The Australian Wine Research Institute

Engineering Fermentation

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Process & Environmental Engineer

Industry context

- Resources allocated to existing monitoring and control – sample collection, laboratory analysis, winemaker tasting
- Infrastructure demands – tank space, energy use, refrigeration capacity
- Slow and stuck fermentation – labour costs (reseeding, pump-overs, transfers, lab analysis), tank space, loss in quality

→ $$$

"Engineering" Ferments: What are the benefits?

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- Reduced resources requirement for monitoring and operations control
- Improved ***real-time*** control of process to achieve quantified targets – e.g. residual sugar, colour development, tannin
- When combined with process model, can be used to identify and predict problem fermentation behaviour – to reduce instances of slow/stuck ferments

Information ✦ knowledge → action

Why modelling and simulation?

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- To understand and visualise the system
- By understanding the response of a system to a given disturbance, we can develop an appropriate control strategy
- Predictive capability and optimisation
- Advanced control systems – feed forward, fuzzy logic, adaptive learning

Monitoring and Control Objectives

AWRI

- Goal is to develop:
  - Robust models for industrial wine fermentation with predictive capability, to evaluate fermentation performance in real time and reliably control every fermentation to the maximum quality outcome
  - Robust instrumentation to support monitoring and control objectives
  - Fermentor design that facilitates reliable control

Instrumentation for Monitoring

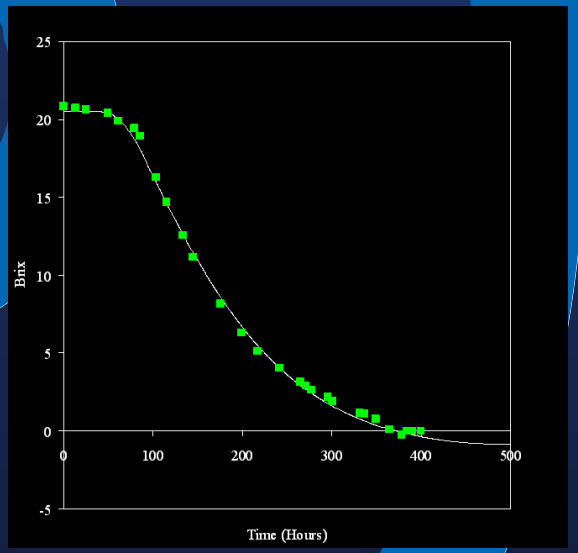
- Density
- Weight loss
- Optical (e.g. RI)
- Osmolality
- Spectral (e.g. NIR)

Instrumentation - Density

- Hydrometer
- Pressure transducer
  - Already in place in some Australian wineries to infer tank fill height
  - Can also be used to measure Baume (density) if fill height is known

$$P = \rho g h$$

- Case studies:
  - UC Davis teaching winery (Davis, CA)
  - Anheuser-Busch brewery (Fairfield, CA)

