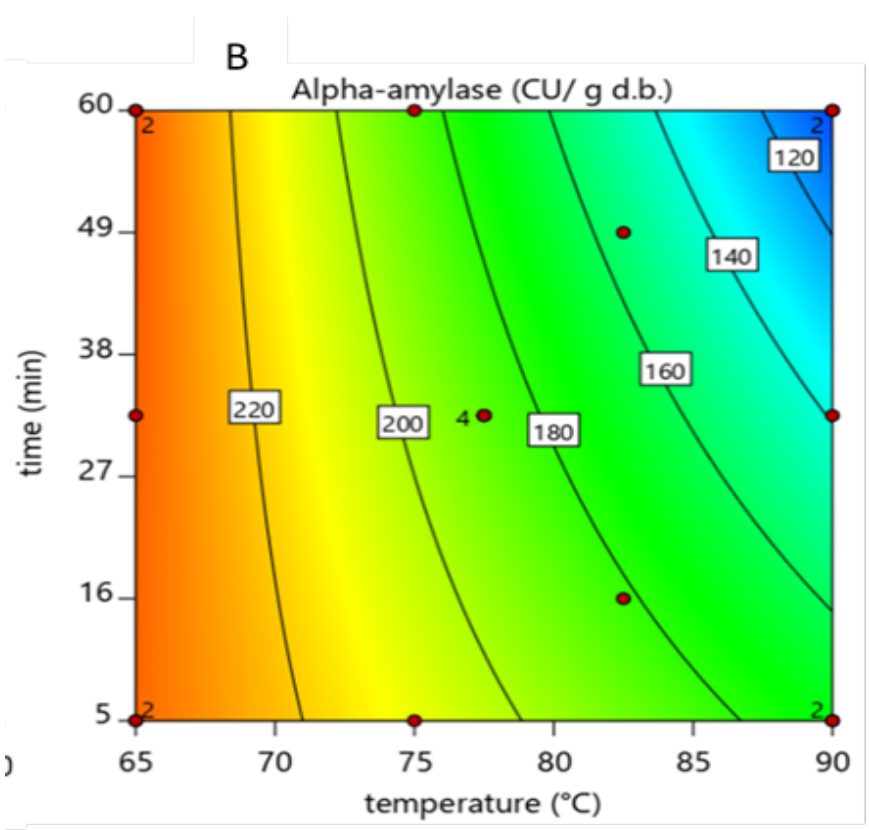
Contour plot showing the influence of a short (5-60 min) heat treatment (65-90°C) in a convection oven on the total lipoxygenase activity of green malt (U/ g d.b.),

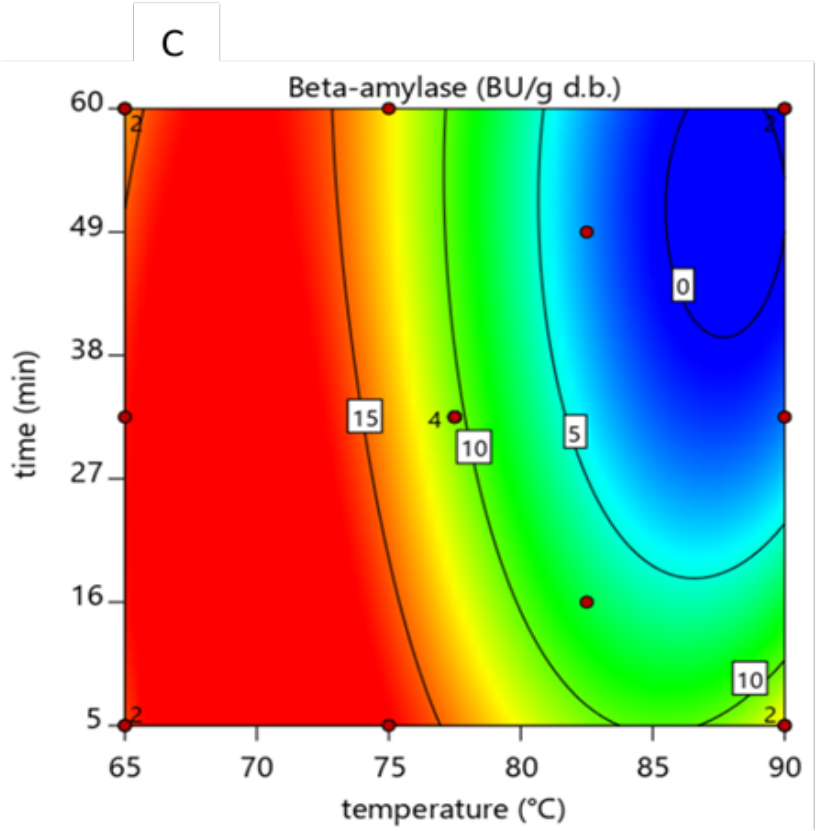
Initial activity: 14.6 U/g d.b. Colour legend: yellow (high) – blue (low)

