Traditional and Alternative Fermentation Techniques

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The Absolutes of Fermentation

- **1)**

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- **2) See rule number #1**

The Non-Absolutes of Fermentation

- **Why no absolutes?**
  - Difference between ale, lager and other yeasts
  - Differences between yeasts in in the same family
    - Not all lager behave the same and not all ales etc.
  - Absolutes don't indicate degree of impact
  - Other variables are not the same as the one reference
    - Estery yeast or low ester yeast?
    - Fermenting standard gravity or ferment high gravity?
    - Low attenuation or highly attenuated beer?
    - Standard fermentation rate or rapid?
    - Yeast flocculation characteristics of particular yeast?
    - The inherent genetic stability of a strain?
    - Fermentation more complex than one parameter causing one result

Fermentation Good Practices - Temperature

- **fermentor full temperature should be a degree below fermentation temperature**
- **This prevents cooling coming on before fermentation is vigorous**
  - Early cooling creates localized temperature gradients before fermentation is robust
  - Early cooling can shock yeast
  - Early cooling can prolong fermentation

Fermentation Good Practices – Fill Time

- **Long fermentor fill times should be avoided**
  - Track and control hours from yeast/oxygen addition to fermentor fill as a critical control parameter
  - Depending on aeration/oxygenation rates and fill frequencies yeast can move in and out of anaerobic condition
  - Yeast growth can be excessive
  - Stratification of tank can become an issue
- **If long fill times cannot be avoided then:**
  - Aerate instead of oxygenation to aid in mixing
  - Don’t add yeast on early brews
  - Always aerate the final brew

fermentor Fills

- **Fill number maximum typical 4 brews single brew lane or 8 brews for double brew lanes**
  - Single brew lane fills every 2hrs – Total time 4 brews = 8hrs
  - Double brew lanes fill every 1hrs – Total time 8 brews = 8hrs

