Improved design and operation of cylindroconicals

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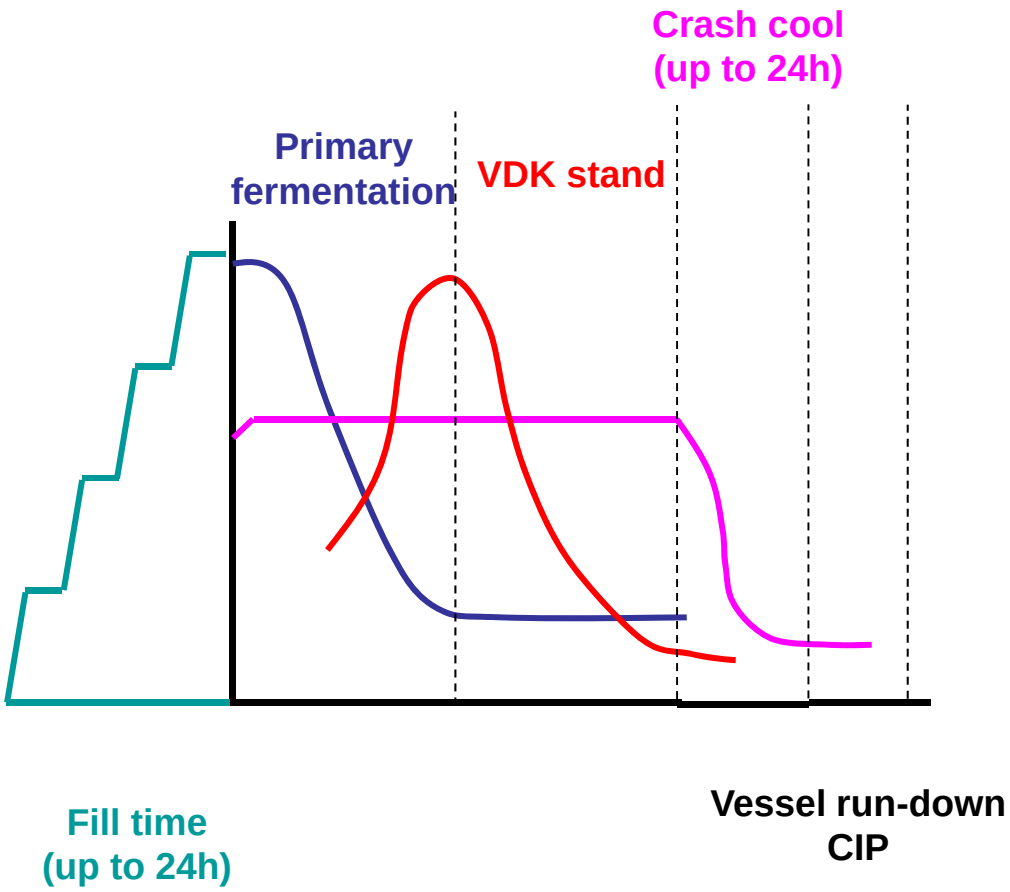
Current trends in fermentation practice

- Conicals preferred choice of vessel
- Usually high gravity brewing
- Increased temperature to shorten cycle times (15 - 20^{o}C)
- Often large capacity (1000 – 5000hl)

Performance wish list

- Cycle times
  - Short
  - Consistent
  - Predictable
- Yeast
  - High crop viability
  - Consistent physiology
  - Genetic stability
  - Stable performance throughout extended number of serial fermentations
- Beer quality
  - Consistent analysis
  - Ability to manipulate volatiles in predictable ways
  - Increased emphasis on flavour stability
  - Long shelf life for small-pack beers
- Wort gravity
  - Move to ultra-high gravity

Elements of cycle time



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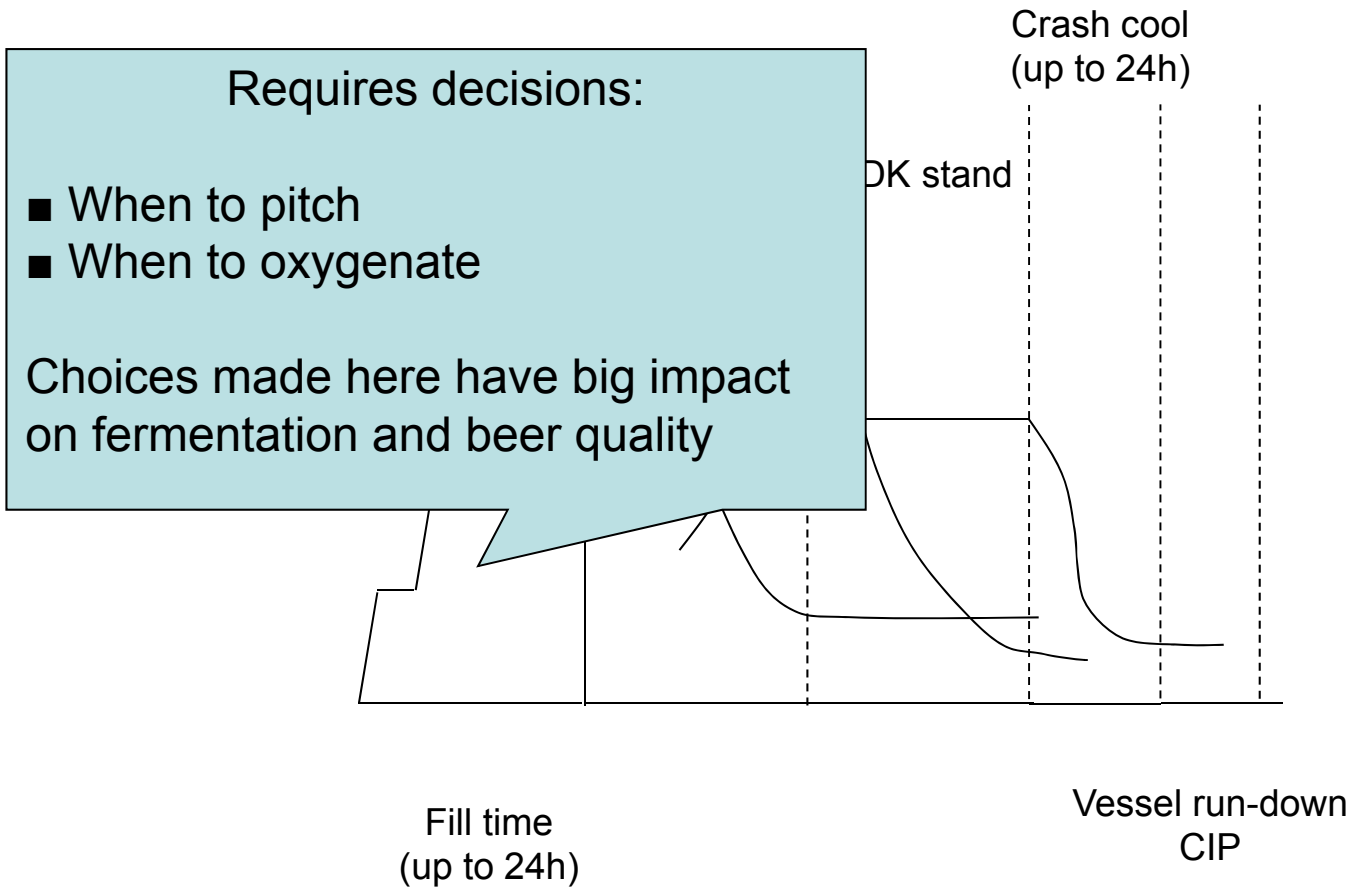

