

# A stable platform for control of fermentation

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# Current trends in fermentation

# Current Trends in fermentation

- Bigger batch sizes
- High or very high gravity worts
- Use of higher temperatures
- Limited number of serial fermentations



# Current fermentation control

- Generally adequate control of primary parameters
  - Initial extract
  - Pitching rate
  - Oxygenation
  - Temperature



# Problems to resolve

# Some current problems

- Management of yeast stress
  - Sustainable serial re-pitching
  - Management of yeast dispersion
- How to ensure short and consistent cycle times
- Predictable manipulation of yeast-derived beer flavour compounds
- Reliable markers of progress
  - Lack of suitable on-line sensors

# Yeast dispersion and fermentation performance

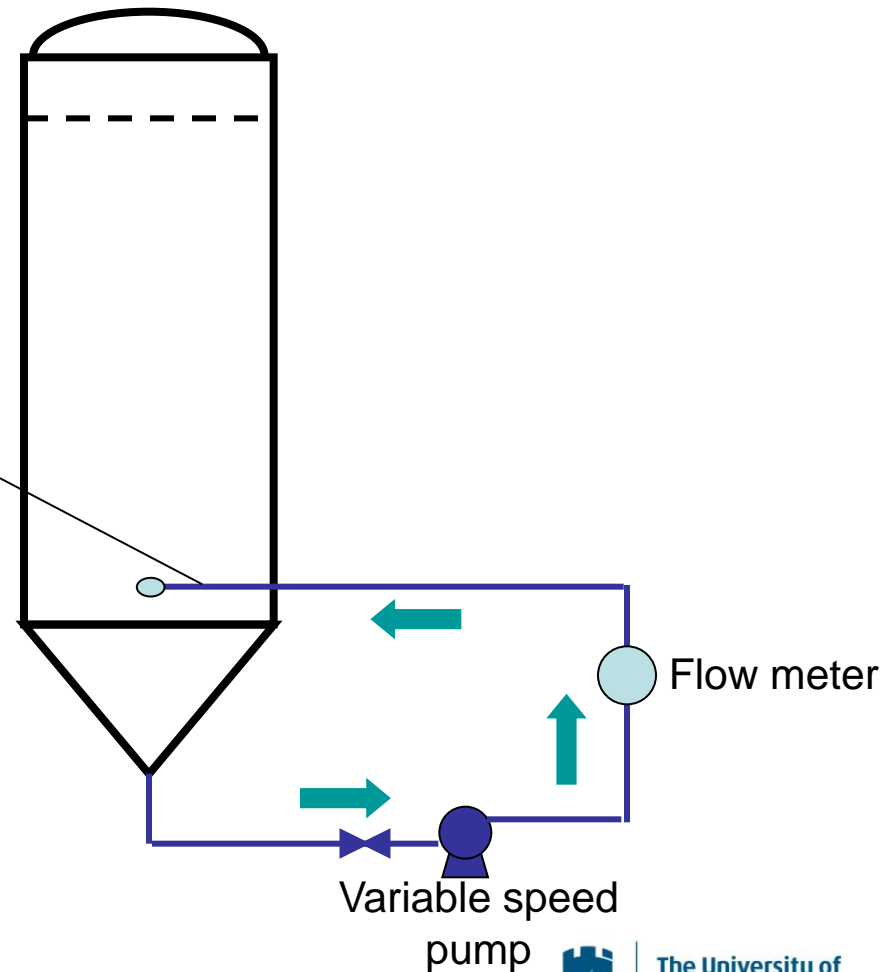
- Natural mixing of vessel contents is poor
  - Spatial heterogeneity throughout most of fermentation
  - May hinder transport of yeast metabolites
  - Off-line sample analysis may not accurately reflect actual conditions in vessel
  - Uncertainty of when crop forms

# Provision of mechanical mixing remedies man of these problems

Rotary jet head (ISO-MIX A/S)