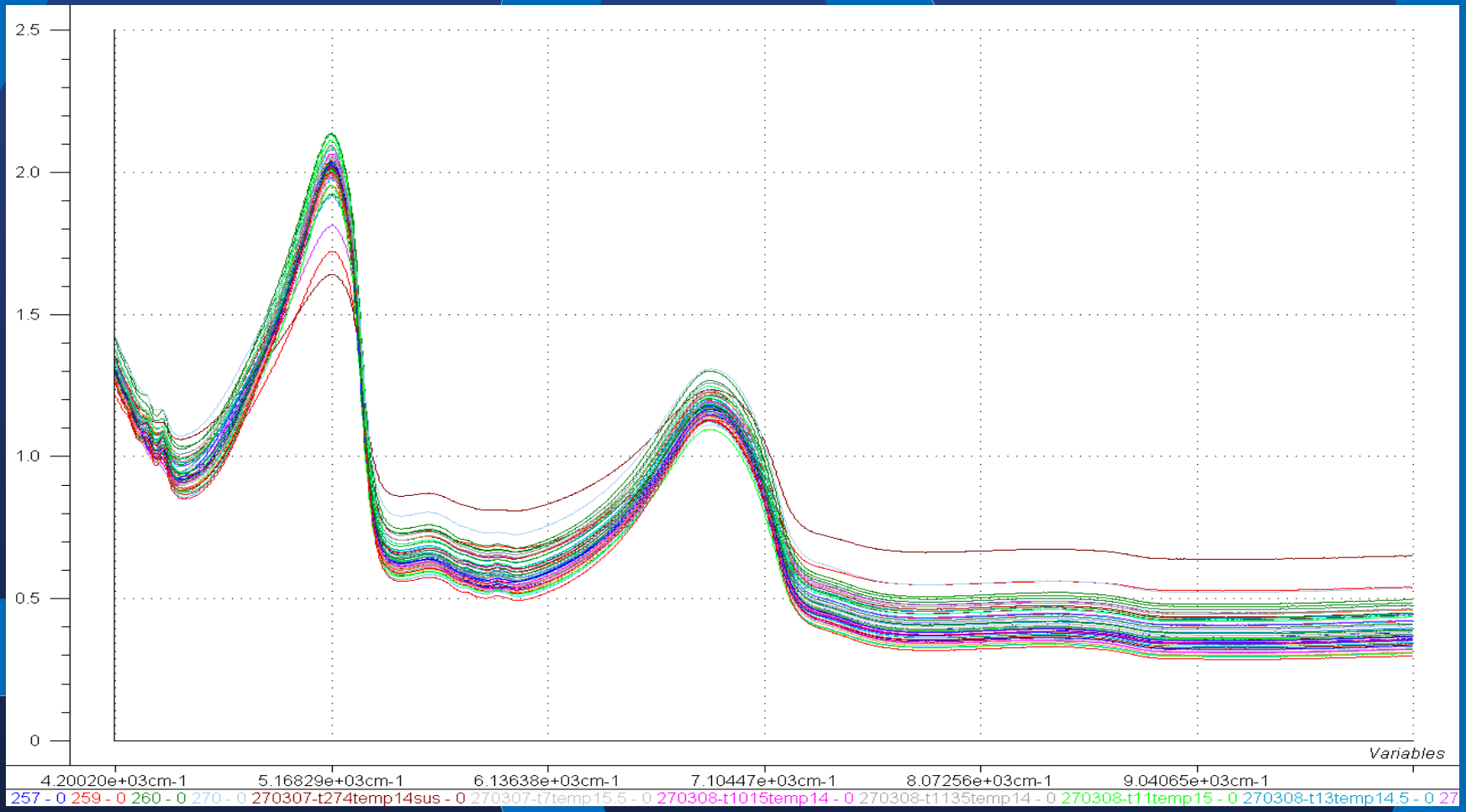


Source: Boulton (2005)