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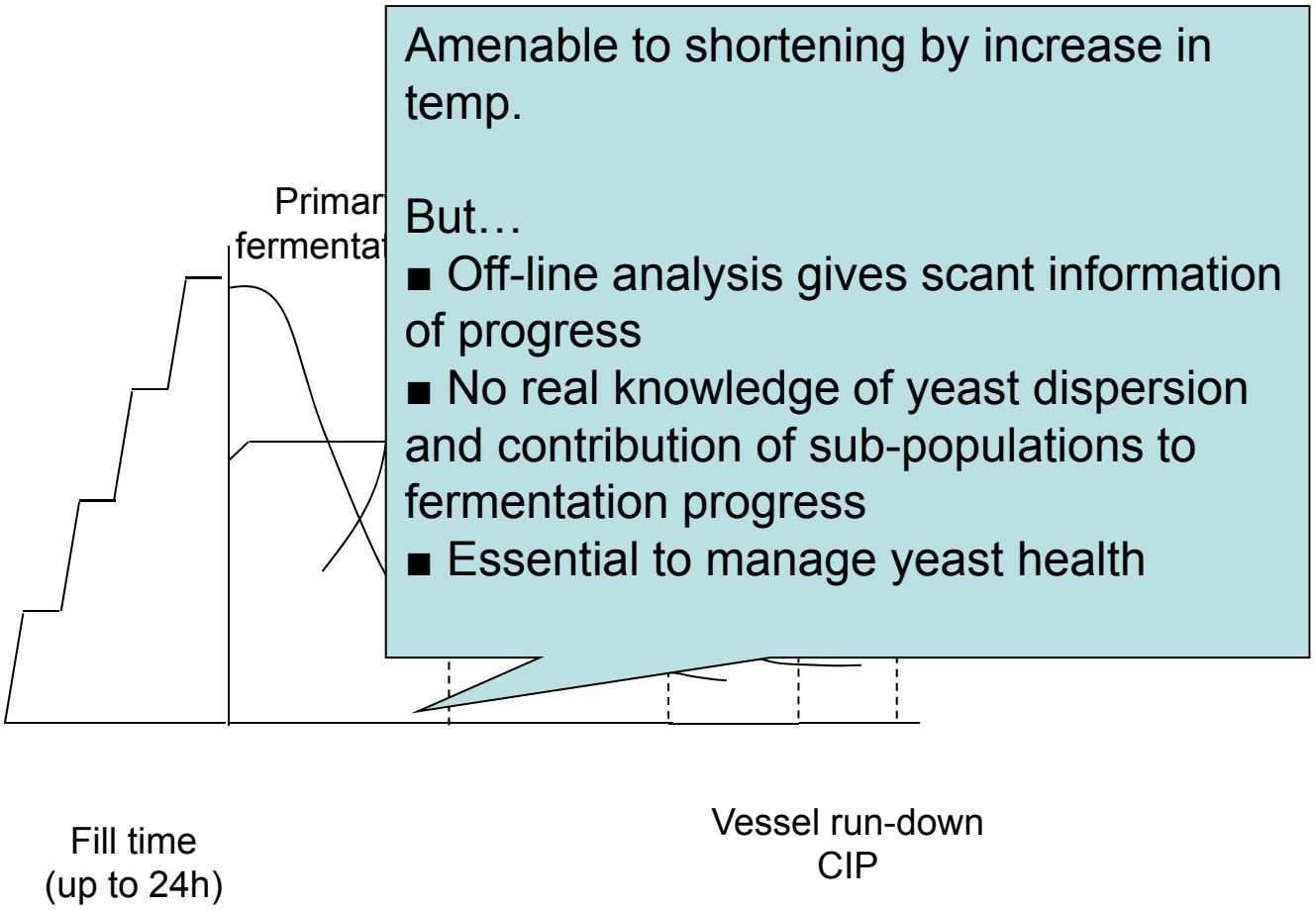

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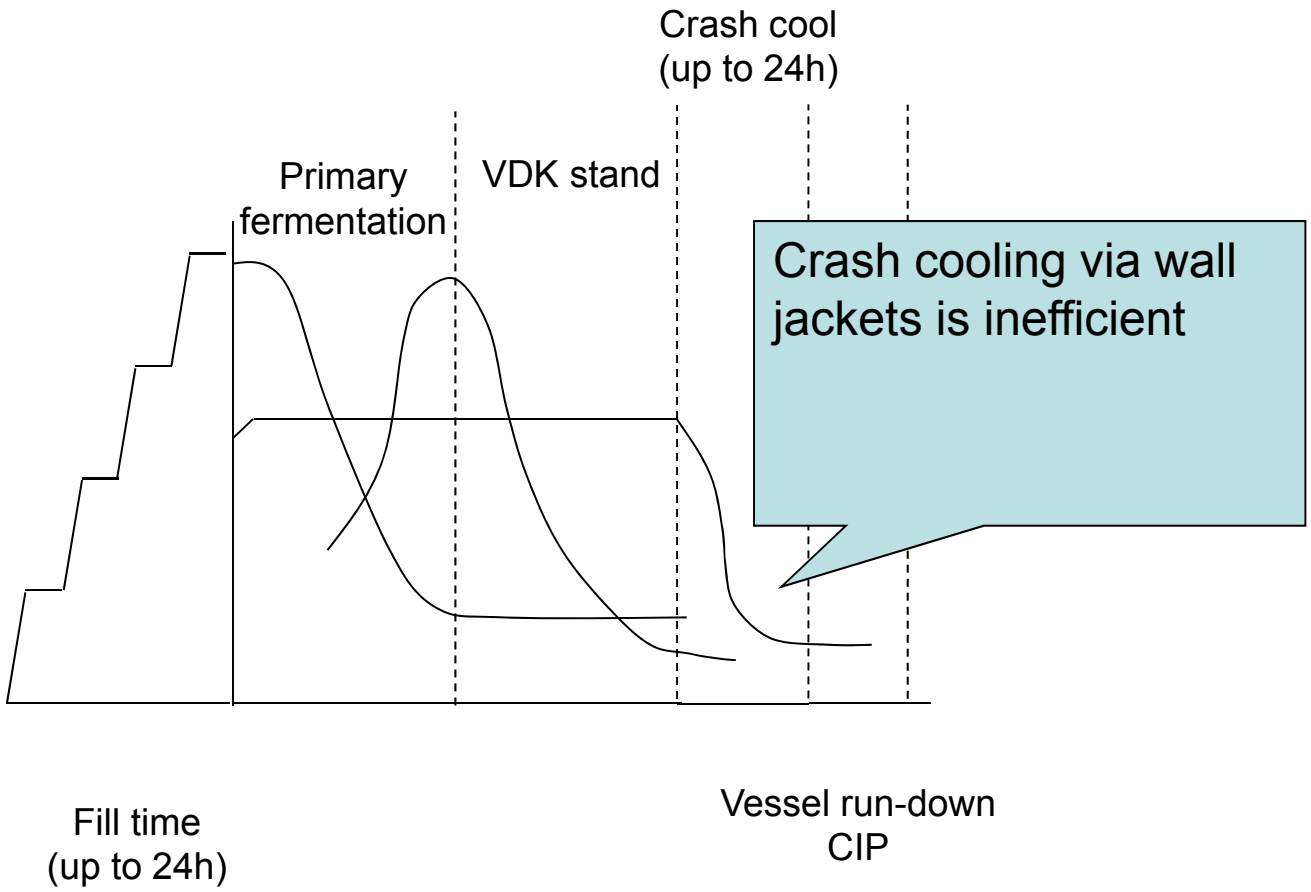