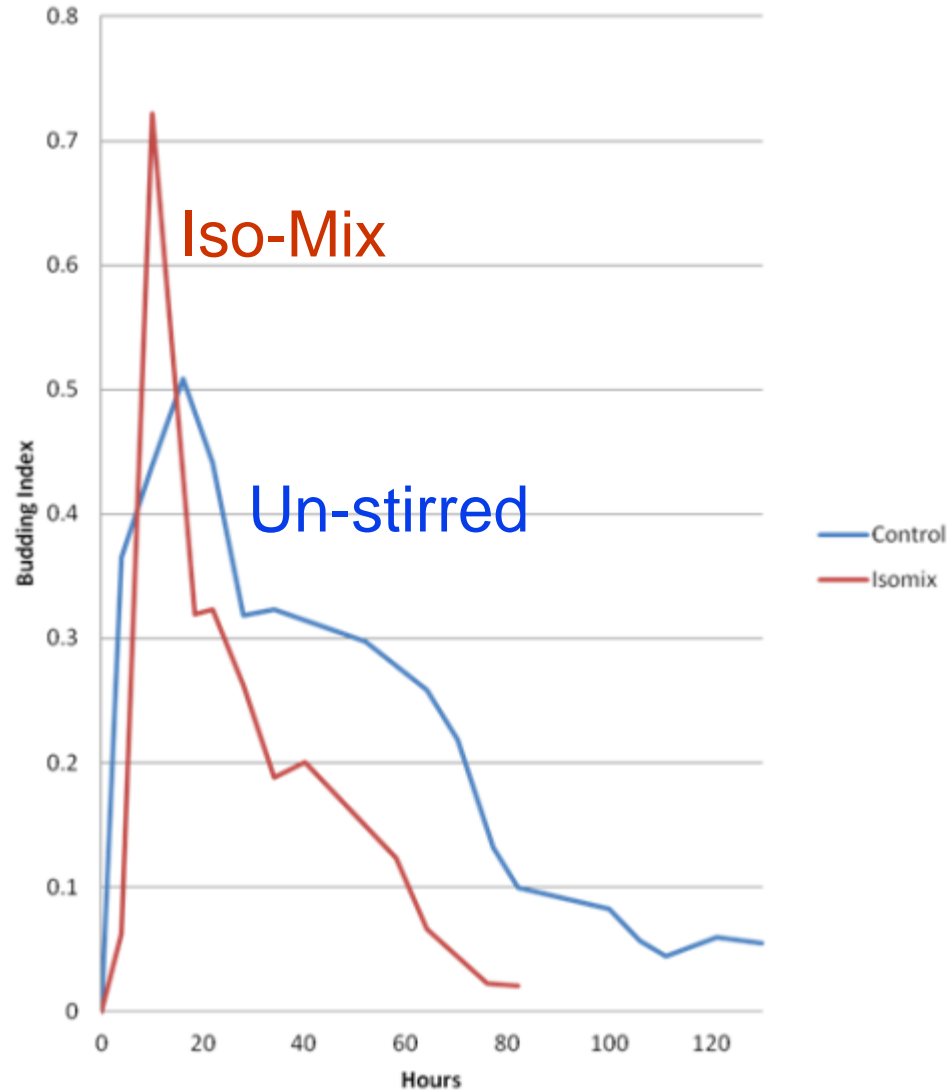
Rotary mixing head suspended in wort





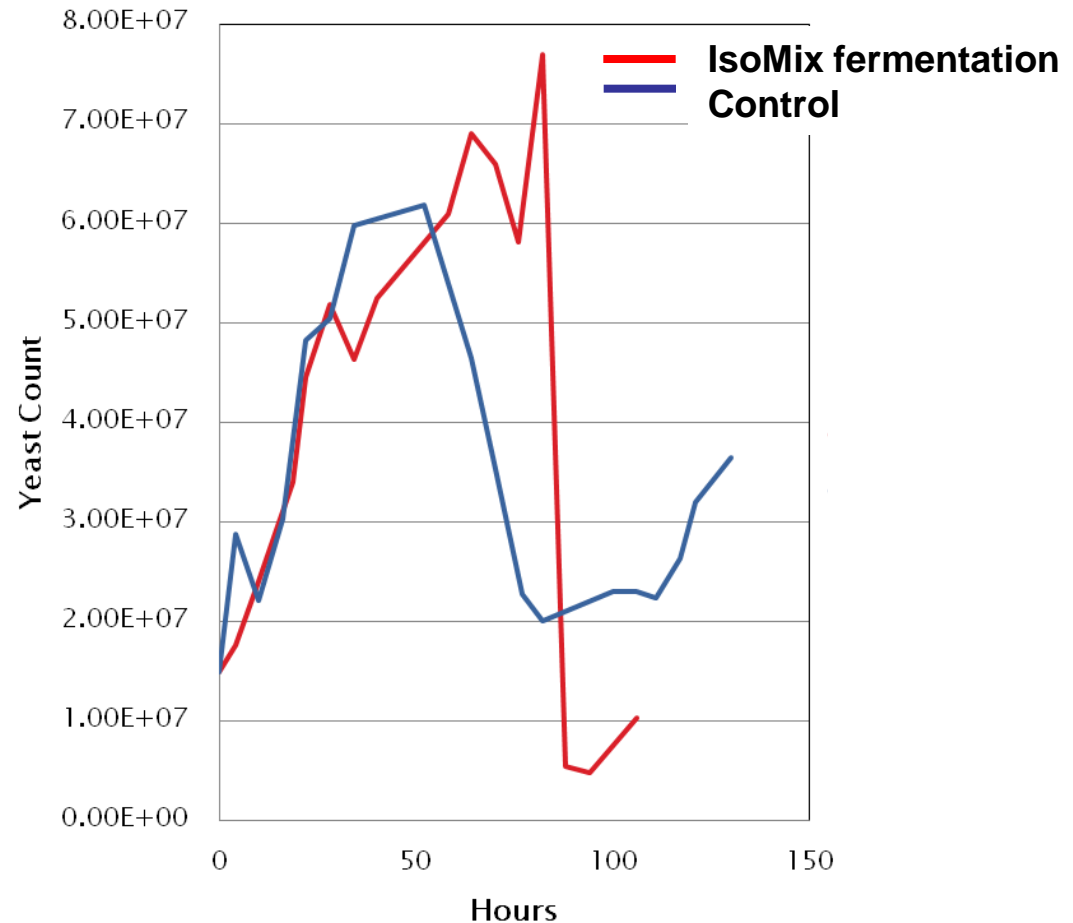
# Initiation of yeast growth (single pitching)

- Yeast budding index (% budding cells) for stirred and unstirred fermentations
- More cells initiate budding at same time
- Synchronicity maintained for longer
- Ensures consistent start point



# End of fermentation

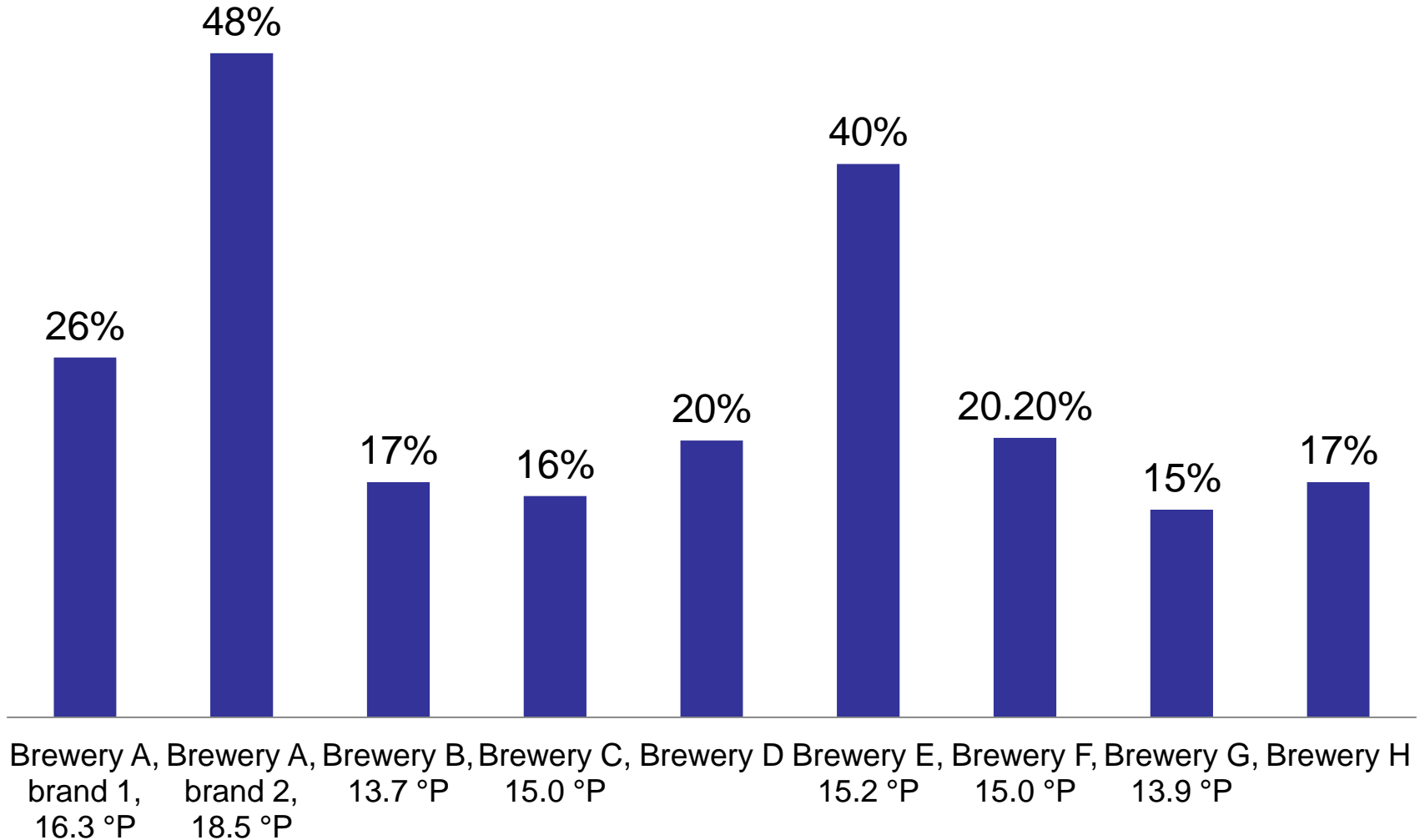
- Essential to manage yeast stress
- Remove crop as soon as possible
- Very rapid yeast sedimentation when loop switched off
- Predictable and rapid crop formation