ICBS

α- and β-amylase activities in green malt following a short (5-60 min) heat treatment (65-90°C)

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA





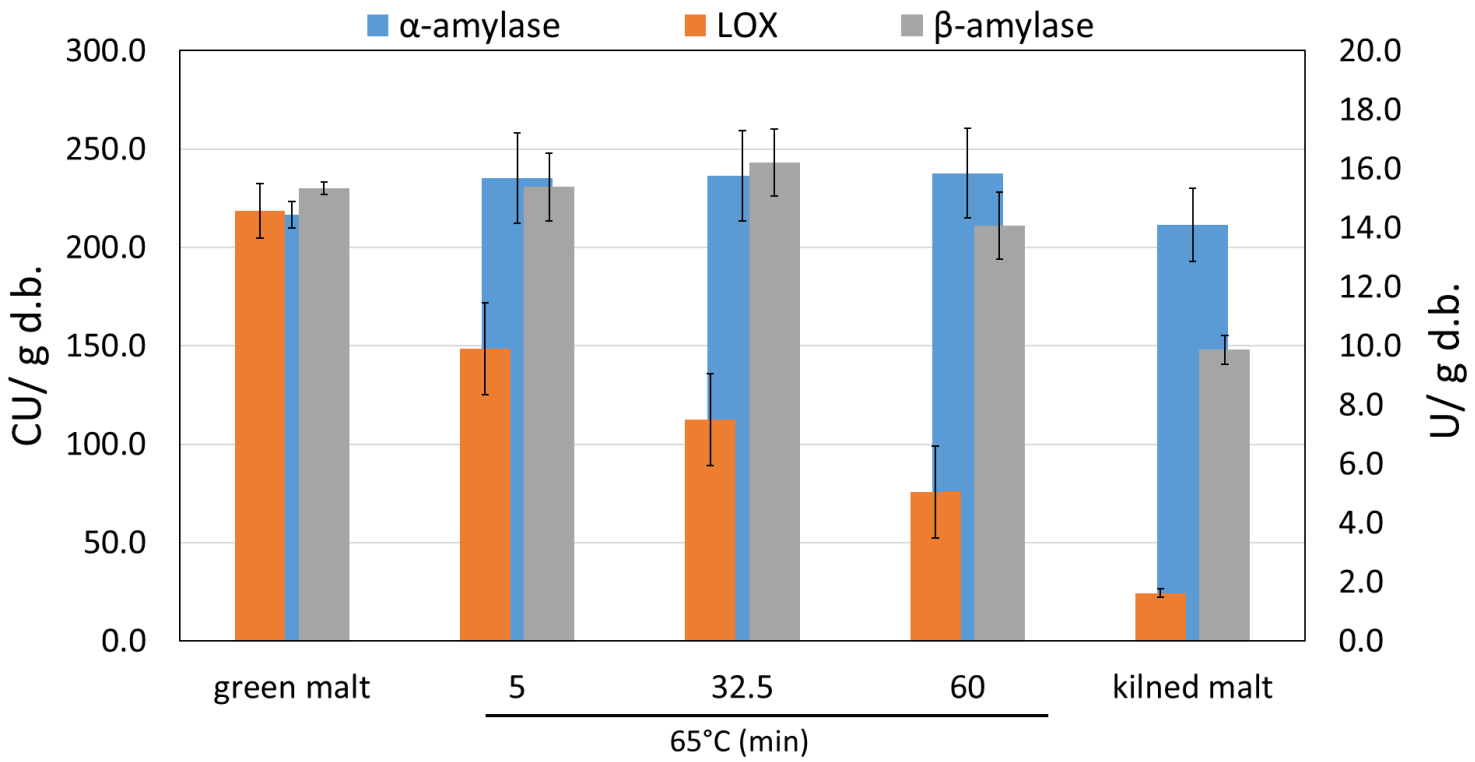
Contour plots showing the influence of a short (5-60 min) heat treatment (65-90°C) on the activities of (B) α-amylase (96.7 – 251.0 Ceralpha U/ g d.b.), (C) β-amylase (0.4 – 16.5 betamyl U/ g d.b.).