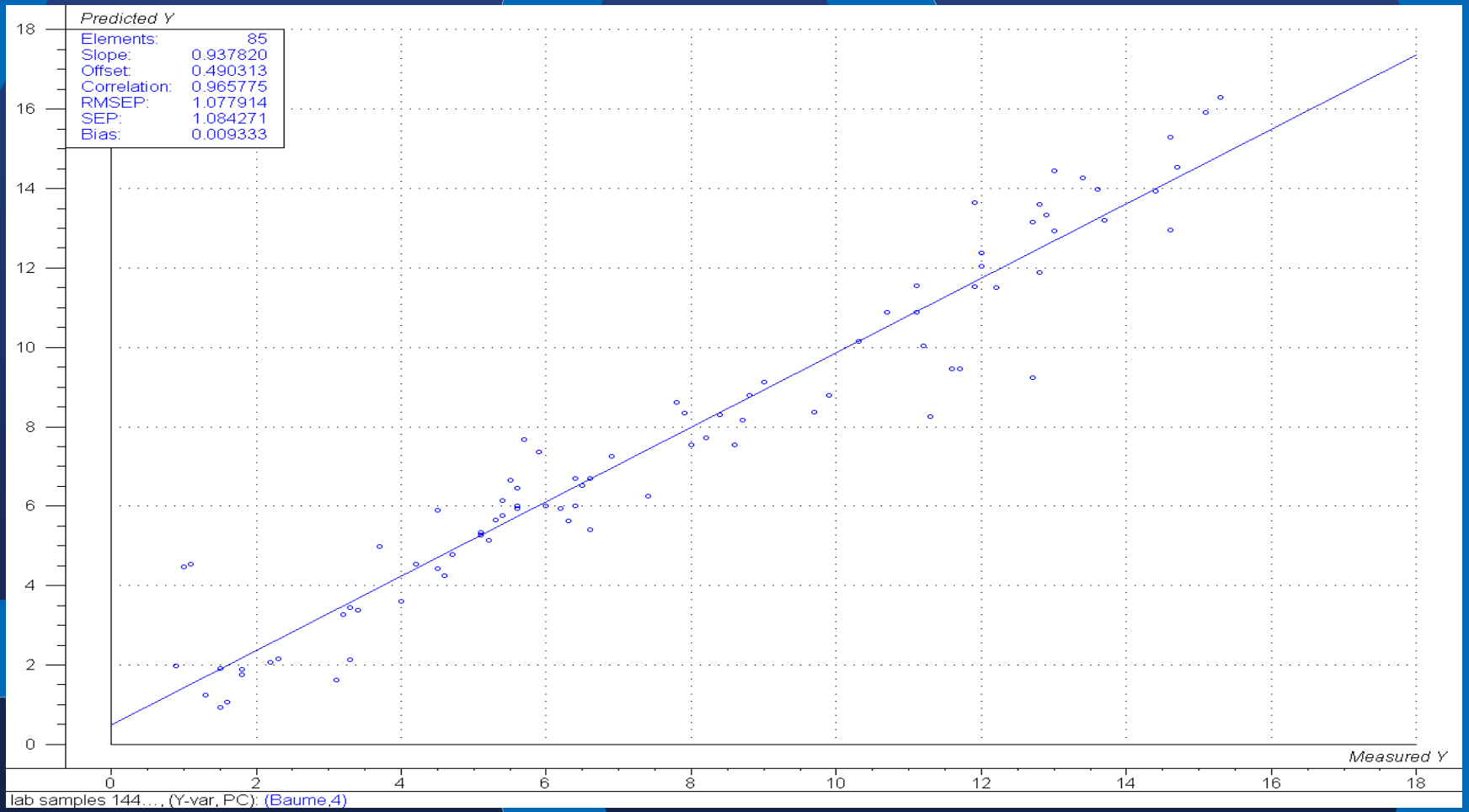
Instrumentation – NIR Spectroscopy

- Multiple fermentation parameters, including:
  - Baume, RS, YAN, TA, Colour, Tannin
- Proof of principle already demonstrated
  - Published studies: e.g. Cozzolino et al (2004)
  - 2008 AWRI Vintage trials with “At-line” probe
- New tool for winery technical staff to monitor ferment parameters to desired quality targets
- On-line real time data collection