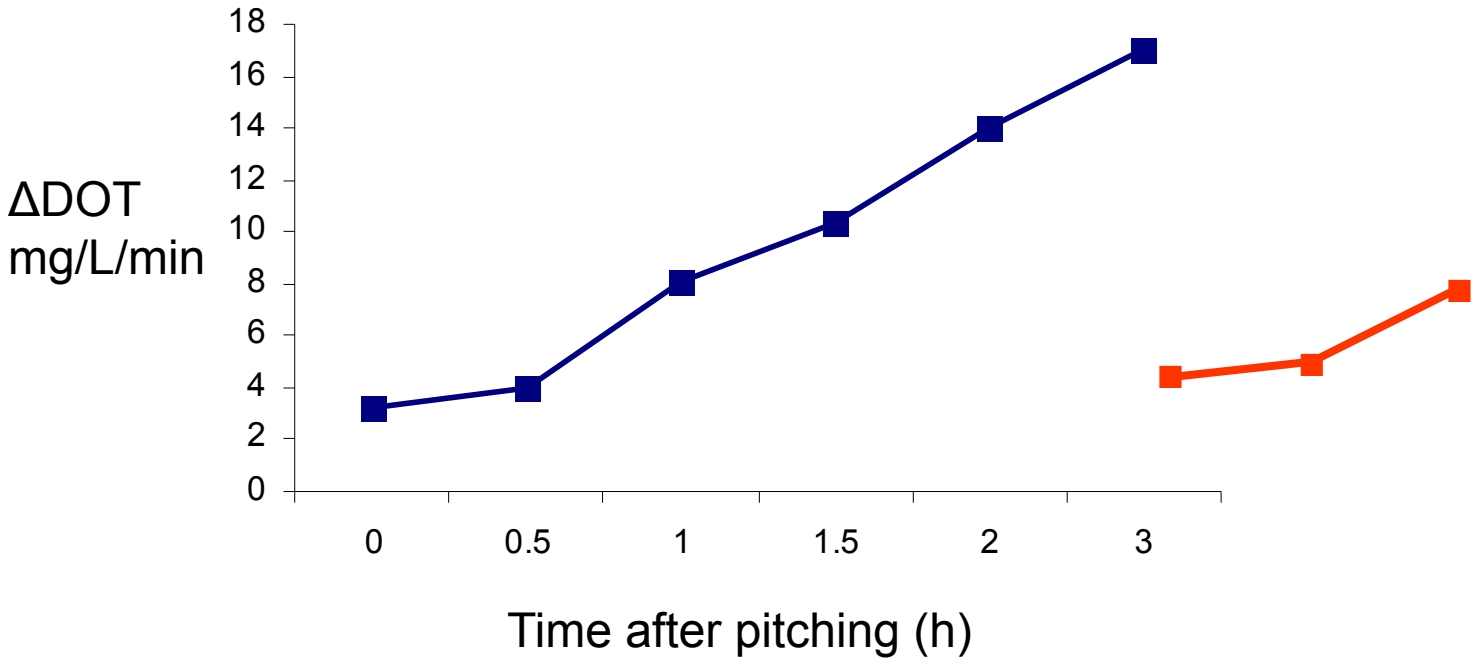
Influence of vessel filling

- Multi-filling of large vessels
- Prolonged fill times (up to 24h)
- Requires more decisions
  - When to pitch
  - When to oxygenate
- When does fermentation actually commence?

Effect of prolonged pitching time

- Early pitched yeast out-competes late pitched yeast for nutrients
- Produces heterogeneous population with differing physiological condition

Rate of oxygen uptake by pitching yeast



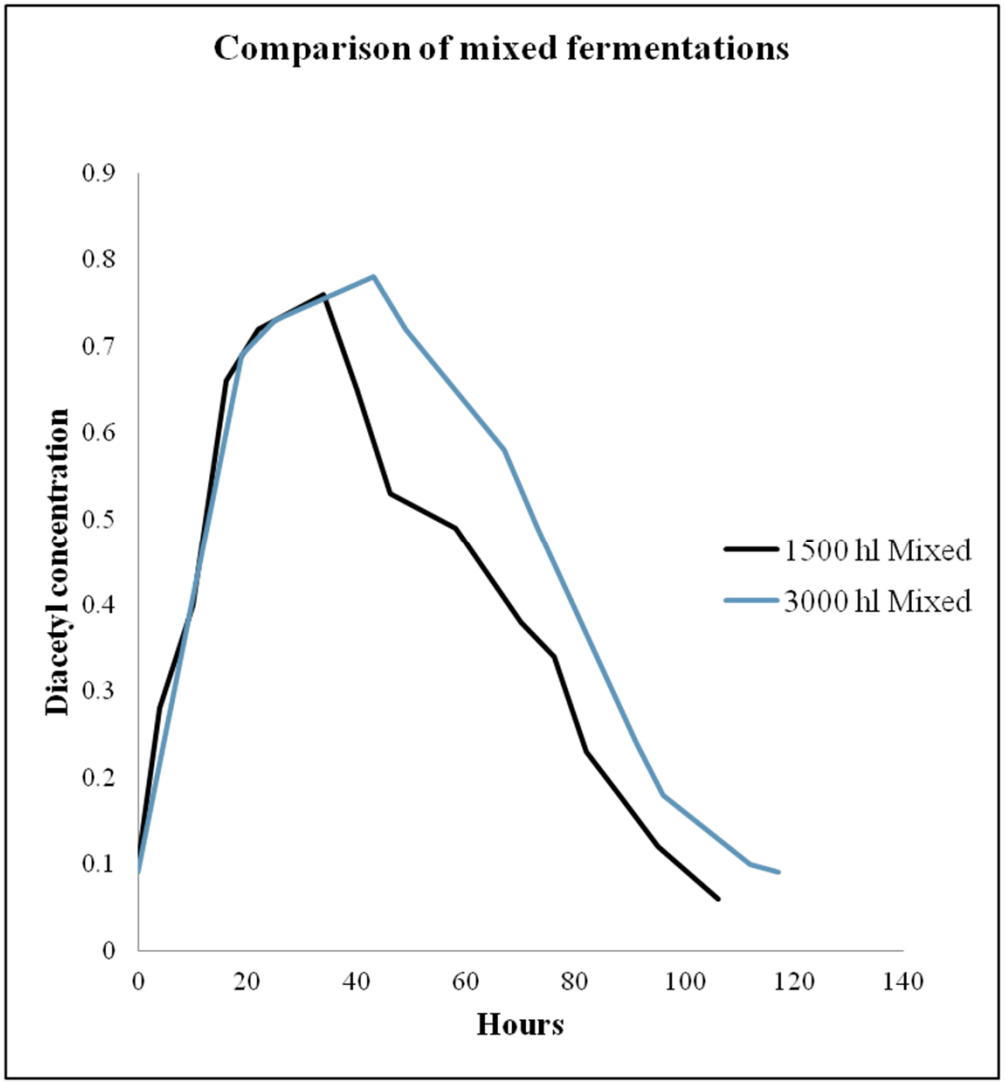
Late pitched yeast has low uptake rate

Effect of prolonged fill times on VDK

- Long fermenter fill with multiple batches of wort
  - Fed-batch system where fresh supply of group A amino acids prevents uptake of Group B amino acids
  - Pushes VDK peak towards right

VDK profiles of 1500 vs 3000 hl high gravity lager fermentations

- Identical worts, pitching rates and oxygenation regimes
- All yeast pitched with 1st brewlength
- Collection times 10 and 18h, respectively