↑  
Loop off at 85h

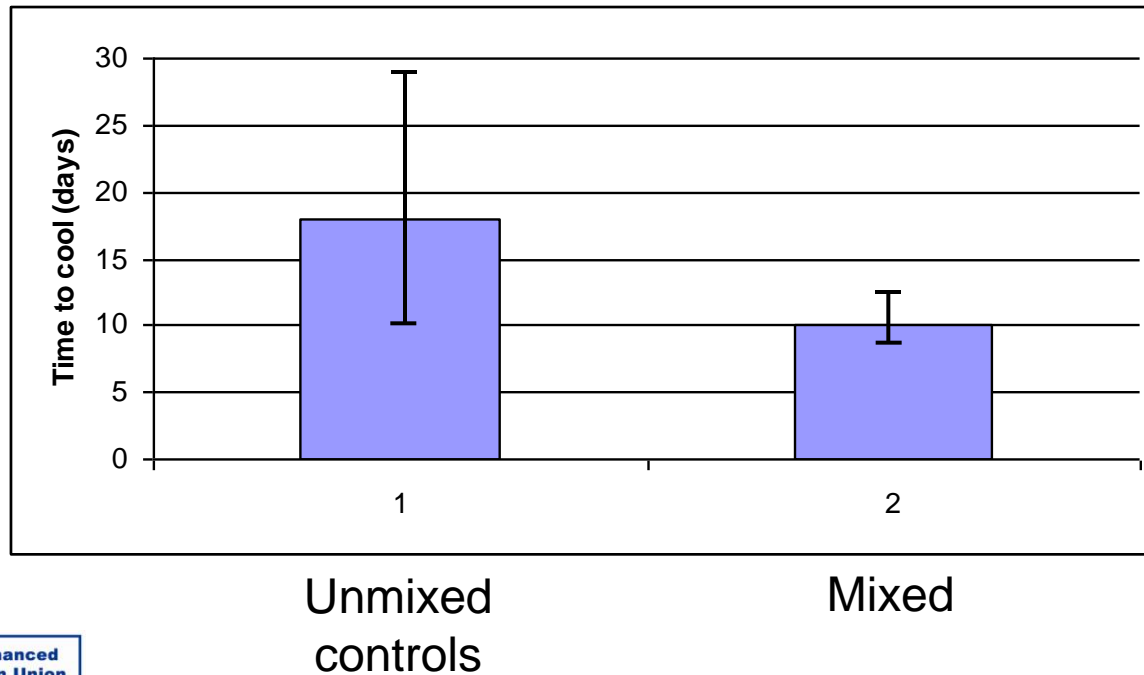
# Effect on process time in different breweries

■ Time reduction



# Fermentation consistency

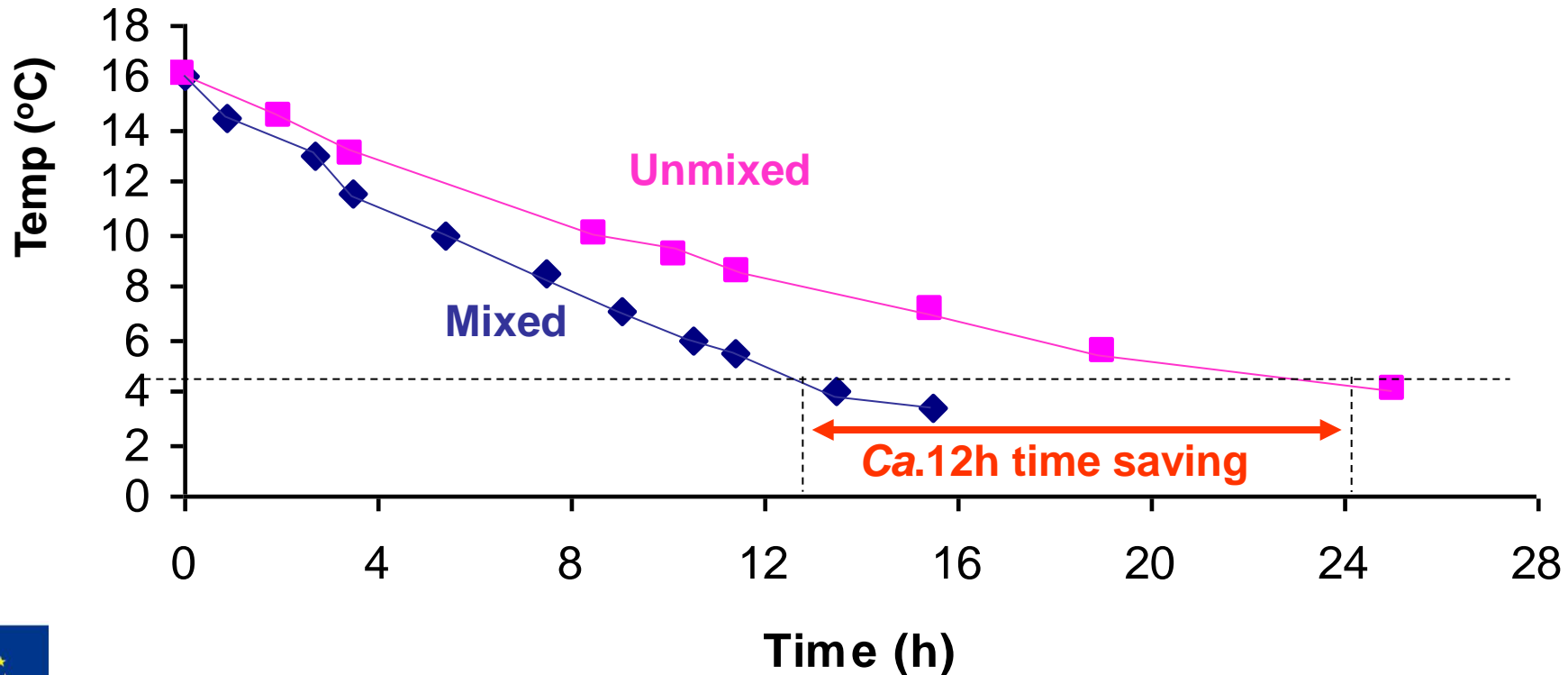
- Lager fermentation (18.5 °P).
- 5000hl ccvs
- Mixing by Iso-Mix system *ca.* 250 hL/h



n = 18

# Improved attemperation

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

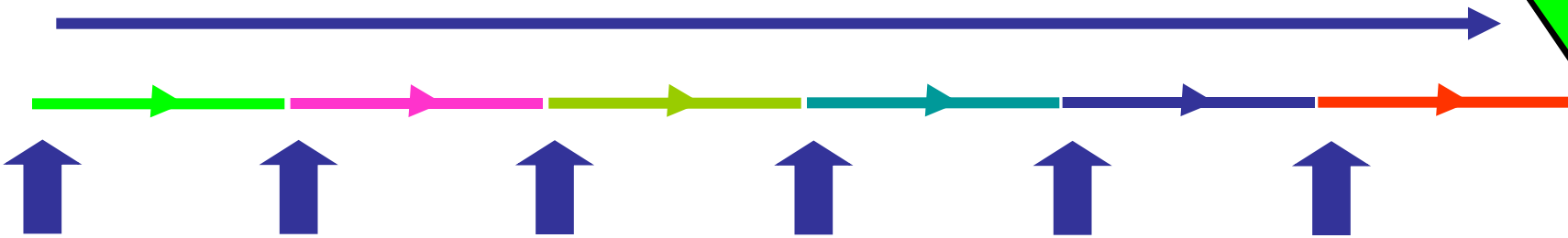


# Influence of vessel filling

- 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?