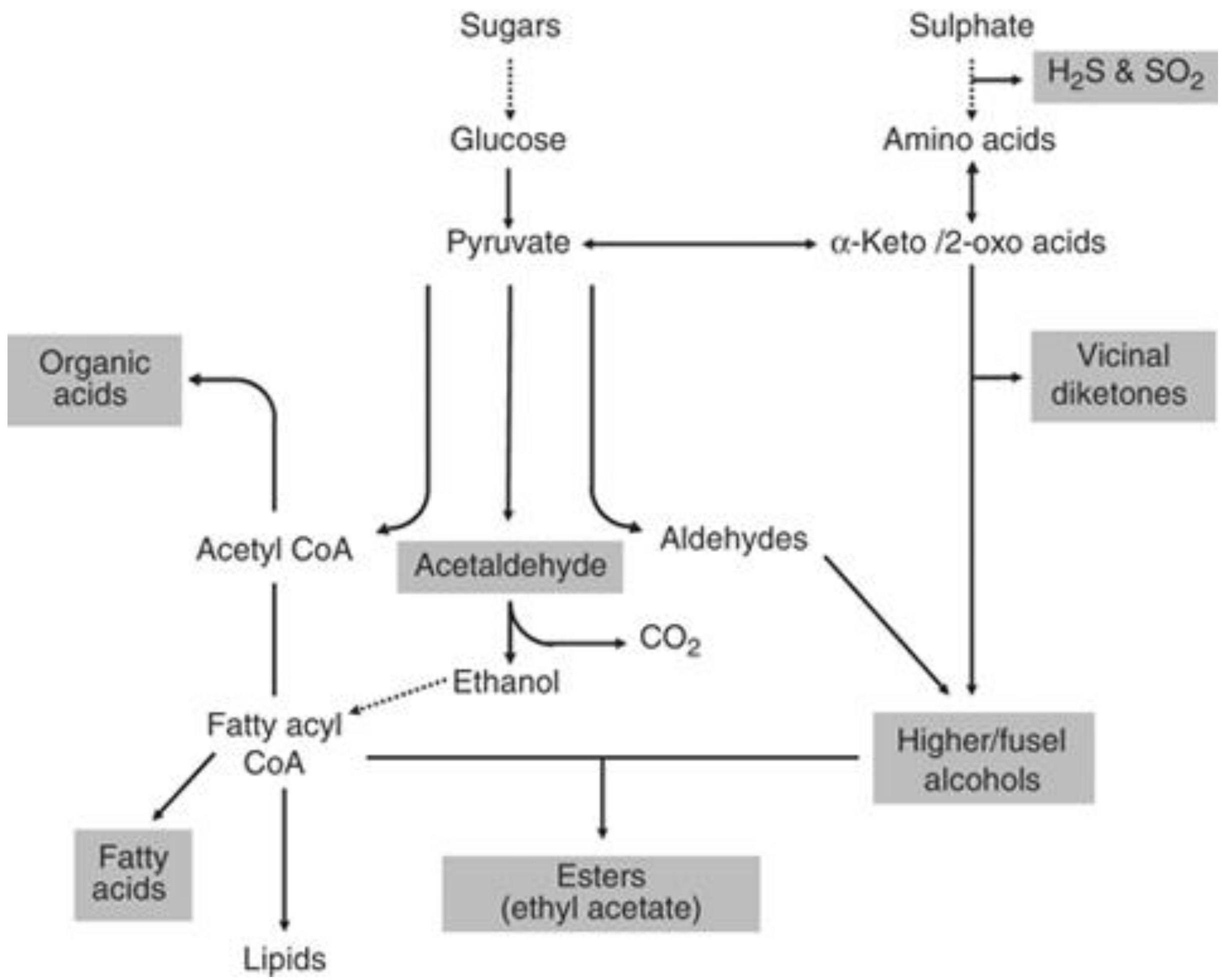
Fermentation Good Practices

- **Avoid growing too much yeast**
- **Typical peak cell count is 80 – 100 million cells/ml depending on original gravity**
  - Greater peak cell counts can lead to loss of beer yield
  - Greater peak cell counts can lead to autolysing yeast if not removed mechanically
  - Greater peak cell counts can lead to greater peak diacetyl
    - Use of FAN beyond valine produces more diacetyl
  - Greater peak cell counts can lead to poor yeast health in beers brewed with higher proportions of adjuncts

Fermentation Good Practices

- **Avoid high hydrostatic pressures**
  - Some yeast sensitive to CO_2 in solution
  - Large tank ratios 2:1 Height to Diameter max
  - Greater the pressure then lower the ester formation
- **Avoid temperature shocking yeast**
  - Gentle cooling preferably with proportional control valves
  - 1 degree per hour cooling programs
- **Final cooling of fermentor should be based on VDK analysis**
  - Never adjust attenuation level through cooling instead fermentability needs to be controlled through mashing scheme

Yeast Metabolism and Flavor Active Compounds



FEMS Yeast Research
Volume 8, Issue 7, pages 1018-1036, 15 SEP 2008 DOI: 10.1111/j.1567-1364.2008.00433.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1567-1364.2008.00433.x/full#f3

General Fermentation Schemes

Perhaps the first photograph of men drinking beer, circa 1844 in Scotland, by Hill & Adamson

General Fermentation Schemes – 2 Vessel

- **Traditional approach is 2 vessel fermentation**
- **Ferment 80 – 90% of extract and then transfer to a second vessel**
- **Advantages:**
  - re-suspend yeast for finishing beer more quickly
  - blending opportunities
  - greater throughput for initial vessel
  - Maximize tank capacity of second vessel
- **Disadvantages:**
  - Additional transfer and losses, additional utilities to support secondary tanks

General Fermentation Schemes – 2 Vessel with Krausening

- **Similar to the two vessel system but with fresh wort added**
- **What is krausening?**
  - Add fresh wort at a rate of 10-20% and typically fresh yeast and air/oxygen when 80% of fermentation is complete
  - Fresh wort, yeast and air/oxygen is added at time of transfer of primary fermentor
- **Why krausen?**
  - Fresh wort and yeast re-invigorates fermentation to help drive completion of the fermentation and VDK reduction in a shorter amount of time
  - Good for yeasts that tend to settle out