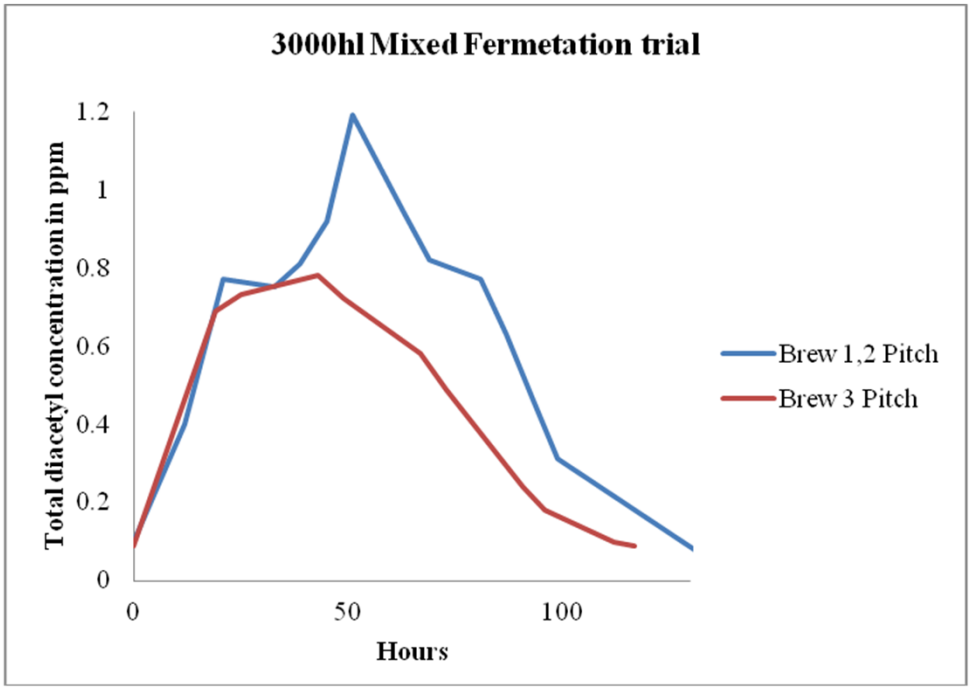


Effect of pitching time on VDK profile

6 brewlengths to fill vessels

Yeast pitched with 1st and 2nd brewlengths

All yeast pitched with 3rd brewlength



Effect of collection on beer volatiles

- Exposure time of yeast to oxygen during vessel fill can be used to modulate ester synthesis yeast

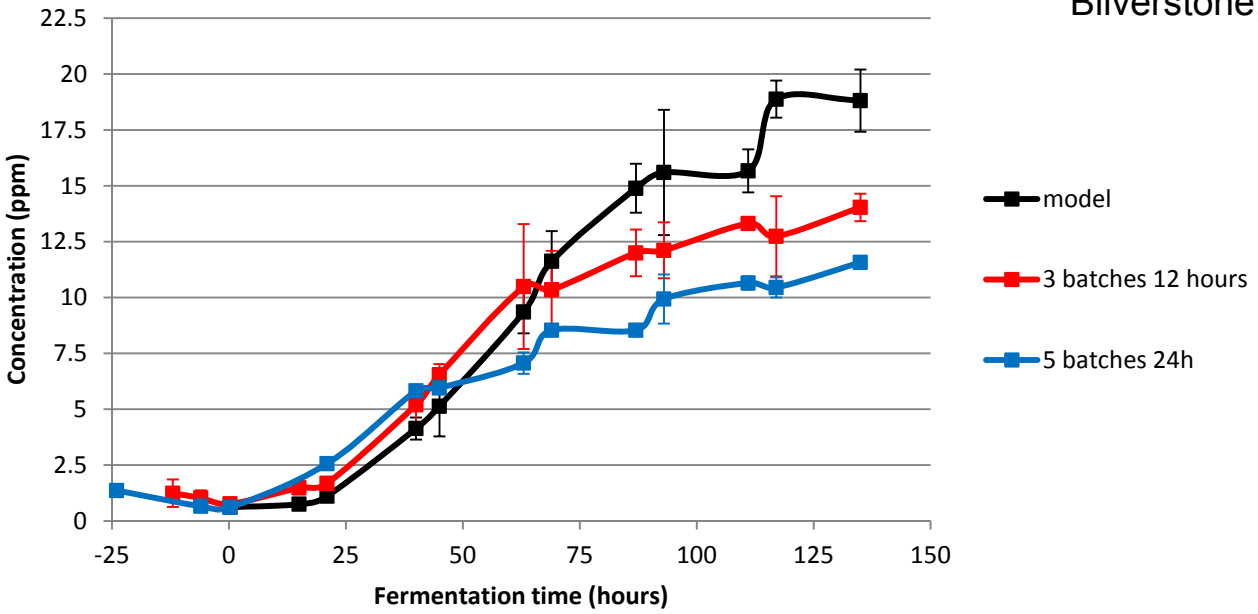
- Acts via repression of ATF genes by oxygen

Experimental conditions

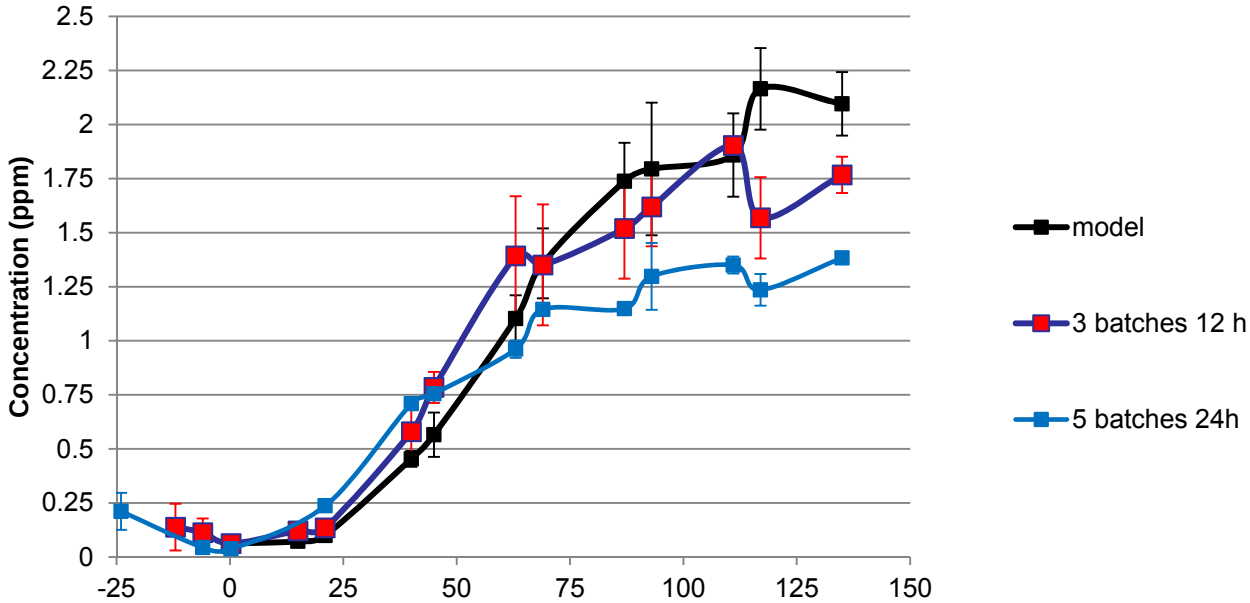
- 3 x 10 litre wort fermentations
- Identical conditions
- All yeast pitched at start
  - Control: all wort added at zero time
  - Trial 1: 3 batches of wort added over 12h
  - Trial 2: 5 batches of wort added over 24h