# Options for pitching and oxygenation during collection

Multi-filling with 6  
brewlengths

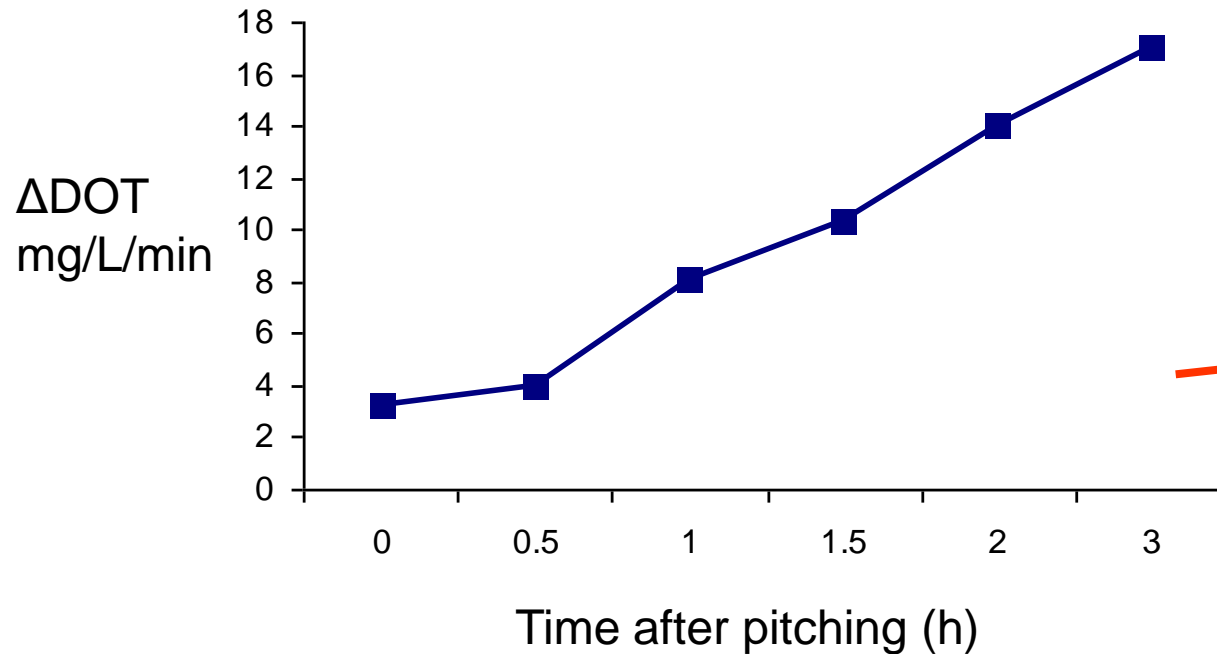


# Effect of prolonged pitching time

- 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

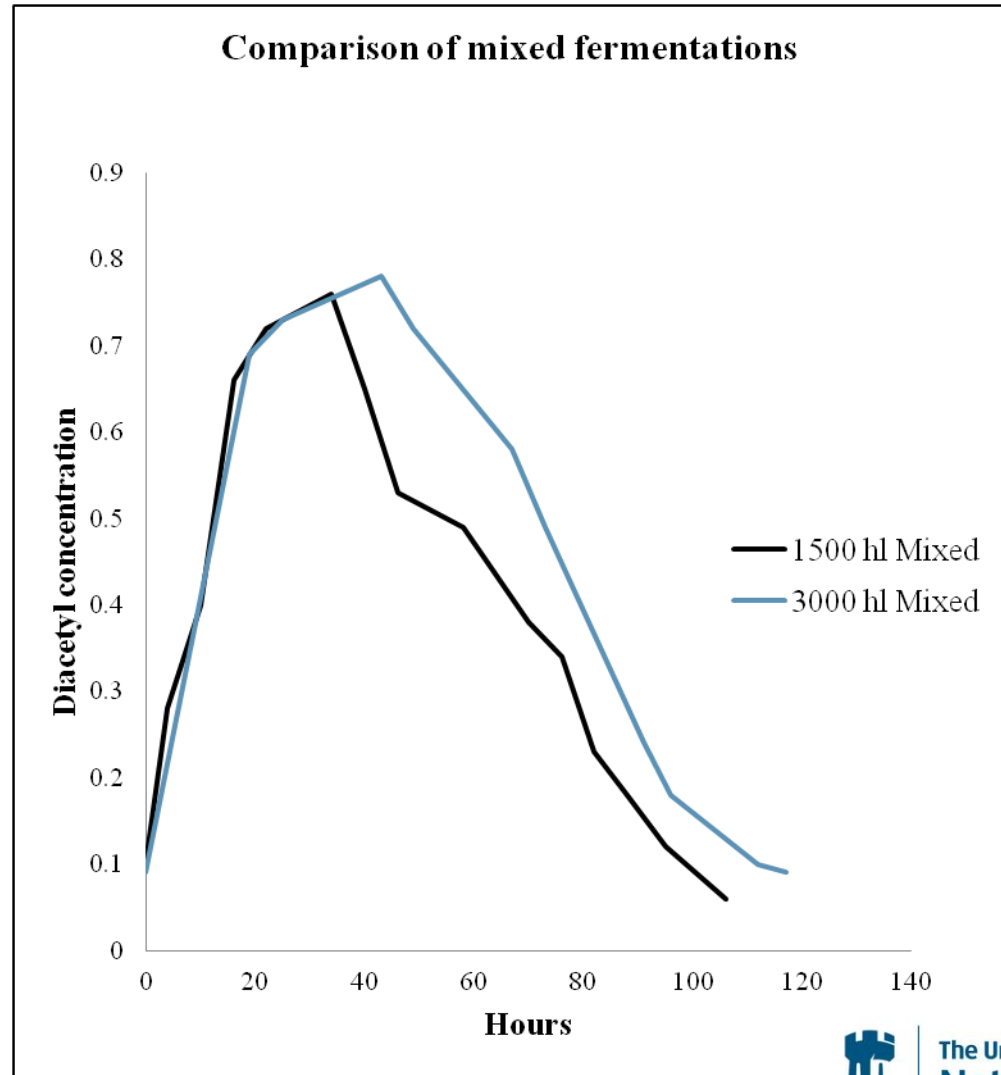
- Long fermenter fill with multiple batches of wort
  - Fed-batch system where fresh supply of group A amino acids prevents uptake of Group B amino acids
  - Pushes VDK peak towards right