Colour legend: red (high) – blue (low)

ICBS

Impacts of heat treatment (65°C; 5-60 min) on the activities of LOX, α-amylase and β-amylase

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA



Primary axis: α-amylase activity (ceralpha units/ g d.b).; secondary axis: β-amylase (Betamyl-2 Units/ g d.b.) and lipoxygenase activity (U/g d.b).; results are presented as mean values *± SD;* n=3, tr= 3

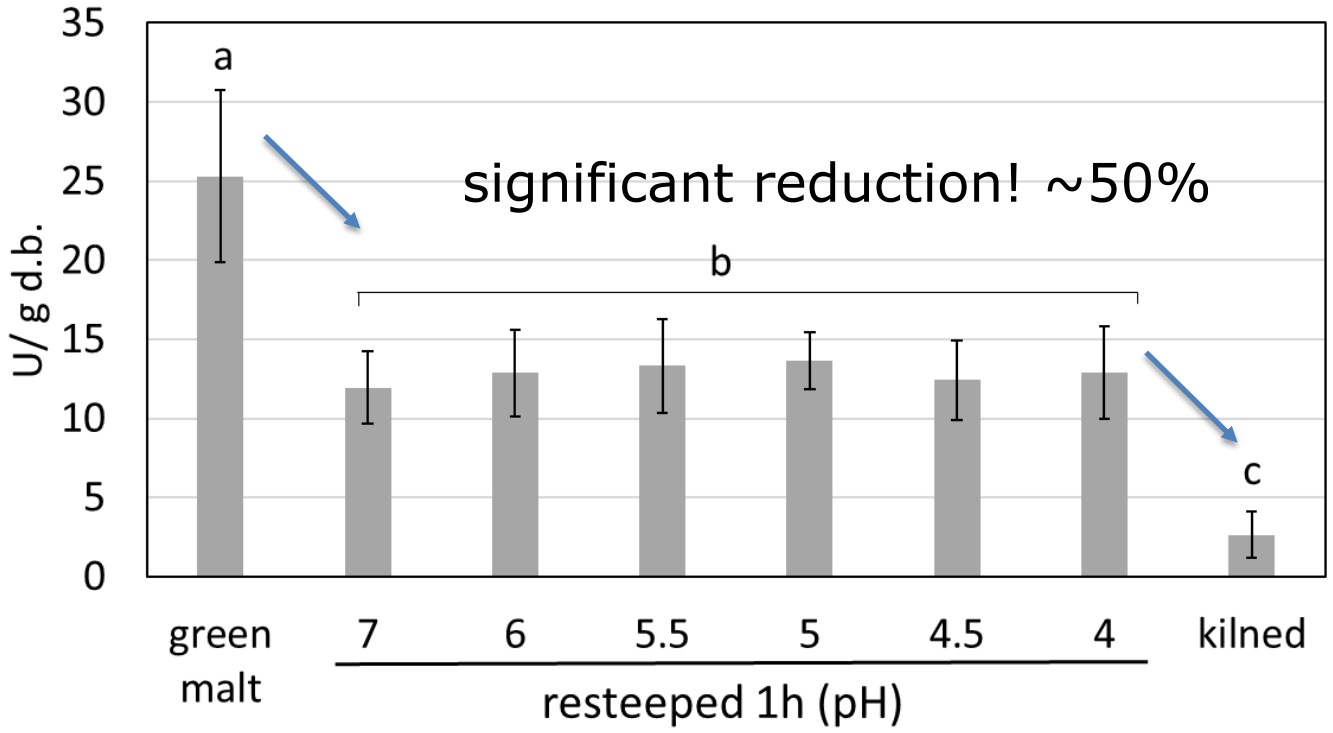
EJD Food Sci

Re-steeping of green malt significantly lowered LOX activity

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Previous studies showed a decline in LOX activity during steeping.

- potentially due to a **lack of oxygen** (Schwarz and Pyler (1984).