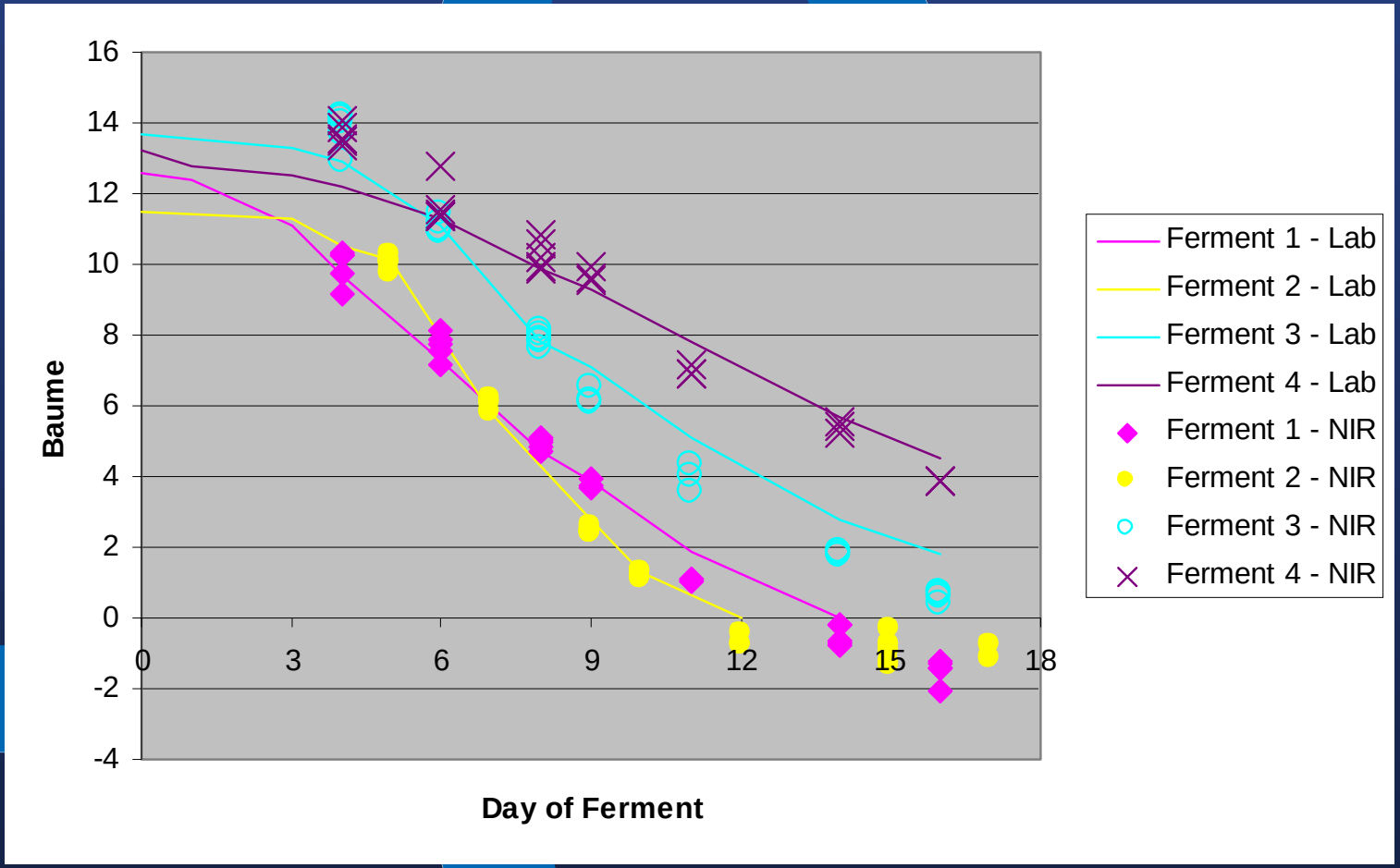
NIR – Ferment Spectra



NIR – Baume Parity Plot



NIR – Baume at tank centre (different tank depths) compared with sample port