General Fermentation Schemes – 2 Vessel with Krausening

- **Advantages**
  - Faster fermentation
- **Disadvantages**
  - Added complexity
  - The krausen brews need to be planned for addition at the right time
    - Possibility of a wort holding tank
  - Added risk of microbiological contamination
  - Vessel utilization is lower as freeboard is needed in second vessel

General Fermentation Schemes – Conical fermentor Two Vessel System

- **A conical fermentor is a vertical fermentor with a cone that allows cone collecting yeast (AKA Cylindro Conical Vessel CCV)**
- **It can be used as a two vessel system**
- **Advantages**
  - Same as two vessel system already described
  - Additionally yeast harvest can be collected from cone avoiding stress of centrifuge collection
  - Yeast can be collected earlier in process so presumably healthier
  - If used as only primary fermenting vessel does not need to be pressure rated
- **Disadvantages**
  - Same as two vessel system already described
  - Need flocculent yeast

General Fermentation Schemes – Conical fermentor Single Vessel System

- **More recent approach is to use a single vessel for fermentation and maturation (also known as Uni-Tank)**
- **Ferment all extract, reduce VDK's, settle/collect yeast and age beer all in one tank**
  - Advantages
    - Less tank movements and loses
    - Less CIP's
    - Lower contamination risk
    - Multiple yeast removals lowering downstream loading
  - Disadvantages
    - Lower capacity utilization
    - Limited to flocculent yeast varieties
    - Vessels are more expensive (need pressure rated vessels)
    - Lower downstream blending opurtunities

Lager Fermentation

Traditional Lager Fermentation

- **Cool in at 6-7C (43-45F) and free rise to 9C (48F)**
  - Hold until entire fermentation is complete
  - Primary 6-8 days but secondary can be an additional 14 days or longer
- **Advantages**
  - Reduced higher alcohol production
  - Reduced ester production
  - Reduced protease activity so better head retention in final beer
- **Disadvantages**
  - Slow

“Warmer” Lager Fermentations

- **Cool in at 9C (48F) and free rise to 11C (52F)**
  - Hold until entire fermentation is complete
  - Primary 6-8 days but secondary can be an additional 10 days or longer
- **Advantages**
  - Lower higher alcohol production
  - Lower ester production
  - Lower protease activity so better head retention in final beer
  - Slightly faster
- **Disadvantages**

