Effect of Yeast Propagation Methods on Fermentation Efficiency

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Ethanol Technology

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Objective of Propagation

To supply yeast at correct time into the fermentor with the following properties:

- Adequate numbers/ml
- High viability
- High vitality
- Low contamination
- Log growth phase
Growth phases of yeast in propagator

Generic Yeast Growth

- **Lag**
- **Log**
- **Stationary**

**Yeast count**

**Hours**

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12

**cells/ml (million)**

- 0
- 50
- 100
- 150
- 200
- 250
- 300
- 350
- 400
- 450
- 500
In-plant yeast propagation is NEVER completely successful!!

Typical Goals:
- Increase yeast cell numbers in-house
- Reduce lag times
- Increase fermentation rates
- Decrease overall fermentation times

True ‘Propagation’ Requires Pure Yeast Culture, Low Carbohydrate, High Oxygen
- Pure yeast culture not available in commercial quantities (cost prohibitive)
- Requires specialized equipment and expertise

Best left to yeast production plant
Continuous Fermentation

Special case – Only two options

1. Prefermentor – with or without refreshing of yeast
2. Yeast recycle – some minor options within process

Prefermentor – commonly used in continuous processes where fermenters contain high levels of solids (e.g. grain solids)

Yeast recycle – commonly used in continuous processes where fermenters have low levels of solids (e.g. sugar / molasses utilization)

Both these processes have very similar pros & cons
Continuous Propagation

Saccharification

Equal flow out of propagator

Continuous flow

1/4th of mash flow

Air injection

Propagator

Fermentor

Fermentor
Continuous Fermentation Yeast Recycle

Saccharification →

Yeast slurry → Fermentor → Fermentor → Fermentor → Beerwell

Centrifuge

Beer feed → Distillation

Ethanol Technology Institute
<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
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<tbody>
<tr>
<td>Minimal cleaning</td>
<td>Steady state of yeast to mash feed</td>
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<tr>
<td>High cell count</td>
<td>Yeast forced into stationary phase (low budding)</td>
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<td>Minimal yeast usage</td>
<td>Depletion of sterols &amp; unsaturated fatty acids</td>
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<td>Easily automated</td>
<td>High potential for yeast mutation</td>
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<td>High risk of bacterial infection</td>
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<td>High risk of selection of fast growing bacteria or wild yeasts</td>
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<td>Difficult to clean</td>
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<td>Very high stress on yeast in fermenter train due to steady state</td>
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<td>Lower alcohol limit on system</td>
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Types of in-plant Yeast handling

Types of propagation options for **batch** fermentation

- Continuous propagation
- Semi-continuous propagation
- Multiple batch propagation
- Single batch propagation
- Rehydration only – direct pitch
- Direct pitch
Continuous Process Flows

- Liquefaction / Cook
- Continuous flow
  - 1/10th of mash flow
- Propagator
- Equal flow out of propagator
- Fermentor
- Air injection
Continuous Propagation

Propagator maintains level & yeast count

Flow in matches flow out

Feed to fermentor throughout fill time

100% yeast in fermentor at 100% fill
Semi-Continuous Process Flows

Liquefaction / Cook

Continuous flow
1/10th of mash flow

Air injection

Propagator

Variable flow out of propagator

Fermentor
Semi Continuous Propagation

Propagator maintains yeast count

Slug dose at start of fill (4%)

Feed to fermentor throughout fill time once propagator regains level

100% yeast in ferm at 100% fill
Multiple Batch Process Flows

Liquefaction / Cook

Continuous flow
1/10th of mash flow

Air injection

Variable flow out of propagator

Fermentor

Propagator
Yeast count increases following dilution

Slug dose at start of fill (4%) & possibly 40-50%

Feed to propagator is fast fill & stop

100% yeast in fermentor at 50% fill
Single Batch Process Flows

Liquefaction / Cook

Variable flow – fast fill of propagator

Propagator

Variable flow out of propagator

Fermentor

Air injection
Yeast count increases following dilution

Propagator emptied at start of fill (4%)

Feed to propagator is fast fill & stop

100% yeast in fermentor at 5% fill

Ability to optimize propagator time
Propagation Optimization

Lag

Log

Stationary

Yeast Count

Budding

Time
Direct Pitch

Liquefaction / Cook

Calculated yeast dose

Fermenter

Yeast Tote

Rinse / CIP

Flow
100% yeast in at start of fermentor fill

Requires higher yeast dose

Ability to optimize dose & time of addition easily
<table>
<thead>
<tr>
<th>Pros &amp; cons (Batch fermentation systems)</th>
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<tbody>
<tr>
<td><strong>Continuous</strong></td>
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<tr>
<td>Cell Numbers at start</td>
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<tr>
<td>Sterol reserve</td>
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Yeast volume at start
Cell count 410 million
Volume 64,260 litre

Total feed = 90 litres / min

Yeast doubling time = 2.5 hours

Yeast volume after 2.5 hours
Cell count 410 million
Volume 77,800 litre

Assuming the original cells double, & the final volume increased by 13,400 L
the theoretical cell count should be 676 million

Is Stationary phase forced?

Dilution Effect

26,346,000,000,000,000 cells

31,925,880,000,000,000 cells
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Offset of full yeast cost?

Value of alcohol in fermenter?
- $2,000,000 \times 17\%(\text{v/v}) = 340,000 \text{ litre}$
- $340,000 \times € 0.49 = € 166,600$

€ 500.00 equivalent = $500 / 0.49 = 1020 \text{ litres}$

Alcohol required to achieve break-even
- \[
\frac{(340,000+1020)}{2,000,000}
\]
- \[
\frac{340,836}{2,000,000} = 0.1704 = 17.05\%
\]
Single Batch - Cons

Increased yeast cost?
  - Equates to €0.0015 per litre

Increased cleaning
  - Simple - Gives improved hygiene performance
Single Batch - Cons

Increased handling
- Does require increase in operator handling
- Amount depends on previous system

Lag/rehydration phase at beginning
- Design good SOPs to allow a hydration step & to reduce lag effect
- Or use fresh yeast (Thermosacc / Liquid Yeast) which has no rehydration required & has short lag
- Or increase yeast food to get faster growth and metabolism resulting in increased numbers
### Pros & cons (Batch fermentation systems)

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- No lag phase in growth observed
- Yeast growth slower and stages down over time (2.6 to 5.5 to 7.8 hr⁻¹)
- Higher yeast counts obtained
- Stationary phase reached (this test)
- Dry yeast used in propagator
- Lag phase in growth observed
- Yeast growth very rapid (<1.2hr\(^{-1}\))
Mash Density vs ethanol at drop

Mash Density

% Alcohol w/v at drop

Continuous • Single ▲ Single

Actual Plant Data

Kurt Kohler, 2004
Value to a ethanol plant

• On a daily basis a 190 million litre plant will realize increased alcohol production of approximately 17,000 litres

• Which at a price of €0.49/litre would net an extra revenue of €8,330 or €2.85 million per annum

• Some US plants achieving 20% v/v using very high gravity (VHG) fermentations

Converted from Kurt Kohler, 2004
Objective of Propagation

To supply yeast at correct time into the fermentor with the following properties

- Adequate numbers/ml
- High viability
- High vitality
- Low contamination
- Log growth phase
## Comparison of systems

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<th>High Viability</th>
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<th>Log phase</th>
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Conclusions

Consider your production needs when selecting your system (Continuous / Batch / Direct)
Consider your choice of yeast forms (Fresh vs. ADY)
Select the system and the yeast that will allow you to achieve your original objectives
Remember it is the yeast that makes your yield
Effective yeast management will enhance your profits