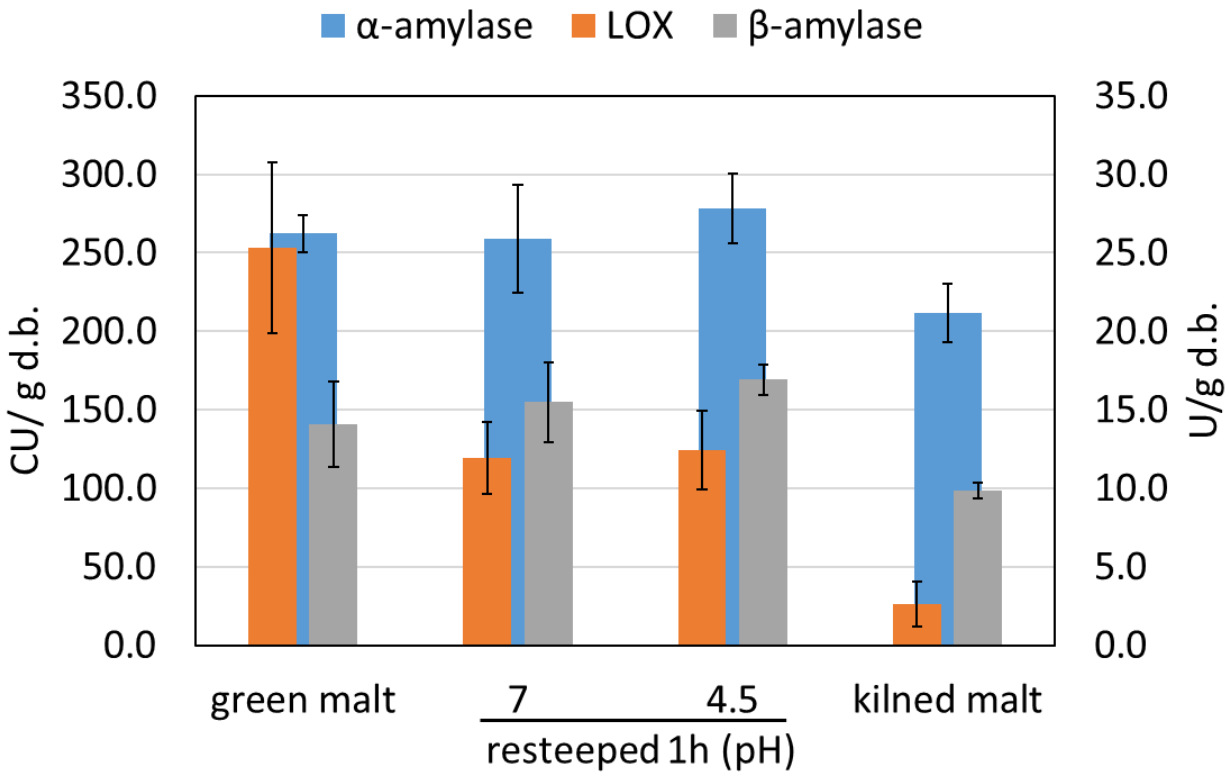
Statistics: one-way ANOVA with Holm-Sidak post hoc test, results are presented as mean values ± SD; n=3, tr= 3

ICBS

Schwarz, P. B., and Pyler, R. E. (1984) Lipoxygenase and Hydroperoxide Isomerase Activity of Malting Barley, *Journal of the American Society of Brewing Chemists 42*, 47-53

Impacts of re-steeping pH on the activities of LOX, α-amylase and β-amylase

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA



- pH of re-steep had no significant effect.
- LOX activity reduced by around 50% whereas no significant changes in amylase activities

Primary axis: α-amylase activity (ceralpha units/ g d.b.) ;
Secondary axis: β-amylase (Betamyl-2 Units/ g d.b.);
lipoxygenase activity (U/g d.b.).

Results are mean values ± SD; n=3, tr= 3

EJD Food Sci

Laboratory mashing study: Sweet wort analysis

Mashing protocol: mash-in >63°C, pH: 5.2, using de-aerated liquor.