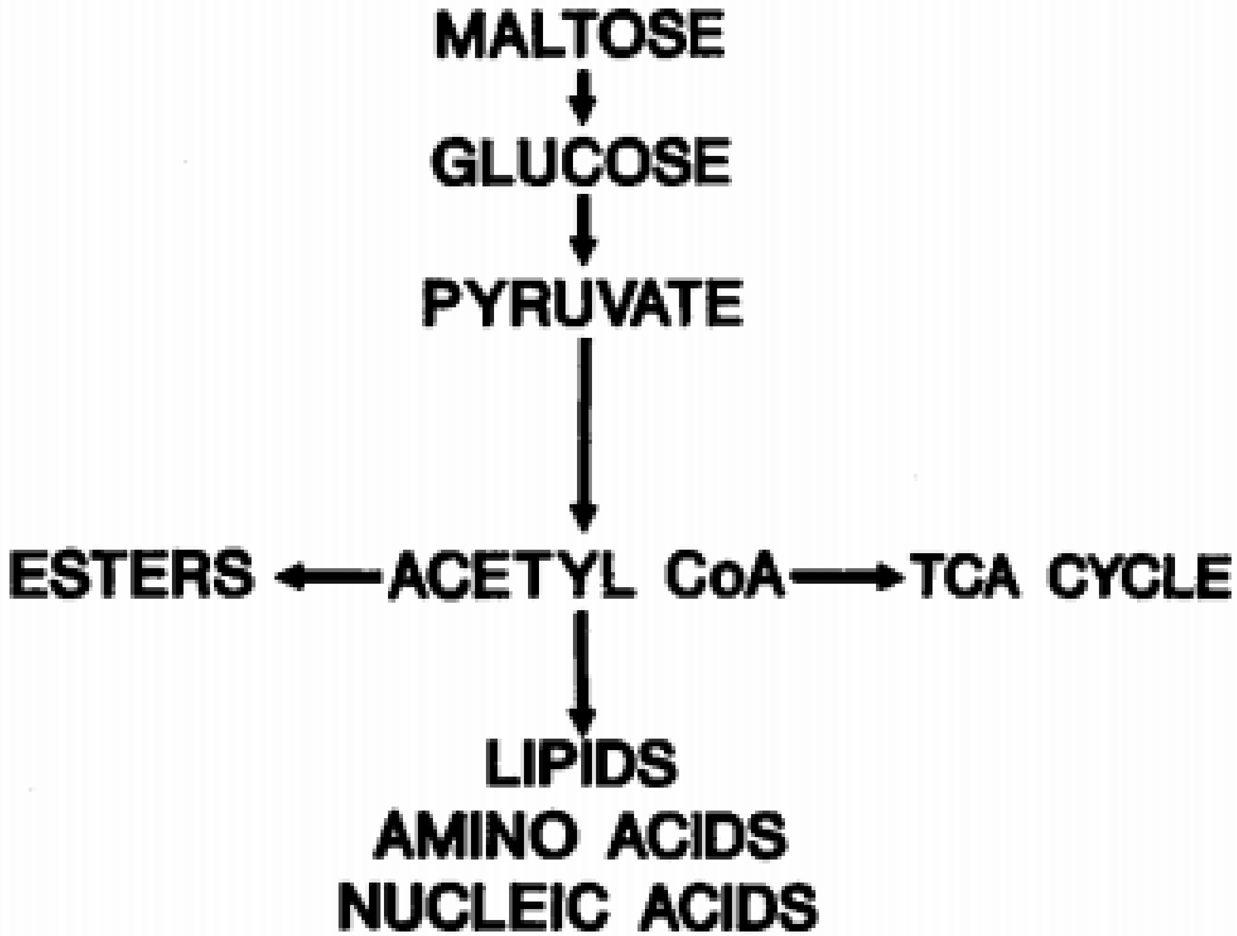
“Warmer” Lager Fermentations

- **Cool in at 9C (48F) and free rise to 11C (52F)**
  - Hold until entire fermentation is complete
  - Primary 6-8 days but secondary can be an additional 10 days or longer
- **Advantages**
  - Lower higher alcohol production
  - Lower ester production
  - Lower protease activity so better head retention in final beer
  - Slightly faster
- **Disadvantages**
  - **Still slow**

Rapid Lager Fermentation

- **Push lager fermentation to fastest possible rate while maintaining sensory profile and yeast health**
- **Esters are formed during yeast growth phase and set at peak cell count**
- **Concept is to allow fermentation to warm after peak cell count**
- **Free rise fermentations allow for rapid reduction of diacetyl to acetoin**

Rapid Lager Fermentation



J. Inst. Brew., September-October, 1990, Vol. 96, pp. 327-331
ESTER FORMATION IN BREWERY FERMENTATIONS
By Hilary A. B. Peddie

Rapid Lager Fermentation

- **Starting temperature = ?**
  - Depends of ester profile, yeast and sensory match to be achieved
- **Free rise initiation = end of cell growth**
- **Free rise temperature = ?**
  - Temperature depends on yeast strain and ability to handle fermentation at higher temperatures
- **Cooling on at end of fermentation**
  - Typically when VDK is in specification

Rapid Lager Fermentation

- **Advantages**
  - Faster overall fermentation time
  - Better vessel utilization
- **Disadvantages**
  - Greater foaming and need for lower percentage fills of fermentor or anti-foams to maintain fill levels
  - More stressful on yeast but yeast dependent
  - Protease enzyme is more active at warmer temperatures and can reduce foam stability in the final beer.