NIR – Fermentation Progress by PCA

AWRI

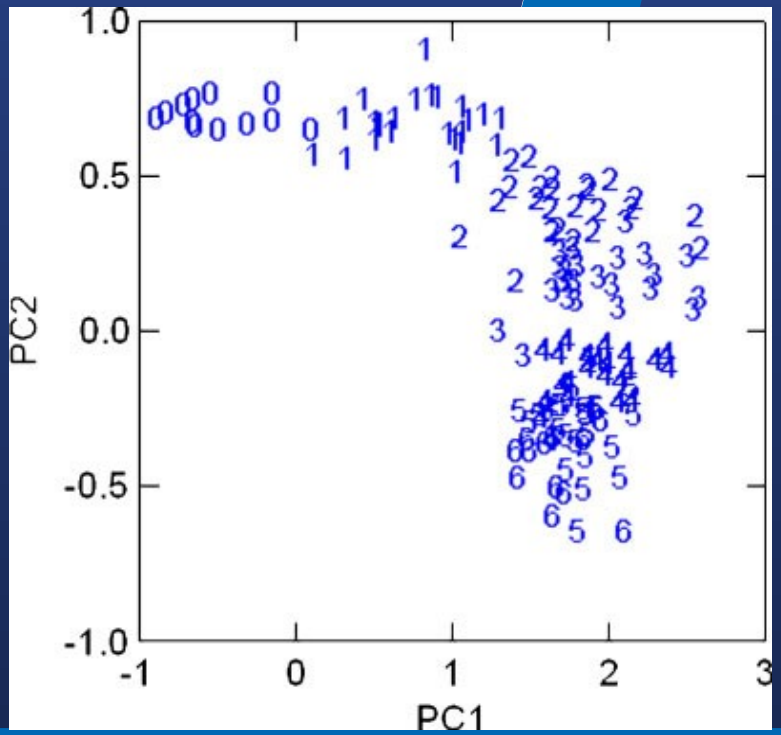


Figure 1

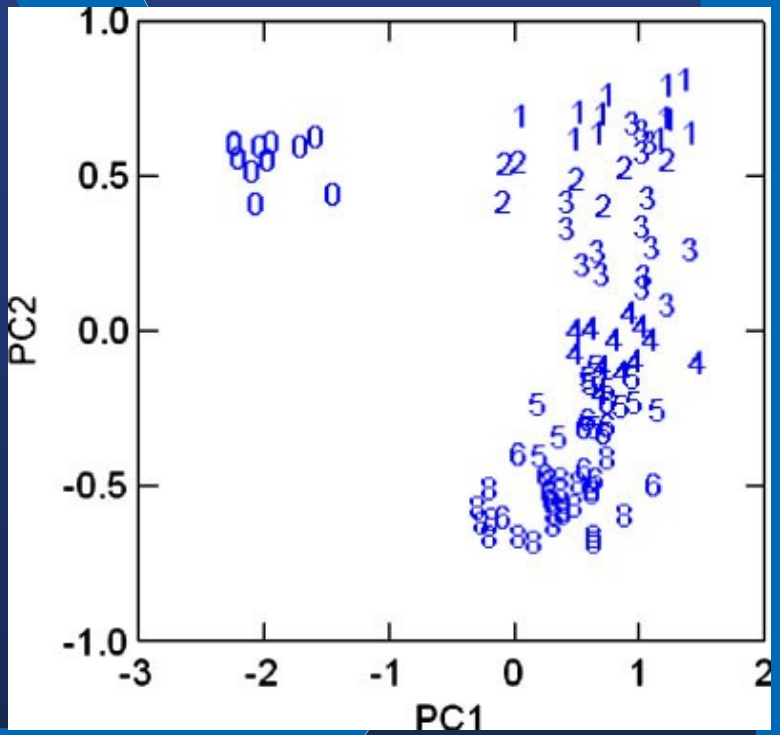


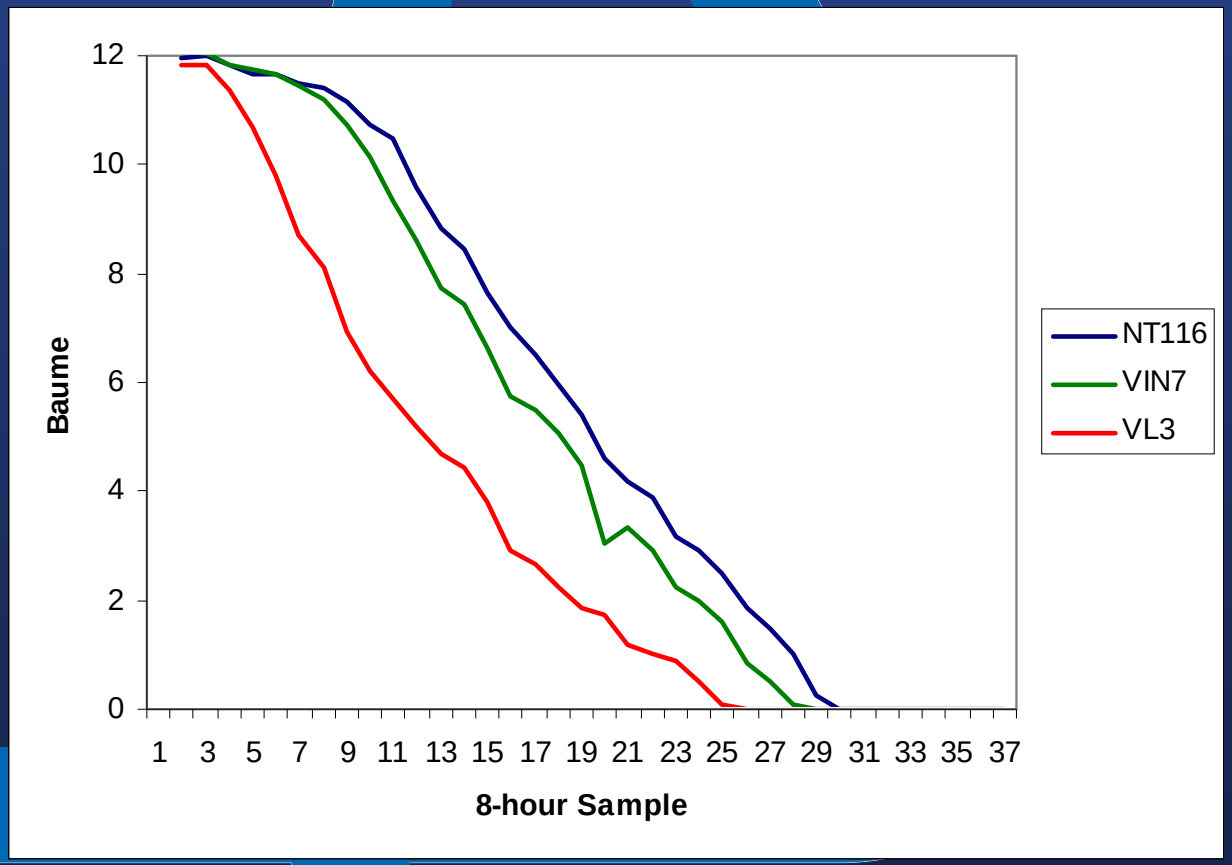
Figure 2