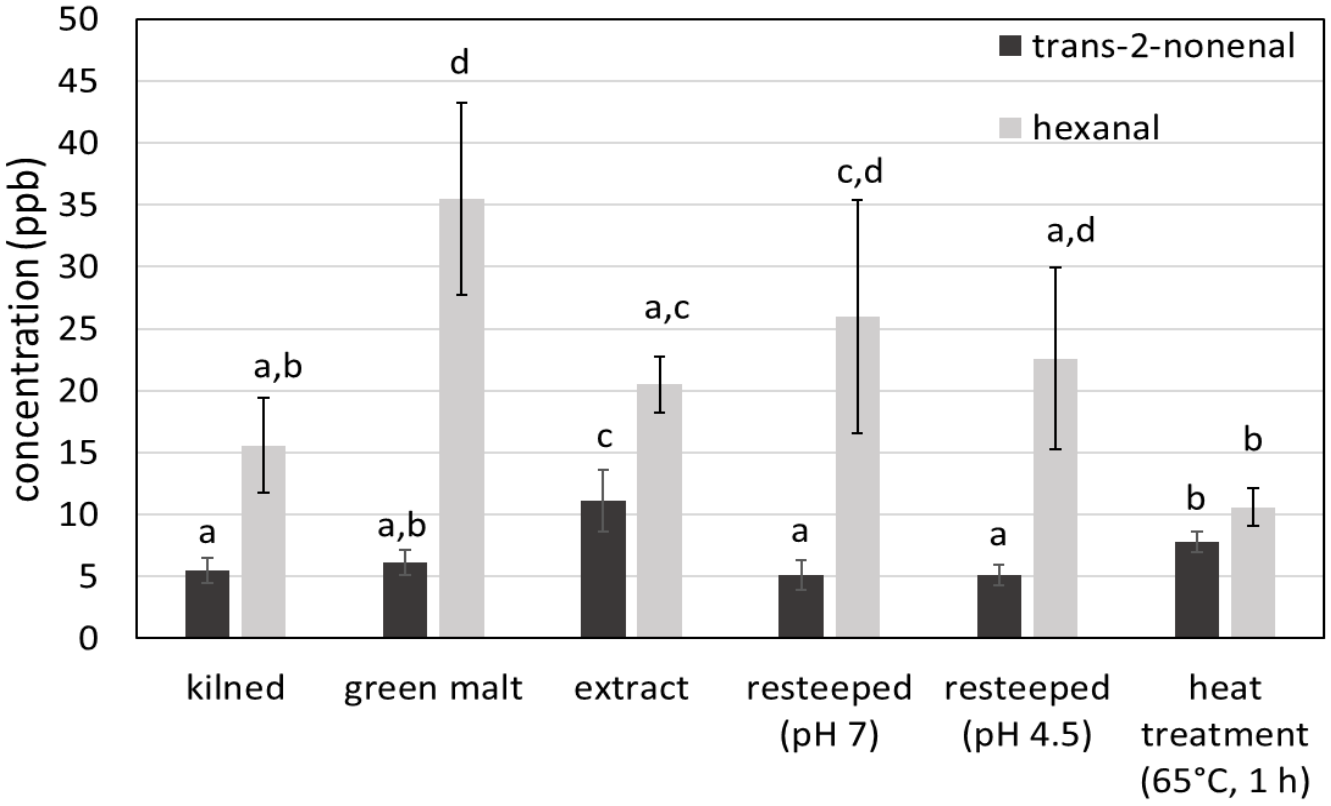
Type of malt	Colour (EBC)*	specific gravity***	Extract corrected for weight used (%)***	FAN (mg/l)***	SMM (µg/L DMS_{eq})***	DMS (µg/L)
kilned malt	3.4[a]	1.0339[a]	82.3[a]	188.4[a]	587.5[a]	88.1
green malt	3.3[a]	1.0390[a]	90.0[b]	224.5[a]	1082.8[b]	40.5
endosperm-rich extract	1.3[b]	1.0271[b]	67.2[c]	125.4[b]	897.3[b]	31.4
re-steeped (pH 7)	2.6[a]	1.0364[a]	84.3[a,b]	189.3[a]	911.9[b]	40.9
re-steeped (pH 4.5)	2.8[a]	1.0361[a]	83.5[a,b]	183.5[a]	858.1[b]	45.2
heated at 65°C ,1 h	2.9[a]	1.0376[a]	86.9[a,b]	215.3[a]	858.0[b]	25.9

Results are presented as mean values (n=3, technical reps = 2)
P<0.05; **P<0.01; ***P<0.001
[a-c] superscripts represent the ANOVA post-hoc groupings

Wort analysis -
oxidation products from LOX activity

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

t-2-nonenal and hexanal potentials (µg/L) after forced aging of wort samples -- - determined according to Drost et al. (1990) and Guido et al. (2005).