Effect of filling on ethyl acetate

Bilverstone, *et al*., WBC Oregon, 2013



Effect of filling on isoamyl acetate



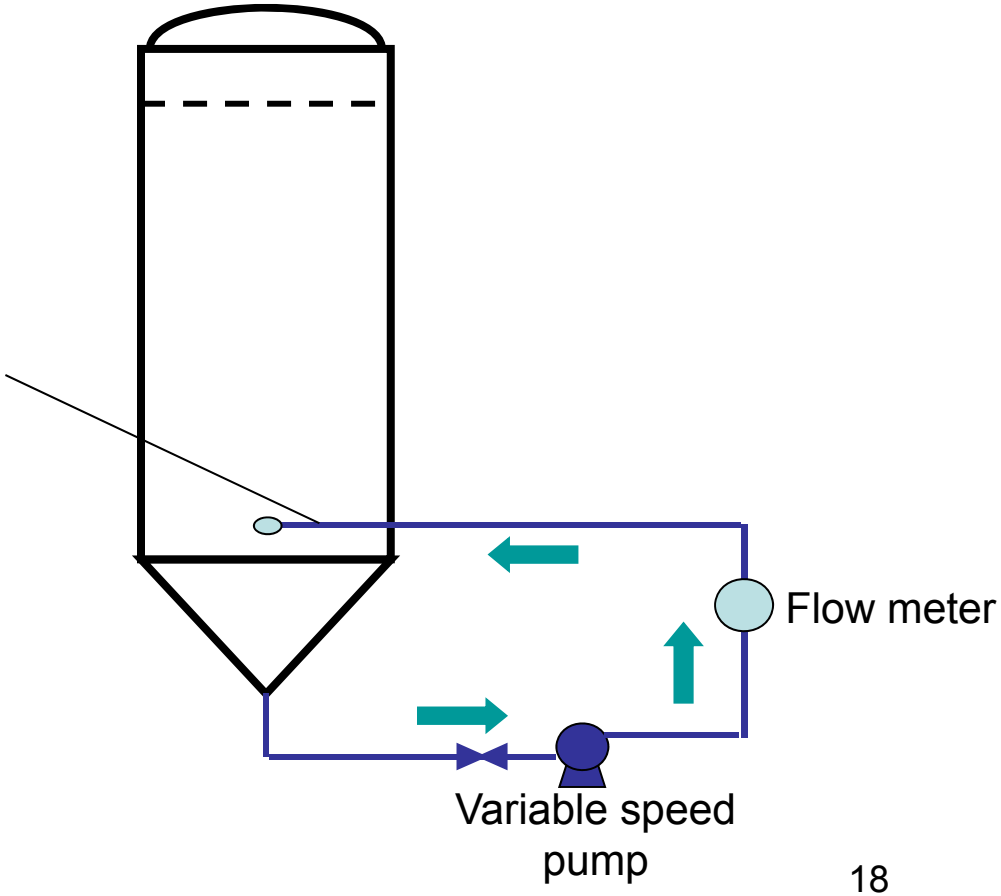
Yeast dispersion and fermentation performance

- Natural mixing of vessel contents is poor
  - Spatial heterogeneity throughout most of fermentation
  - May hinder transport of yeast metabolites
  - Off-line sample analysis may not accurately reflect actual conditions in vessel
  - Uncertainty of when crop forms

Mechanical mixing remedies many of these problems

Alfa Laval Iso-Mix pumped loop mixing system

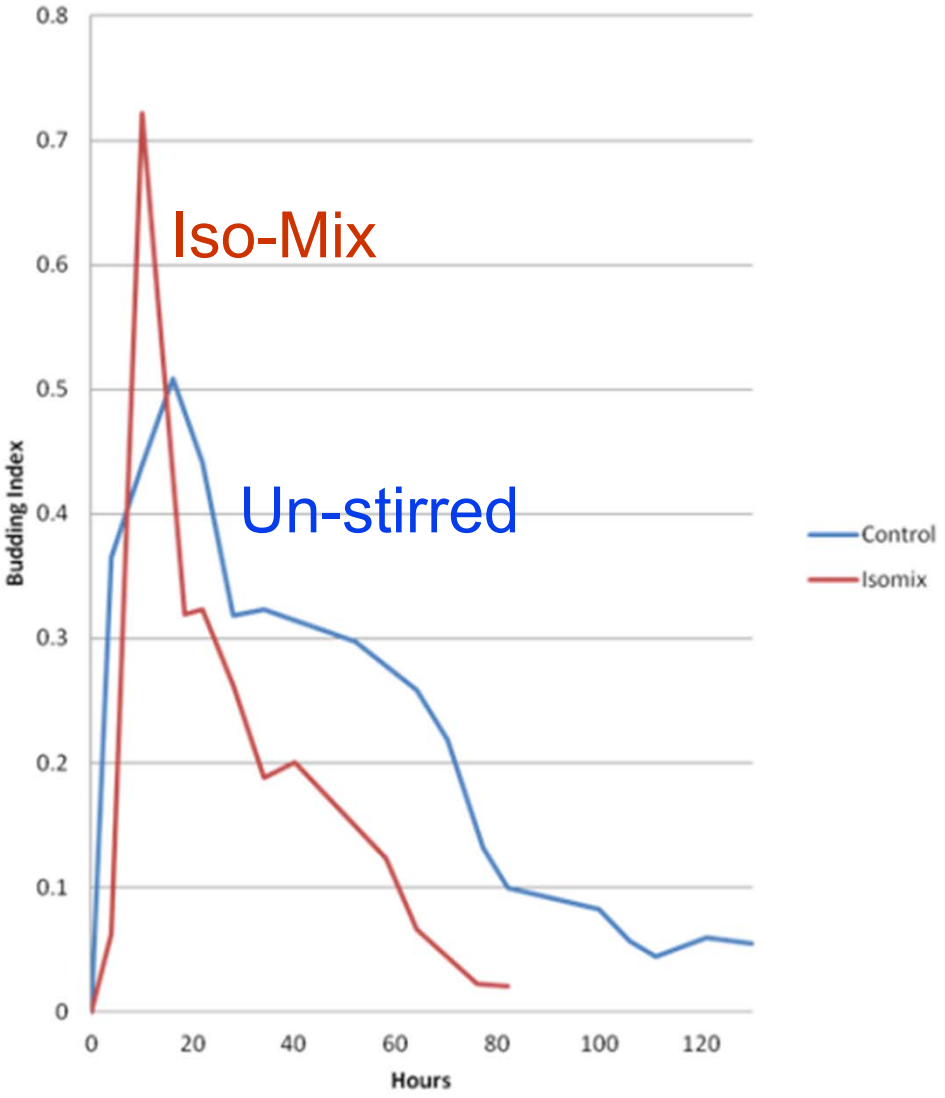
Rotary jet head (ISO-MIX A/S)



Effect of Iso-Mix on initiation of yeast growth (single pitching)