Ale Fermentation

Ale Fermentations

- **Typical ale fermentations 1million cells/ml per degree plato**
- **Oxygen requirement tends to be lower than lagers**
- **~0.75ppm oxygen per degree plato**
  - i.e standard 12 plato is 9ppm
  - i.e. high gravity wort at 17.5 plato 13ppm
- **Typical ale starts warmer than lager and free rises to a warmer temperature**
  - Typical starting is 18 - 19C (64 - 66)
  - Typical free rise is 20C (68 F)

Ale Fermentations

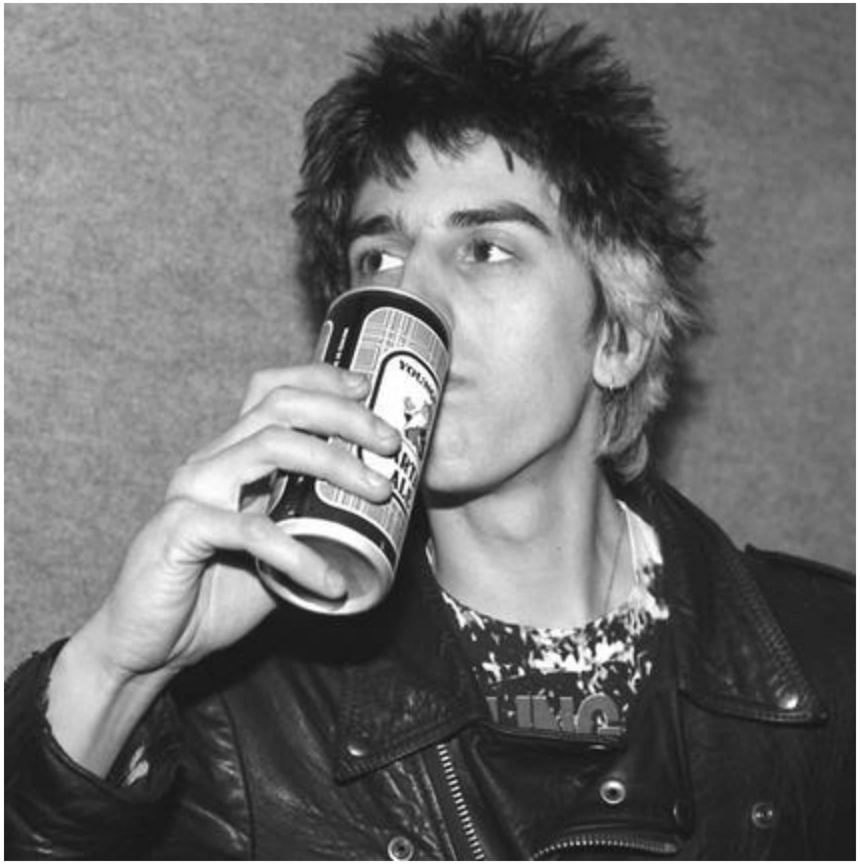
- **Ales tend to be flocculent**
- **Keeping yeast in suspension can be a challenge with some yeasts**
  - Lower yeast in suspension at the end of fermentation the slower the diacetyl reduction is
- **Opportunity for a two vessel system to help rouse the yeast**
- **For open vessel fermentations rousing goosenecks can be used to help re-suspend yeast**
- **Some ales are top cropping others are bottom cropping**
  - Bottom cropping can be collected the same as lager
  - Top cropping yeasts need to be collected from the top of the vessel either with scoops or funnel device

Ale Fermentations

Yorkshire Squares

- **Two floored vessel to aid in top cropping yeast**

So Bring on the Alternative!