# VDK profiles of 1500 vs 3000 hl high gravity lager fermentations

Identical worts,  
pitching rates and  
oxygenation regimes

All yeast pitched with  
1<sup>st</sup> brewlength

Collection times 10  
and 18h, respectively

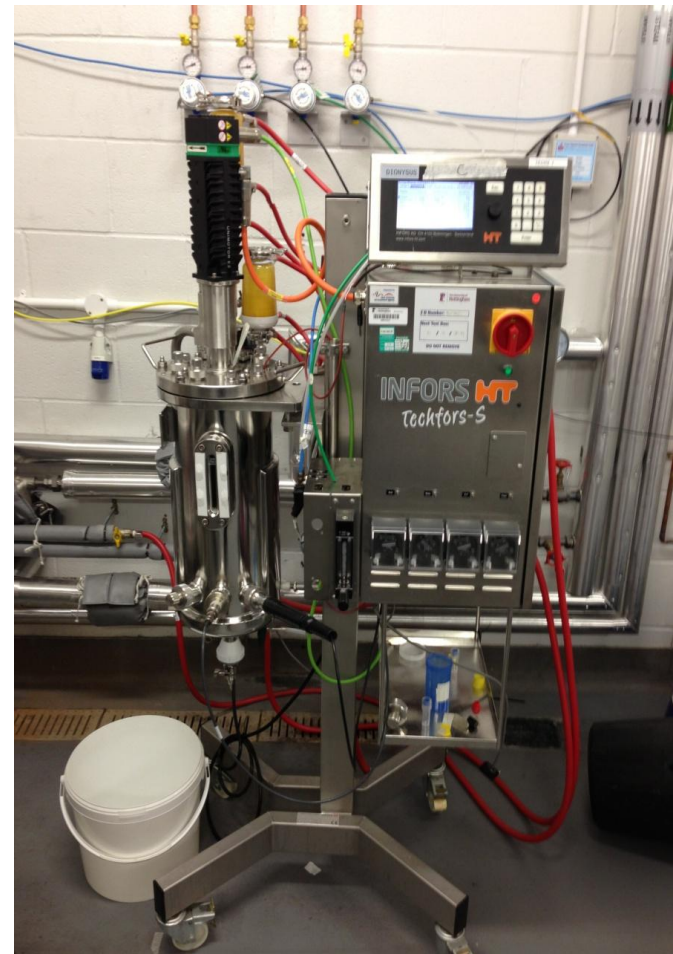


# Effect of collection on beer volatiles

- 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

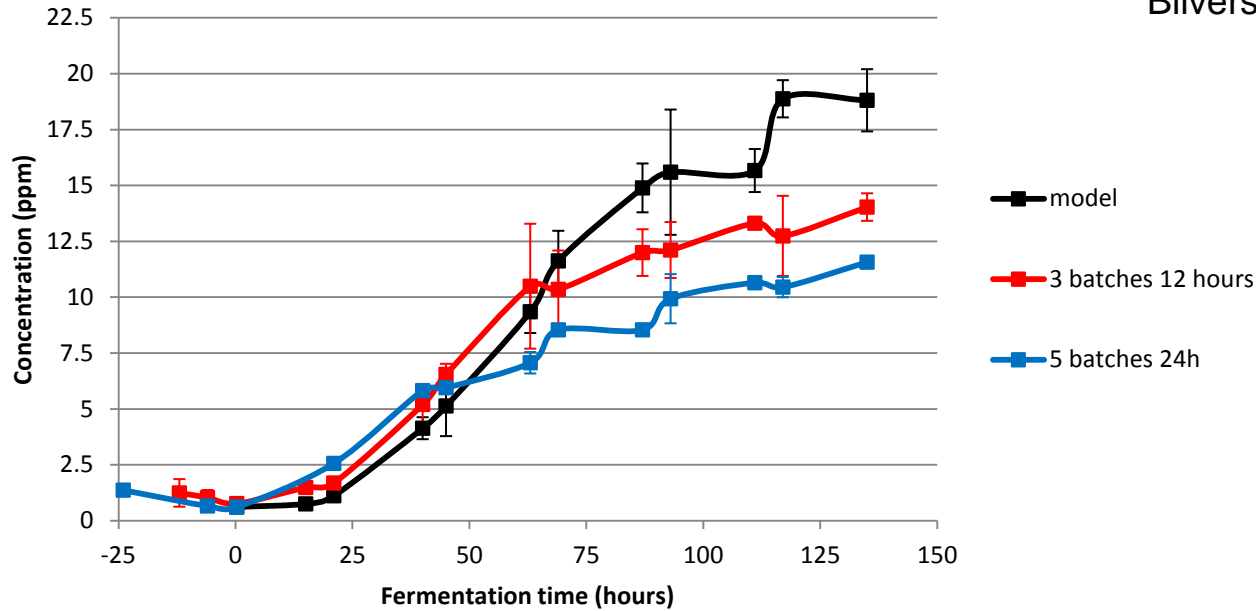