Data are the mean ±SD of 4 biological with each 2-4 technical replicate measurements.

Drost, BW, van den Berg, R, Freijee, FJM, van der Velde, EG and Hollemans, M. 1990. Flavor Stability. *J. Am. Soc. Brew. Chem. 48*: 124-131.

Guido, LF, Boivin, P, Benismail, N, Gonçalves, CR and Barros, AA. 2005. An early development of the nonenal potential in the malting process. *European Food Research and Technology.* 220: 200-206.

Brewing with green malt – pilot scale brewing trials

KU LEUVEN
TECHNOLOGY CAMPUS GHENT

- **5 hL pilot brewery**
- Meura wet milling system
- lipoxygenase hostile conditions (pH: 5.2, mashing-in temp. 63°C, oxygen-free)
- Membrane mash-filter

Aims

1. To evaluate wort/beer quality
2. Prove feasibility of brewing with green malt

EJD Food Sci

Pilot scale brewing with green malt – trial overview

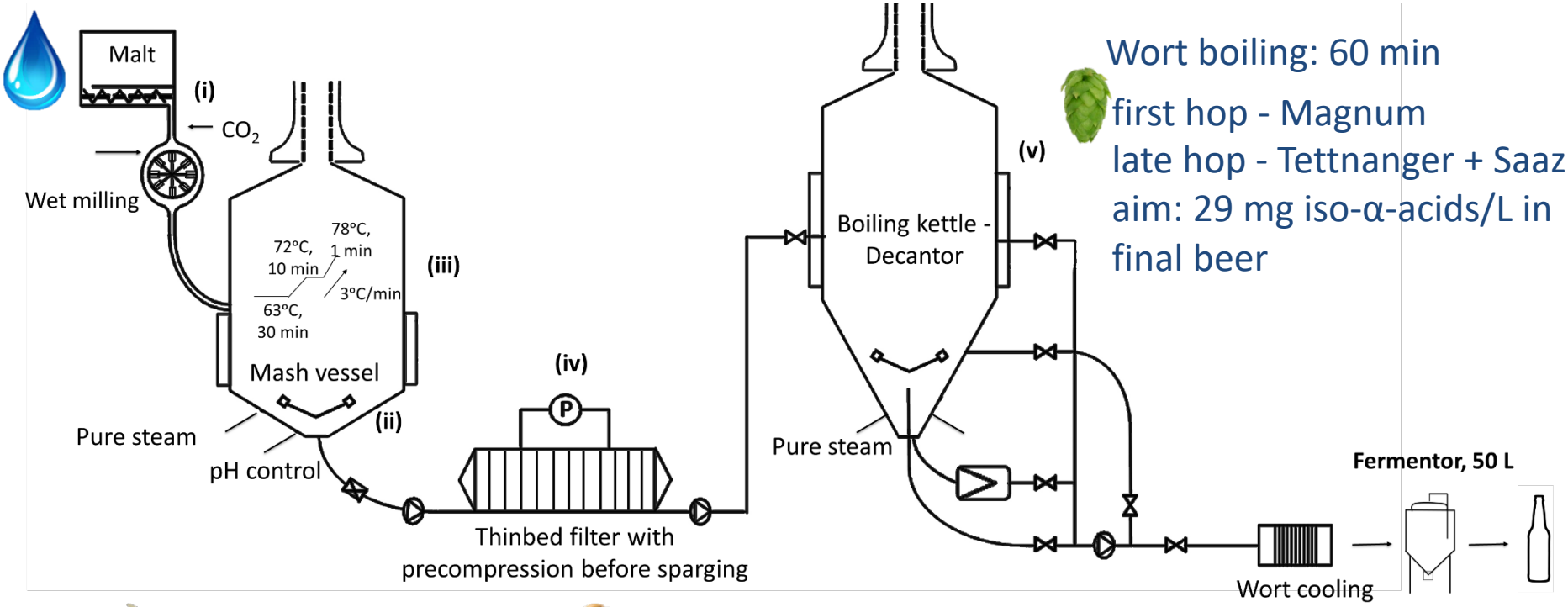
BOORTMALT

KU LEUVEN
TECHNOLOGY CAMPUS GHENT

3 x green malt (100%)	VS.	3 x corresponding reference kilned (pilsner) malt
3 x green malt (100%), re-steeped for 1 hour prior to mashing	VS.	3 x corresponding reference kilned (pilsner) malt