Fermentation progress of 2002 Cabernet Sauvignon (Fig 1) and Shiraz (Fig 2).

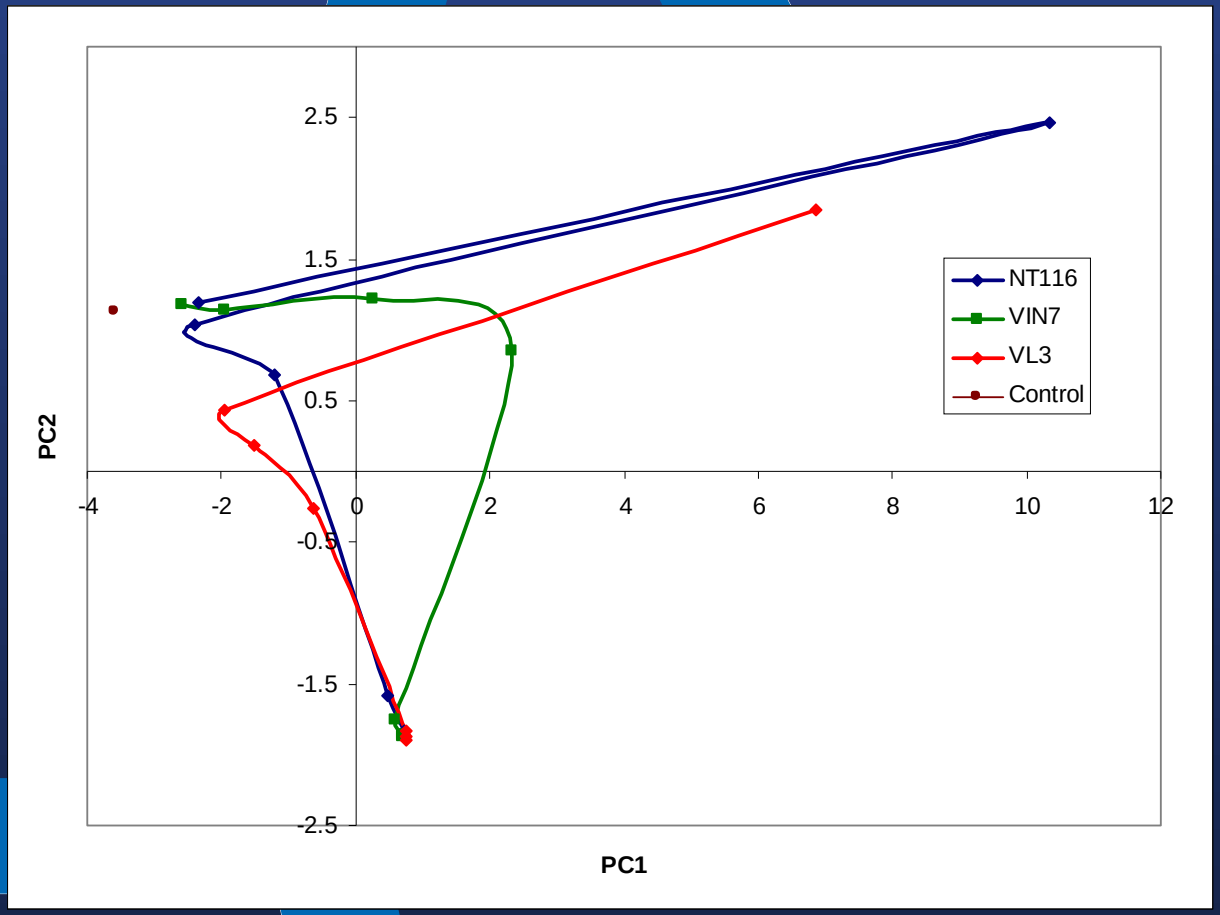
Source: Cozzolino et al (2006) DOI: 10.1002/bit.21067