# Experimental conditions

- 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

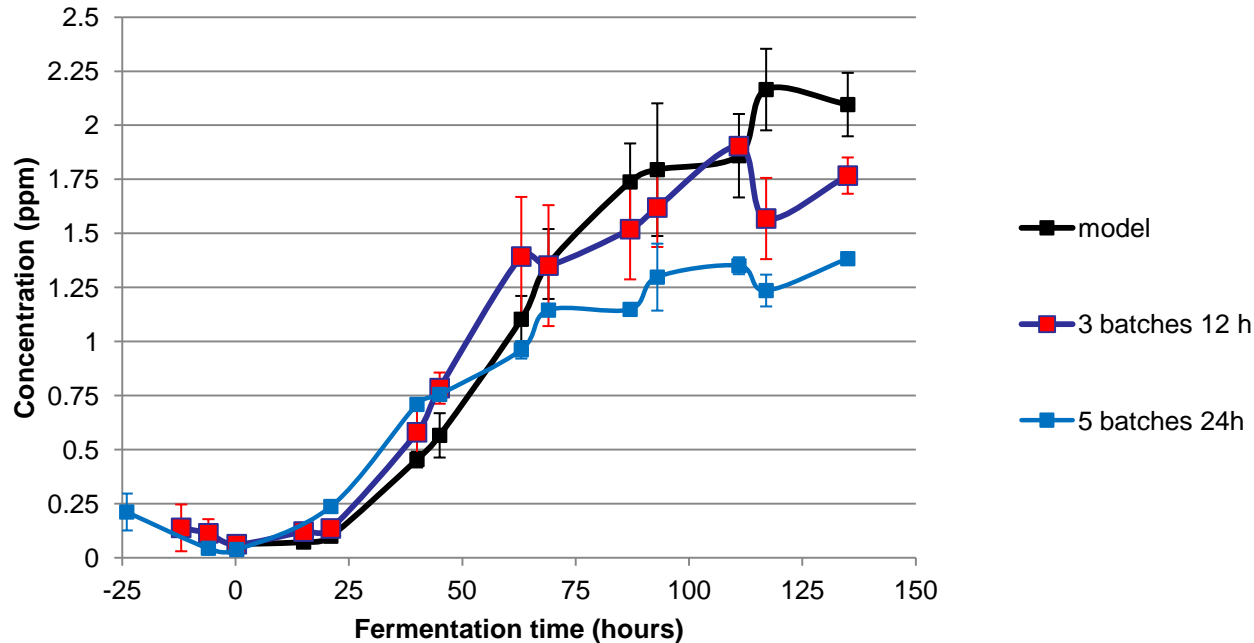


## Effect of filling on ethyl acetate

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

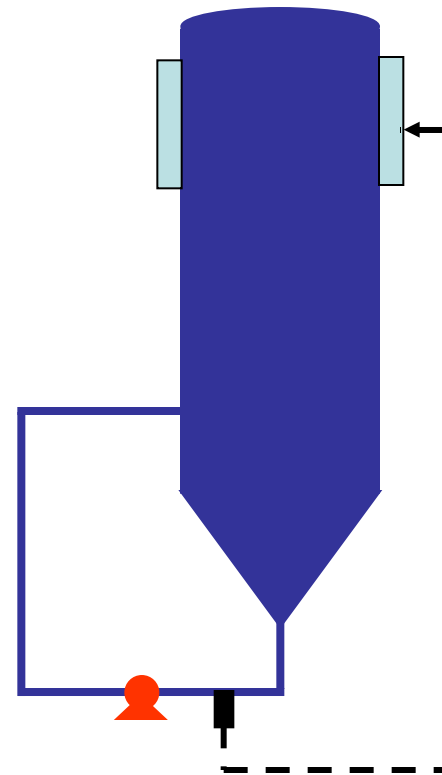


## Effect of filling on isoamyl acetate



# 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



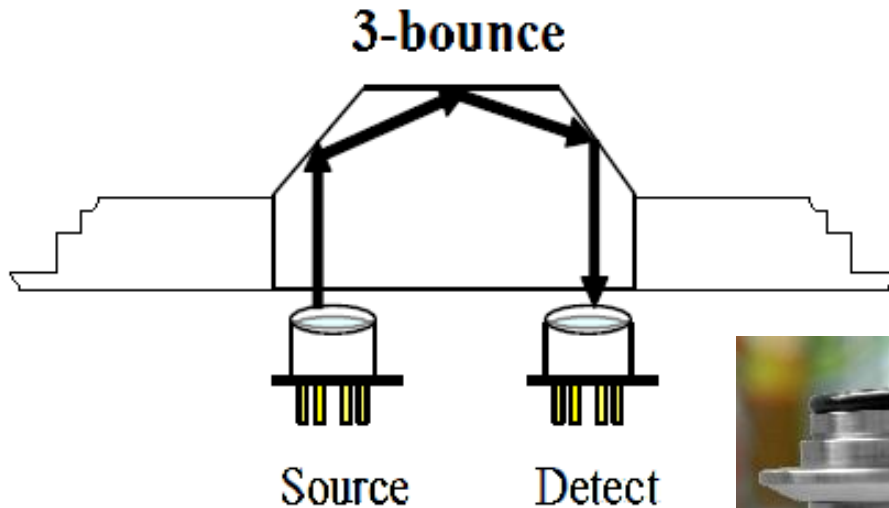