Burton Union System

Continuous Fermentation

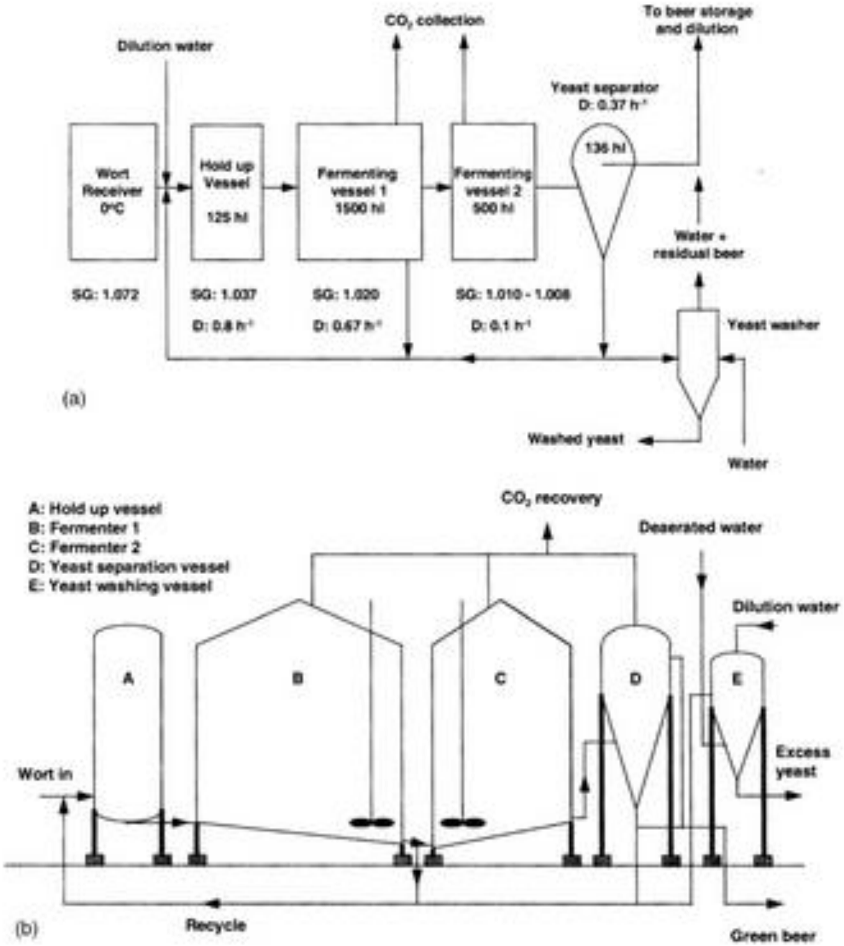


Fig. 5.35 Coutts system of continuous fermentation. (a) Diagrammatic. (b) Schematic of Auckland Brewery continuous plant (from Dunbar *et al.*, 1988).

Alternative Aeration Timing

- **Testing of VHG 22 Plato worts found it is better to oxygenate 12hrs after pitching wort with yeast rather than at time of filling**
  - 33% reduction in fermentation time with good VDK & ester results
- **Oxygen levels reached = 25ppm through fermentor oxygenation**
  - Inline only capable of 9ppm

J. Inst. Brew. 113(2), 168–184, 2007
The Combined Effects of Oxygen Supply Strategy, Inoculum Size and Temperature Profile on Very-High-Gravity Beer Fermentation by *Saccharomyces cerevisiae* *By Heather Jones*