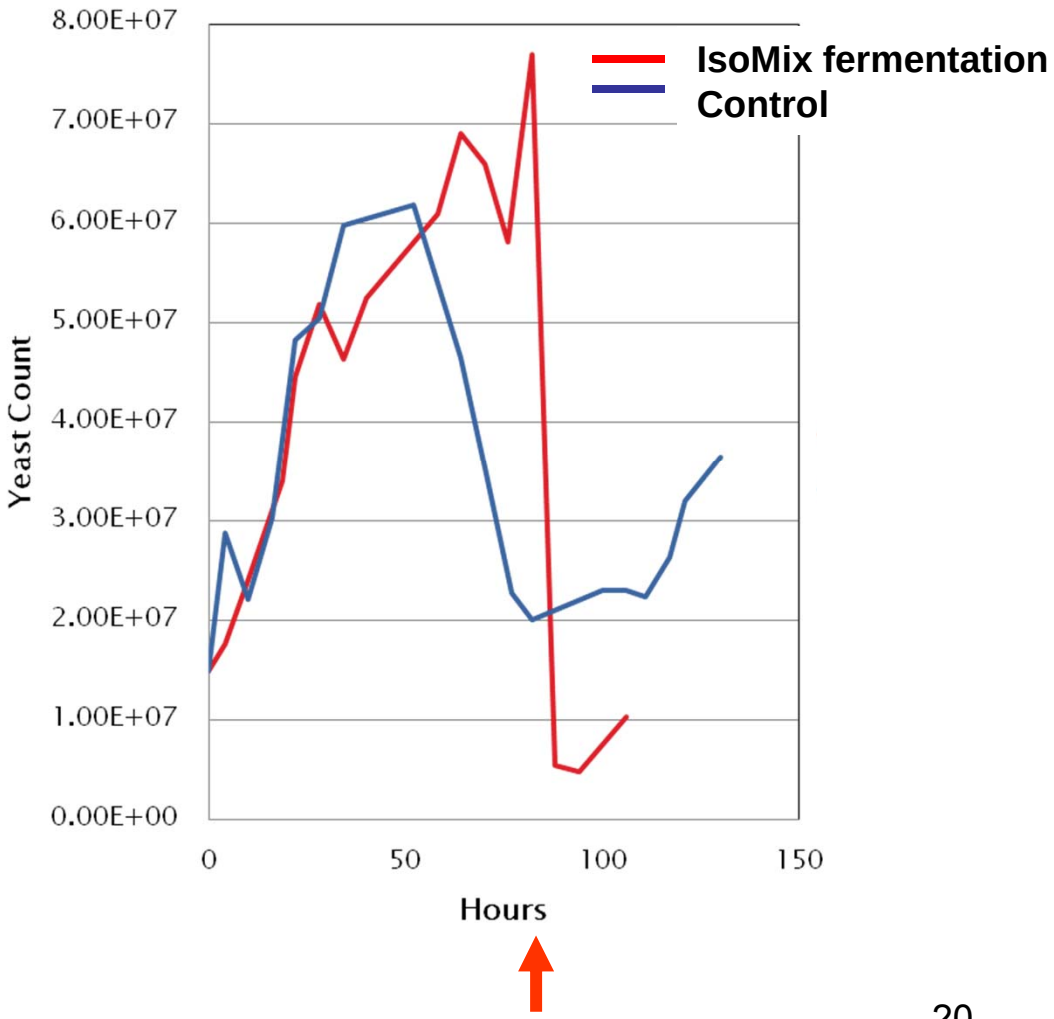
Yeast budding index (% budded cells)

- More cells initiate budding at same time
- Synchronicity maintained for longer
- Ensures consistent start point

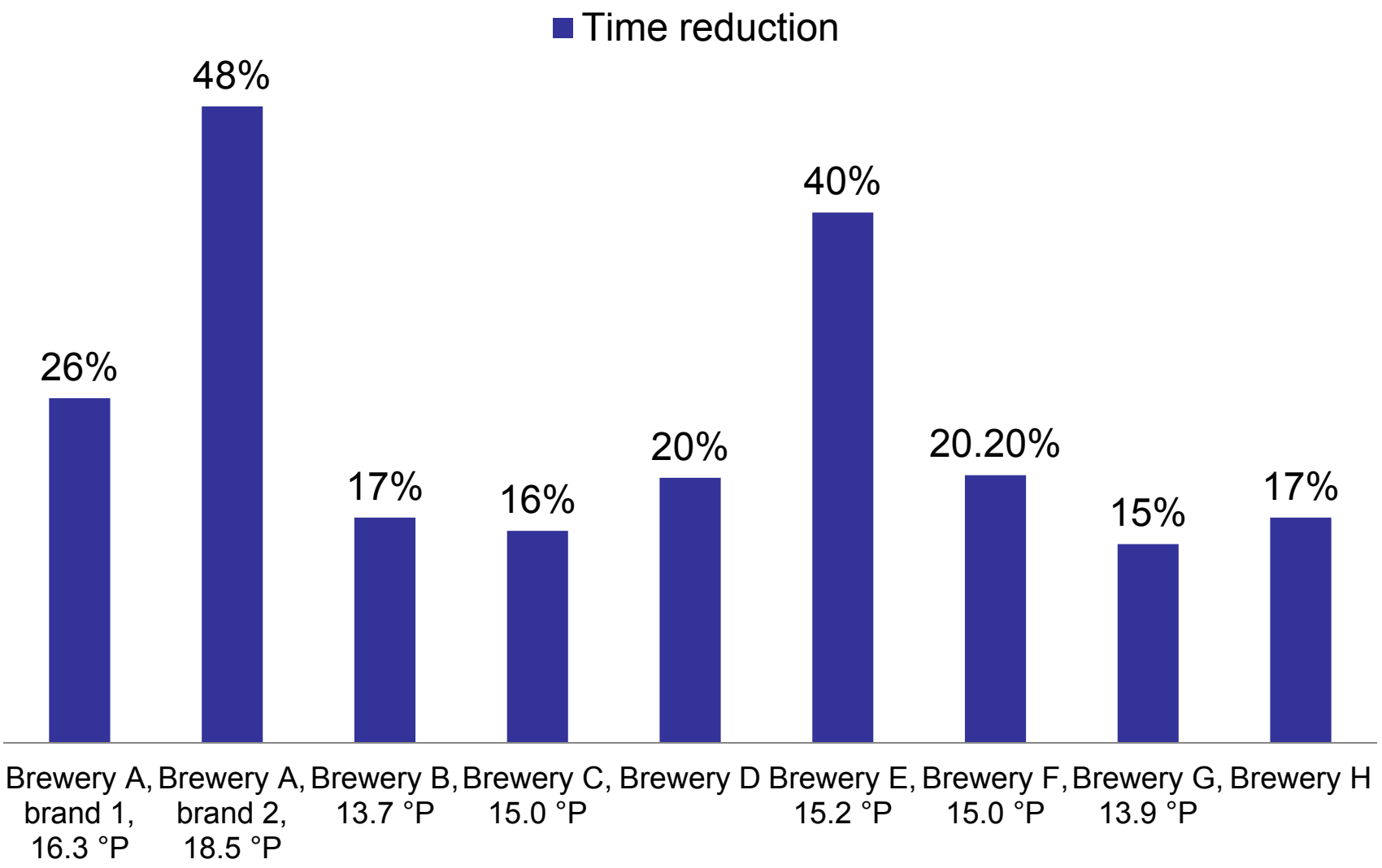


End of fermentation

- Essential to manage yeast stress
- Remove crop as soon as possible
- Very rapid yeast sedimentation when loop switched off
- Predictable and rapid crop formation

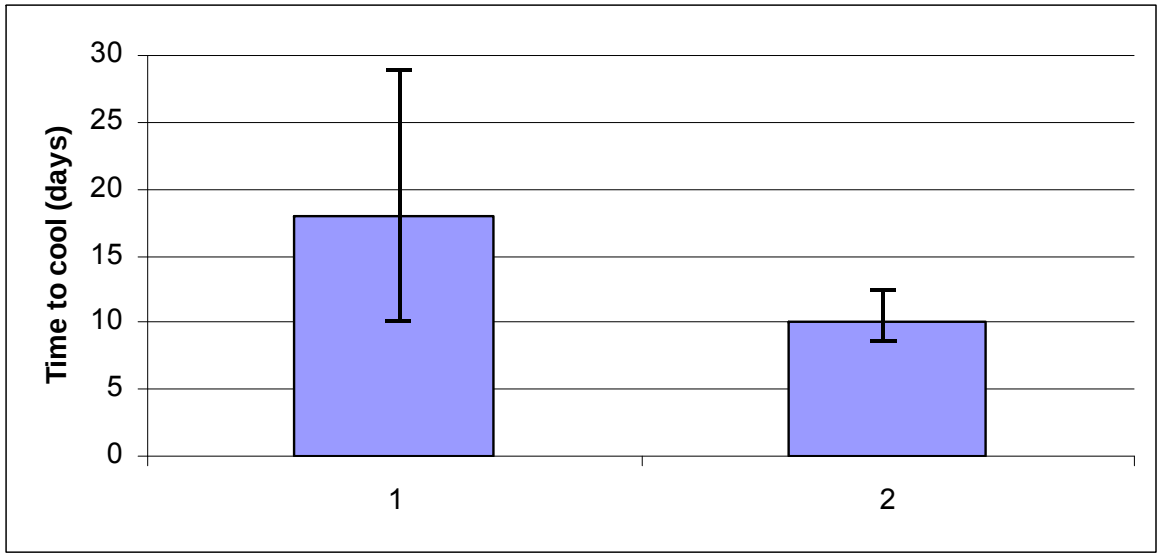


Application of Iso-Mix system – effect on cycle times



Application of Iso-Mix system - effect on fermentation consistency

- Lager fermentation (18.5 °P).
- 5000hl ccvs
- Mixing by Iso-Mix system *ca*. 250 hL/h