# Automatic in-line measurements

- 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<sub>2</sub>



# Principle of sensor

- Attenuated total reflection MIR sensor

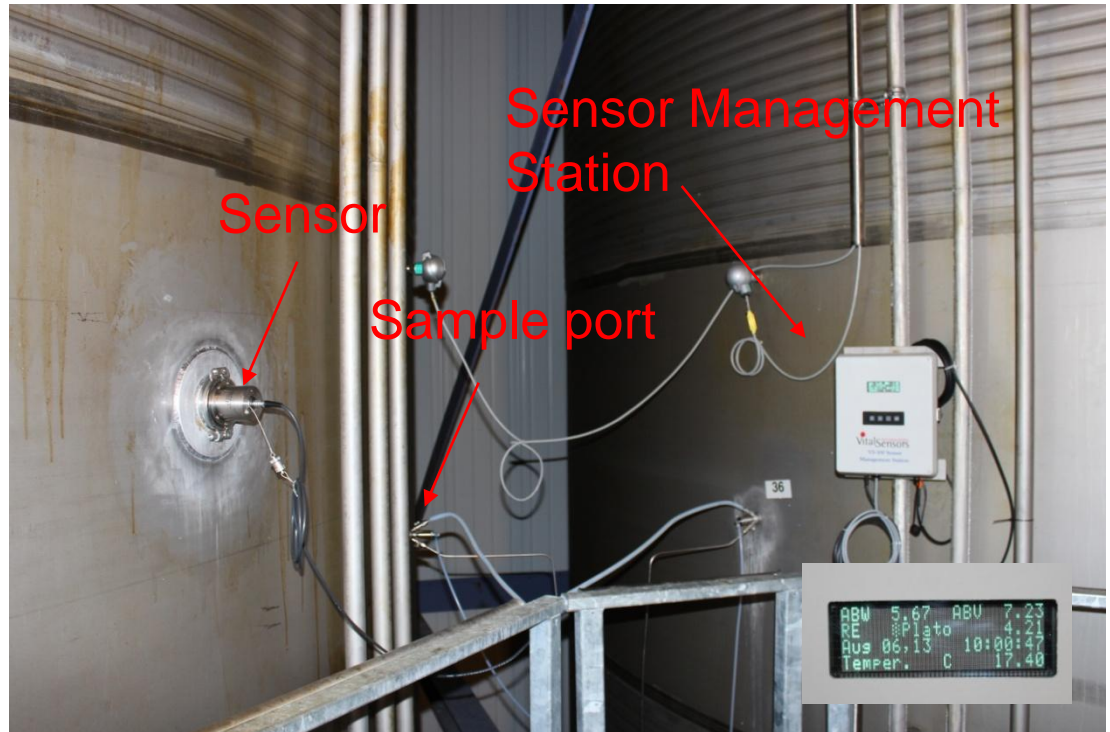


- Ethanol channel
- Sugar channel
- CO<sub>2</sub> channel



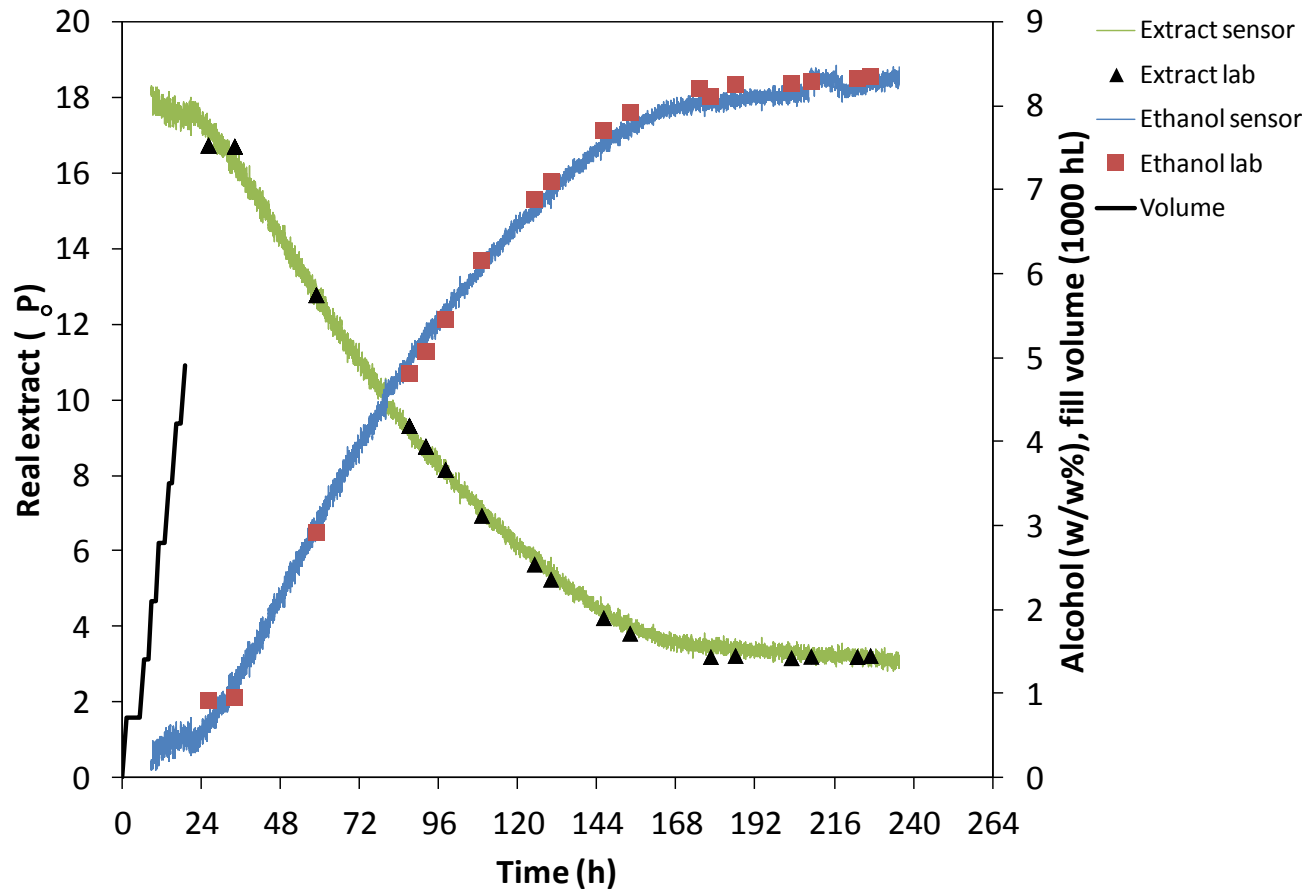
# Installation

- 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



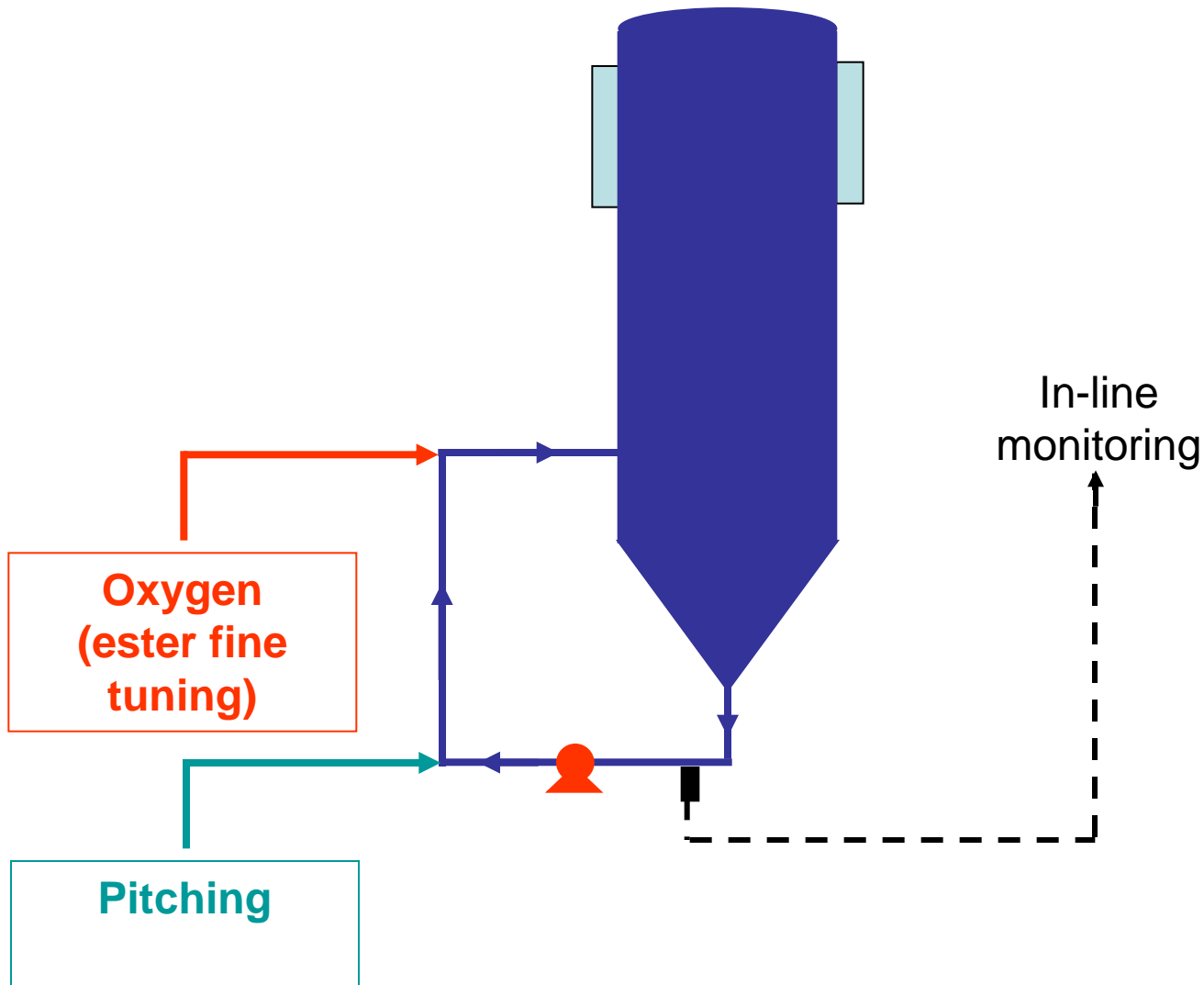
# Results – extract and ethanol

5000HI  