NIR vs Baume for Ferment Monitoring

AWRI



NIR vs Baume for Ferment Monitoring



Principal Component Analysis of NIR spectra gives more "dimensionality" than plotting Baume alone.

Fermentor Design

- Mixing and Stratification
  - Temperature, Concentration
- AWRI - 2008 Fermentation Monitoring
  - For tanks observed, temperature and concentration relatively uniform in axial direction at tank centre
  - "Spot checks" on small scale tanks showed large radial variation at tank wall (*Boundary Layer*)
- AWRI - 2008 Fermentation Monitoring
  - Unbaffled tanks can be prone to "solid body" rotation, even with off-centre impellor
- Heat exchange efficiency ?
  - –5°C to –10°C brine required to maintain an average bulk tank temperature of ~15°C
  - On / off temperature control

Simulation Models

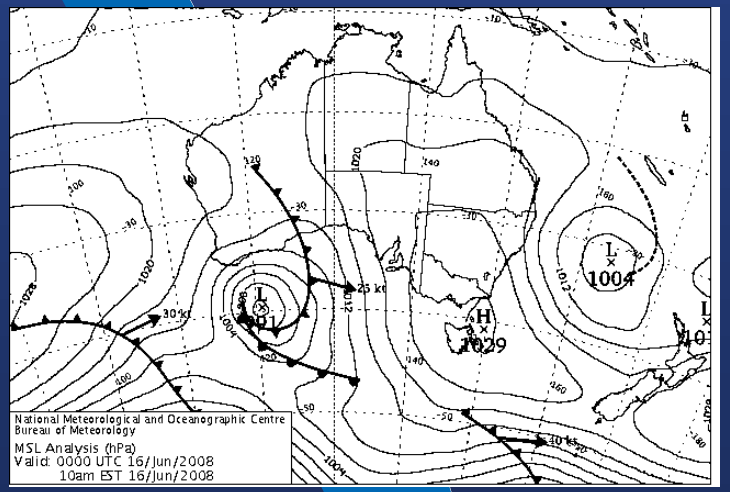
AWRI

- Various models in scientific literature for wine fermentation
  - E.g. Boulton (1980), Colombié (2005), Coleman (2007)
- Models assume perfect mixing and uniform conditions through vessel, and typically ignore hydro-dynamic effects
- Current research
  - Evaluation of models under various conditions for range of fermentor sizes
  - Prediction of future behaviour based on initial conditions and preliminary fermentation data