KU Leuven: 5 hL pilot brewing trial

KU LEUVEN
TECHNOLOGY CAMPUS GHENT

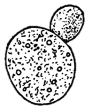


Wort boiling: 60 min

first hop - Magnum
late hop - Tettnanger + Saaz
aim: 29 mg iso-α-acids/L in final beer

green malt: 68.9 kg
moisture content: 40 %
water needed: 70.4 L, 85°C,
109 ppm Ca^{2+}
lactic acid: 1.4 ml/hl

pilsner malt: 44 kg
moisture content: 4 %
water needed: 96.6 L, 69°C,
81 ppm Ca^{2+}
lactic acid: 1.0 ml/hl



yeast: S-04 (Fermentis, top fermenting), 24°C
maturation: 14 days at 0°C,

Brewing with green malt – technical challenges

Green malt mash (2.2:1) hard to mix

- Homogenous mixing hard to achieve.
- Difficulty in reaching desired strike temperature and pH throughout mash
- Structure of spent grains: spongy, cohesive.
- Extended mash filtration, insufficient sparging.

Comparison of pitching wort analysis

	kilned malt	green malt
pH	**5.2**	**5.4**
colour (EBC)	**10.9** ± 1.3	**8.1** ± 1.9
density (g/cm^3)	**1.0439**	**1.0478**
original extract (°Plato)	**11.8** ± 1.3	**12.4** ± 0.5
FAN (mg/L)	**287.45** ± 35.8	**220.9** ± 41.1
Total polyphenols (mg/L)	**379.0** ± 47.1	**311.9** ± 33.6
catechin equivalent (mg/L)	**50.3** ± 3.7	**54.6** ± 1.7
proanthocyanidins (mg/L)	**74.6** ± 20.1	**59.0** ± 7.2
DMS (µg/L)	**97.4**± 22.3	**106.1** ± 41.9
DMS-P (µg/L)	**300.3** ± 253.1	**384.5** ± 149.7
TBI	**45.1** ±4.7	**15.4** ± 1.5

Data are the mean ±SD of six brews

Finished beer analysis

	kilned malt	green malt
pH	**4.42**	**4.19**
alcohol (% v/v)	**5.57** ± 0.12	**5.46** ± 0.43
specific gravity	**1.0083**	**1.0072**
real extract (% w/w)	**4.13** ± 0.42	**3.84** ± 0.33
real degree of fermentation	**68.62** ± 1.93	**69.73** ± 3.45
calories (kJ/100 mL)	**189.9** ± 8.71	**182.86** ± 4.92
FAN (mg/L)	**116.2** ± 32.3	**50.3** ± 4.0
Total polyphenols (mg/L)	**250.9** ± 46.5	**234.9** ± 31.7
catechin equivalent (mg/L)	**60.1** ± 12.5	**92.6** ± 4.6
proanthocyanidins (mg/L)	**44.9** ± 5.2	**39.4** ± 5.7
DMS (µg/L)	**24.3** ± 11.0	**23.8** ± 10.0
SMM (µg/L)	**44.1** ± 13.0	**136.4** ± 37.0