18.5°P



# Pumped loop system

Opportunities for vessel design  
and operation



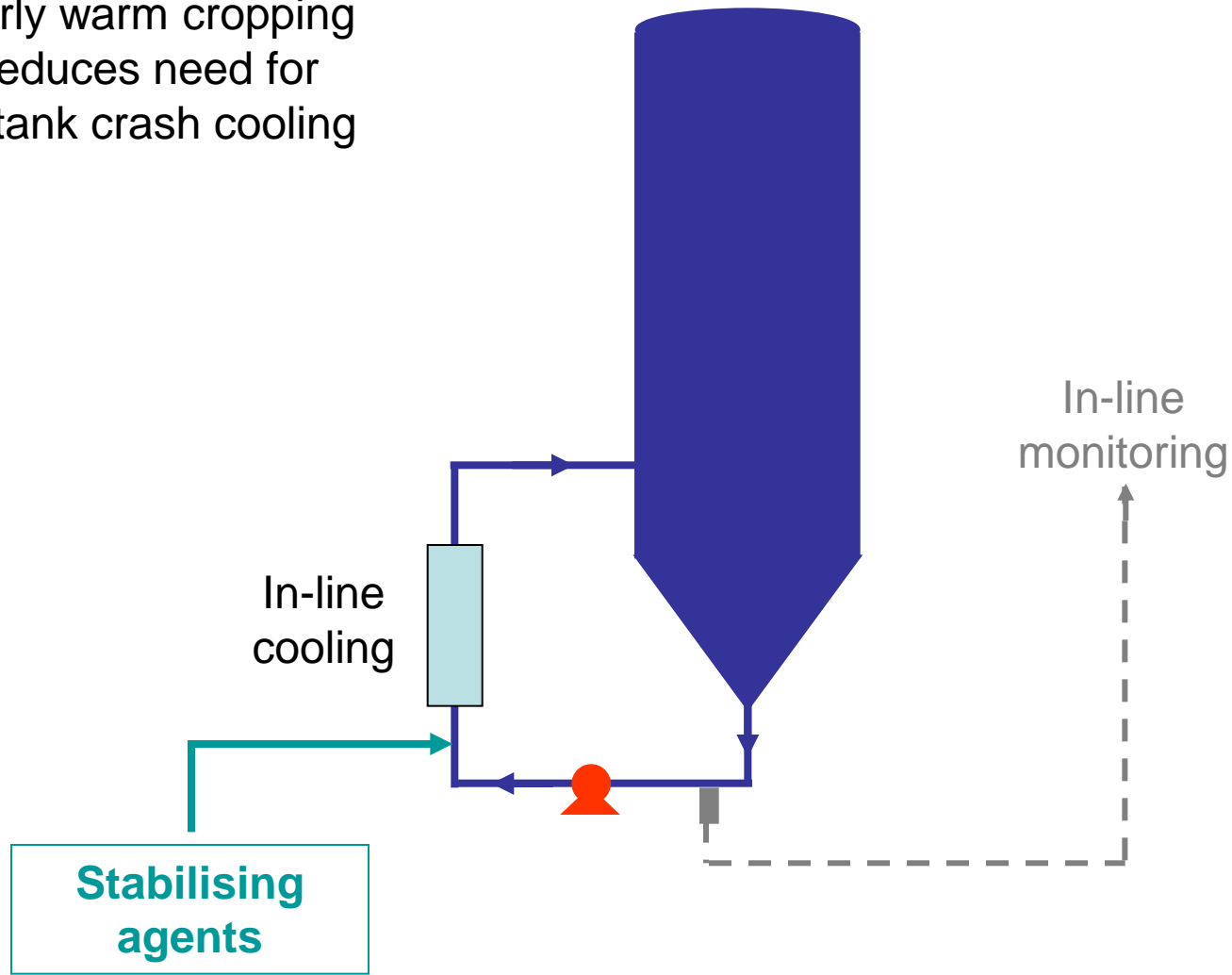
Project Part-Financed  
by the European Union  
European Regional  
Development Fund



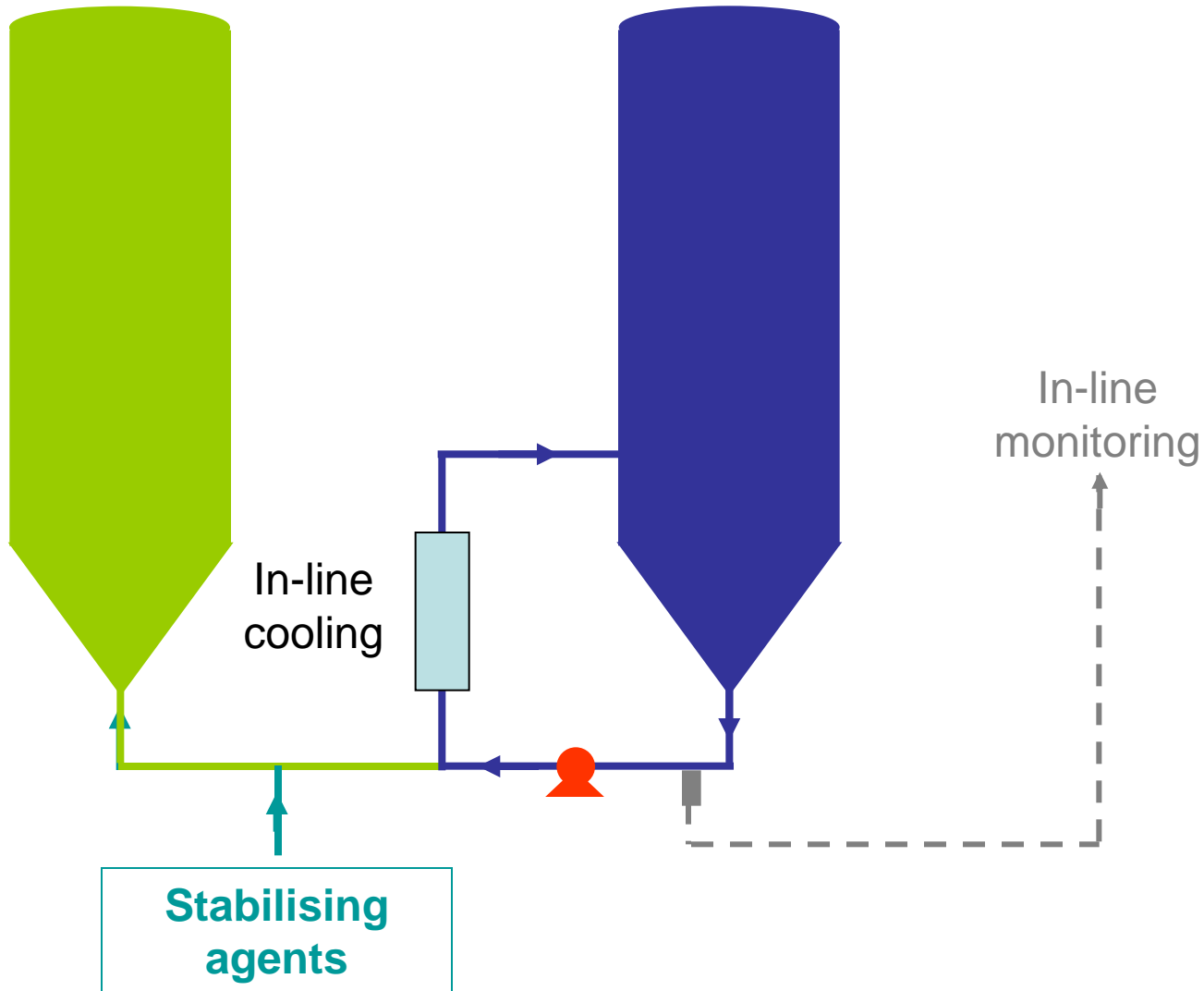
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Early warm cropping  
reduces need for  
in-tank crash cooling



Suitable for dual or uni-tanking operation



# Thank you