Fermentation Good Practices- <u>Alternative</u> Aeration Timing

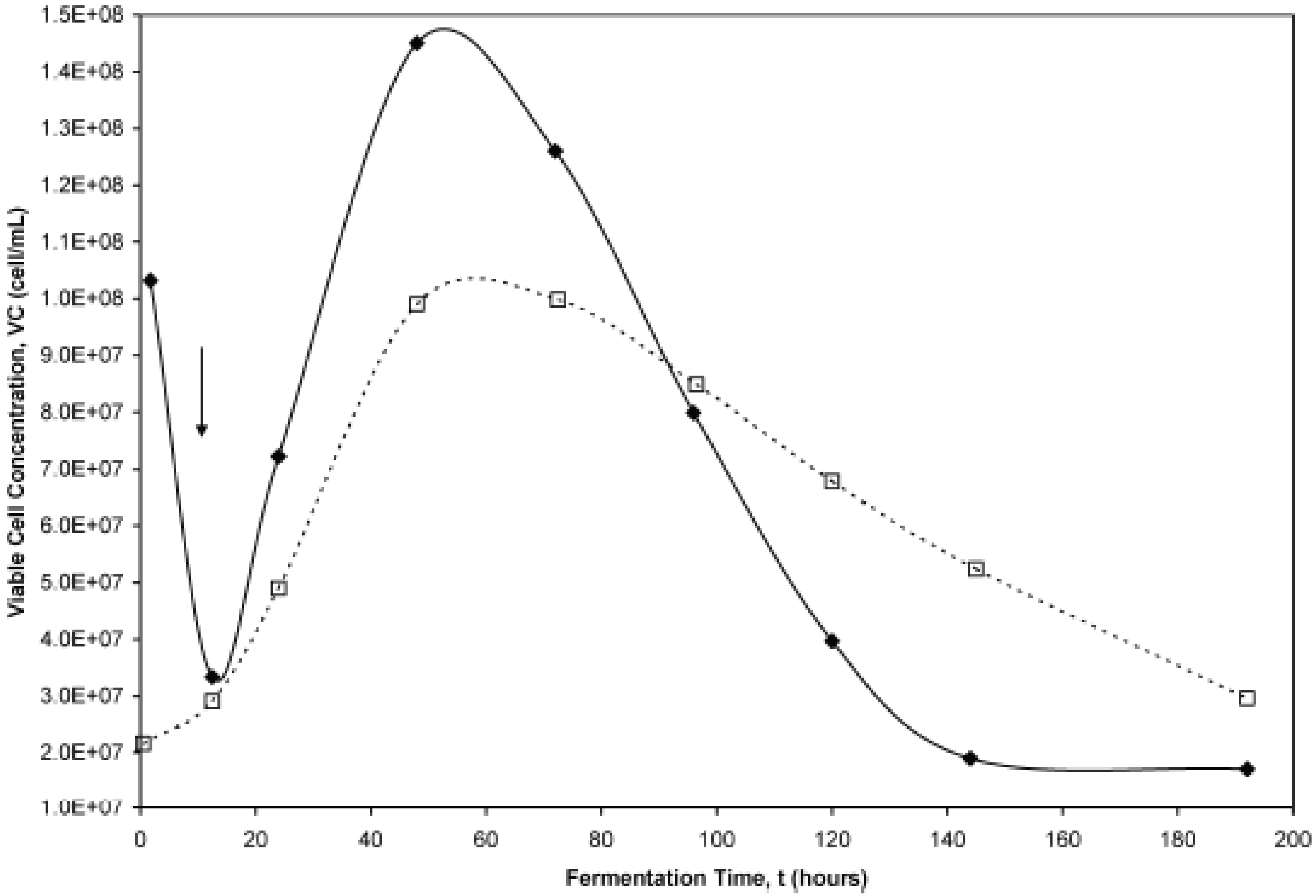


Fig. 6. Viable cell concentration profile comparisons for the third successive fermentation of pilot-scale trials conducted with strain LCC 2034 in 22°P wort. □ = Control process parameters (inoculation rate = 2.2×10^7 cell/mL; oxygen delivery strategy = 22 ppm DO prior to inoculation; temperature profile = 14.5°C then increased to 20°C at 48 h post-inoculation); ◆ = Optimized process parameters (inoculation rate = 3.08×10^7 cell/mL; oxygen delivery strategy = 25 ppm DO prior to inoculation; temperature profile = 14.5°C then increased to 21°C at 35 h post-inoculation). Arrow denotes dilution of fermenting wort with oxygenated wort at 12 h post-inoculation.

Closing

- **Thanks to:**
  - All brewers that contribute and share knowledge of the art and science of brewing
  - MBAA
  - Anheuser-Busch for their support in presenting today

Thank You