Data are the mean ±SD of six brews

Brewing with green malt – SMM and DMS control

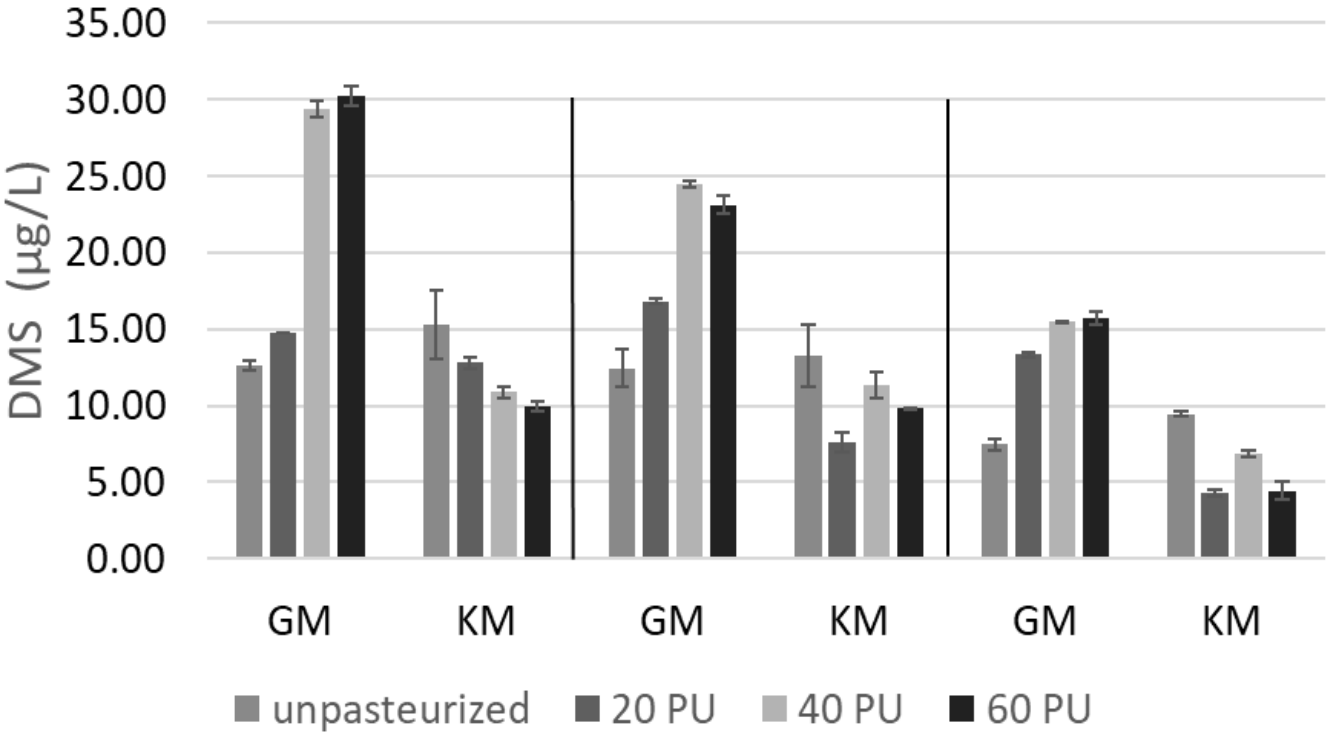
	Onset of mashing (mg/L)	pitching wort (µg/L)	Beer (µg/L)
Green malt **SMM**	7.3 ± 1.3	371.5 ± 120.1	120.4 ± 1.3
Kilned malt **SMM**	3.0 ± 0.4	194.5 ± 195.9	28.8 ± 19.6
Green malt **DMS**	-	122.6 ± 36.1	17.3 ± 10.1
Kilned malt **DMS**	-	77.15 ± 30.6	18.5 ± 10.2

Data are the mean ±SD of three replicate brews (onset of mashing) or of six replicate brews elsewhere.

- SMM levels higher throughout green malt brew stream.
- **Finished beer DMS closely matched between green and kilned malt beers**.

Impact of in-pack pasteurisation processes on finished beer DMS (20, 40, 60 PU)

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA



- Some additional DMS potential from thermal breakdown of SMM
- 20 PU treatment – minor impacts
- 40 and 60 PU – still all three replicate brews < 30 ppb

ICBS

Finished beers:
SurGreen (*Left*) and SurPlus (*Right*)

KU LEUVEN
TECHNOLOGY CAMPUS GHENT

<u>Six pilot beers brewed from green malt to date:</u>

1. No significant taints or off-flavours.
2. No DMS-problem.
3. Low TBI.
4. Acceptable colour, pH, foam
5. Low trihydroxy-fatty acid levels in untreated green malt beers BUT not in re-steeped beers.
6. Promising flavour stability metrics.

Brewing with green malt – Opportunities and challenges

Opportunities
Environmentally friendly beer. Reduced carbon and water footprints.
Create new market for green malt beer (as opposed direct flavour match).
Use with small quantities of roasted malts in grist for colour/flavour.
Use as an enzyme-rich adjunct to digest unmalted adjunct materials.
Produce green malt extracts with greater storability.

Ongoing and future research

- Detailed sensory evaluation of green malt beer flavor characteristics
- Flavour stability of green malt beers?
- Flavour matching of ‘hybrid’ beers
- Use of null-LOX barley varieties
- Brewing process development
  - Wet milling optimization
  - Optimal liquor: grist ratio, mash mixing and mash separation

Questions?

With thanks to:

Luisa Maria Acuña Muñoz (KU Leuven)
Jasper Buyse (KU Leuven)
Susan Clegg (Nottingham)
Irina Bolat (Boortmalt)