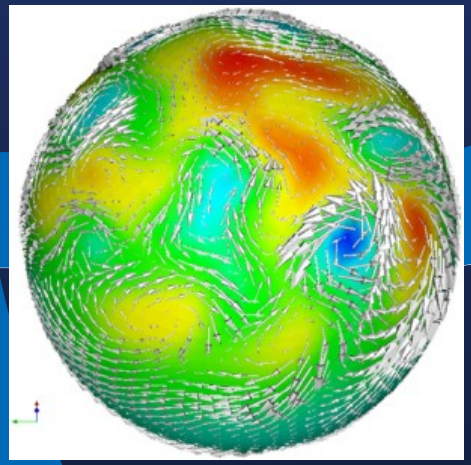
Looking to the Future

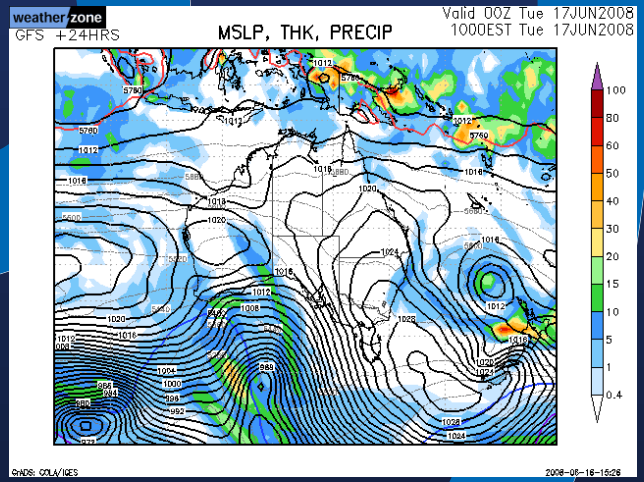
- Case study – Weather forecasting

Then: Data manually collected daily and charts plotted with pencil and paper



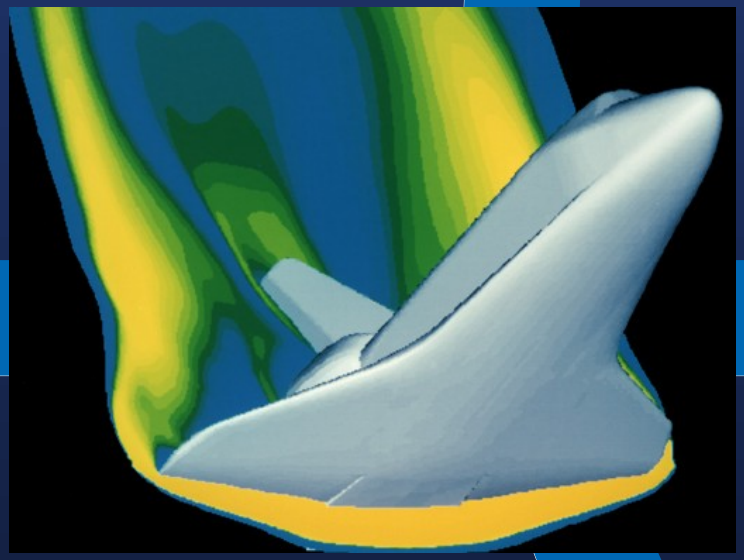
Now: Real-time multi parameter data collection with complex analysis using sophisticated models for prediction and adaptive learning

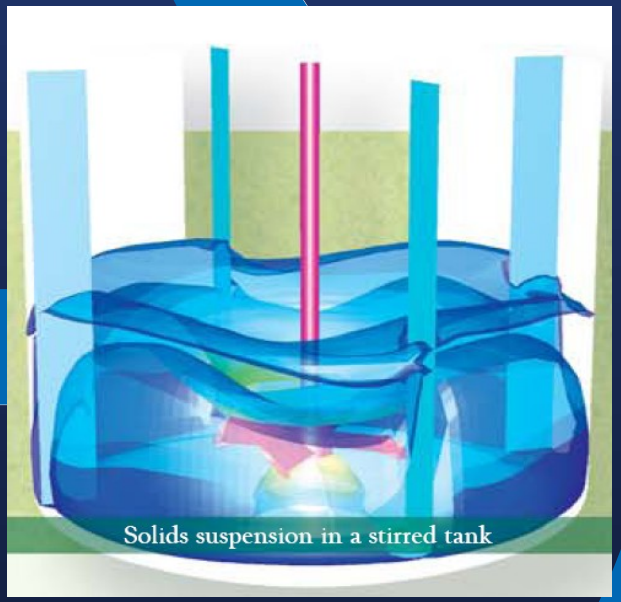




Looking to the Future

- Computational Fluid Dynamics (CFD) – originally developed for aerospace
- Combine with chemistry/microbiology kinetic models that scale from the laboratory to large commercial vessels, tailored to process constraints of facility in question





To recap the benefits of "Engineering Fermentation"

AWRI

- Reduced resource requirement for monitoring and operations control
- Improved ***real-time*** control of process to achieve quantified targets – e.g. residual sugar, colour development, tannin
  - "Proof of principle" for multi-parameter monitoring with NIR has been demonstrated
- Robust simulation models combined with robust instrumentation, to identify and predict problem fermentation behaviour – to reduce instances of slow/stuck ferments

Information ✦ knowledge → action

Acknowledgements

AWRI Industry Applications Team

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