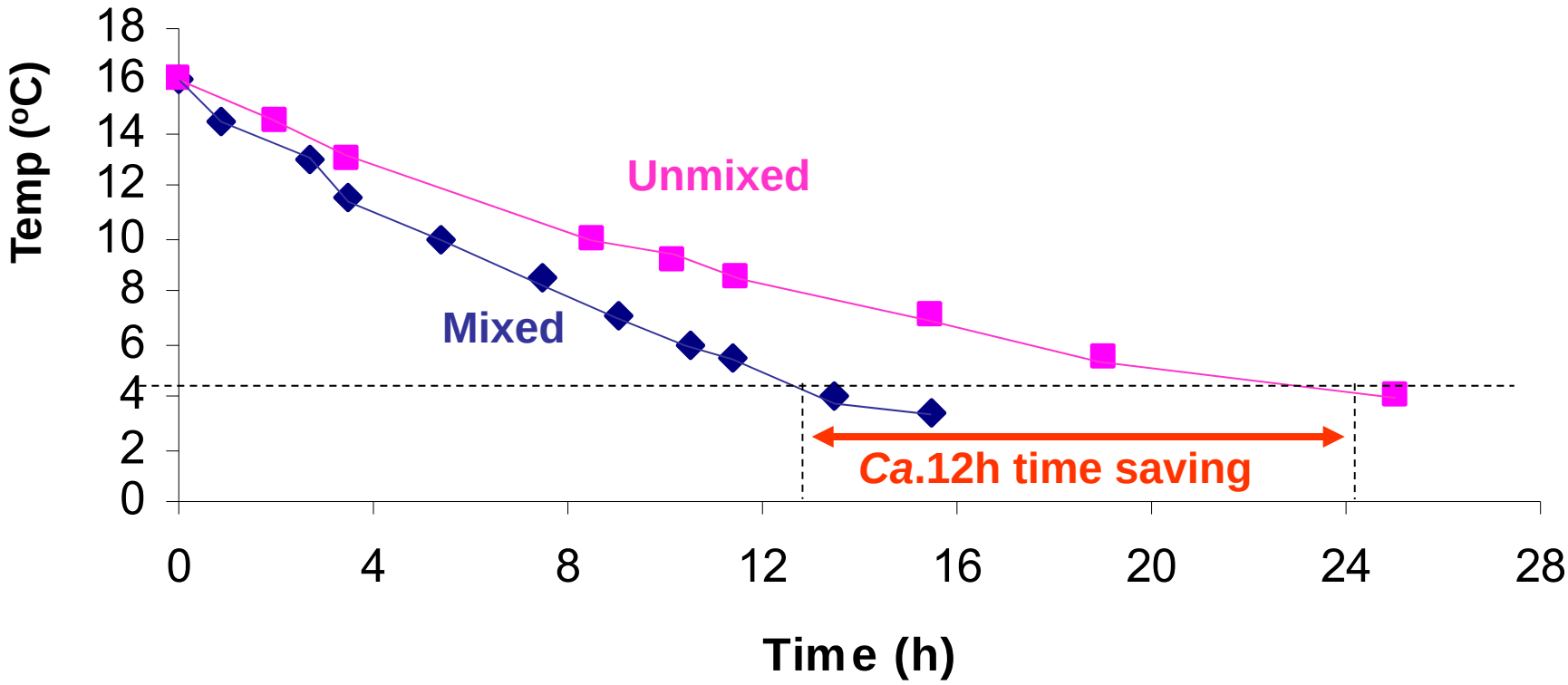
n = 18

Unmixed controls

Mixed

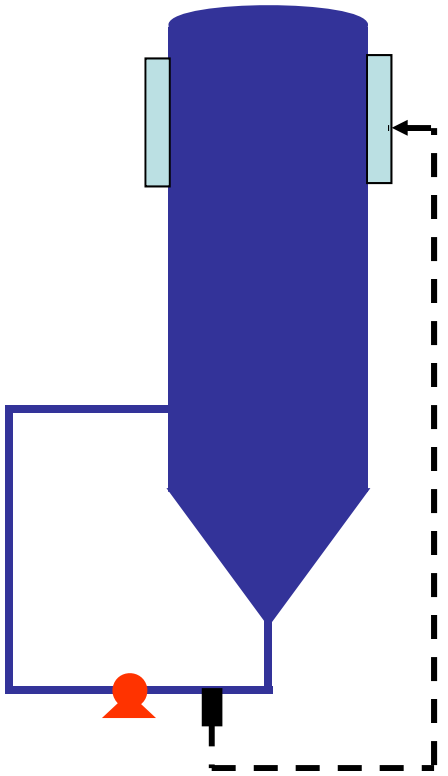
Improved tank cooling

- Crash cooling in 1800 hl conical with or without mixing
- Mixing by a single IM 20 RJH operated at *ca.* 250 hL/h



Improved monitoring of fermentation

- Identification of key stages in fermentation still reliant on sampling and off-line analysis
- Can be a cause of prolonged cycle times
- Pumped loop system an ideal location for suitable in-line probes

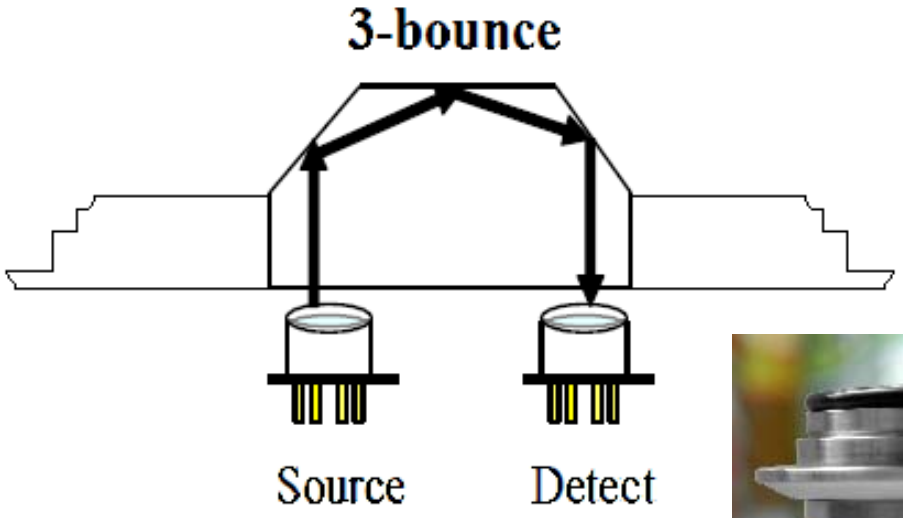


Automatic in-line measurements

- VitalSensors Technologies (Denver, USA)
- Based on attenuated total reflection sampling technique using mid-infra red (MIR)
- 3 channels which can be calibrated for ethanol, extract and CO_2

Principle of sensor

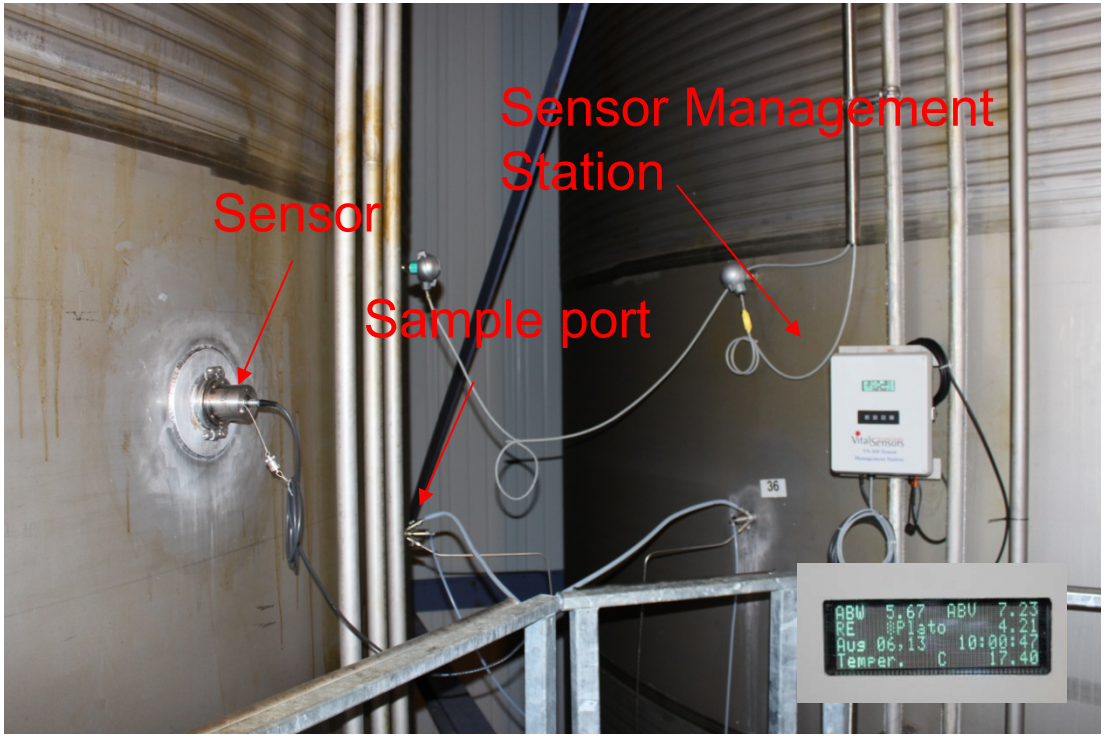
- Attenuated total reflection MIR sensor



- Ethanol channel
- Sugar channel
- CO_2 channel

Installation

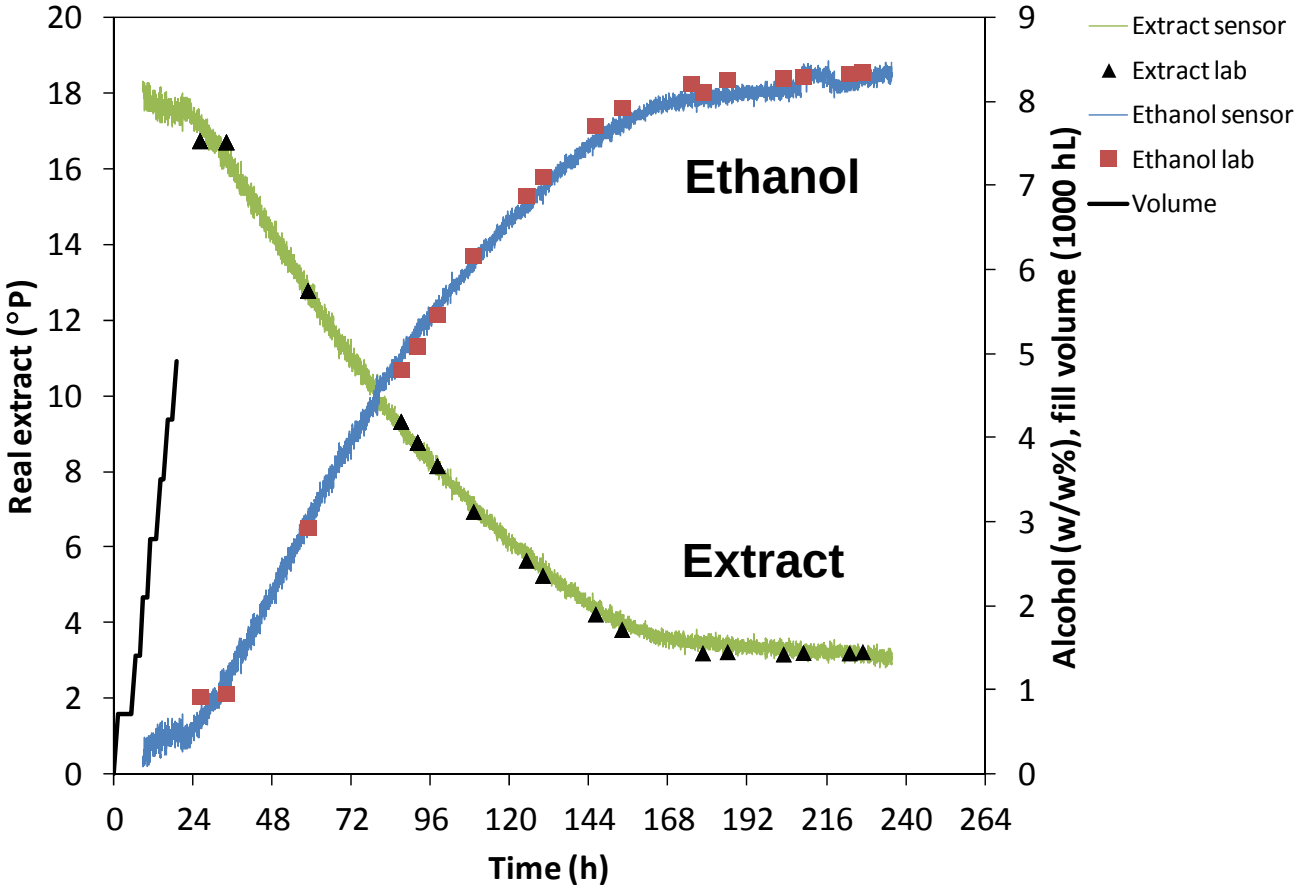
- Working volume *ca*. 5000 hL
- Sensor at *ca*. 2030 hL close to sample port
- Communication with Sensor Management Station via Ethernet
- Integrated into brewery control system



Results – extract and ethanol

5000Hl

18.5°P



Conclusions

- Vessel fill
  - Must adopt rational procedure
  - All yeast pitched over shortest possible time
  - Use oxygenation regime to control growth and modulate volatiles
  - May be better to pitch late and not with first brewlength

Conclusions

- Fermentation management
  - Control yeast dispersion via application of mechanical agitation
  - Control time of crop formation and early removal
  - Pumped loop useful site for in-line probes
  - VDK sensor?

Conclusions

- FV design
  - Run fermentation as entirely warm process
    - Store crop warm if less than 24h to re-pitch
  - Remove cooling jackets and apply attemperation via loop
  - Chill beer in-line during vessel emptying
  - Use loop for oxygenation post-pitching?
  - Use loop for addition of beer stabilising agents (in-tank or in-line during rundown)

Thank you!

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