# Fermentation Management

The Alcohol School Concise

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WIRSPA

West Indies Rum & Spirits Producers' Association Inc.

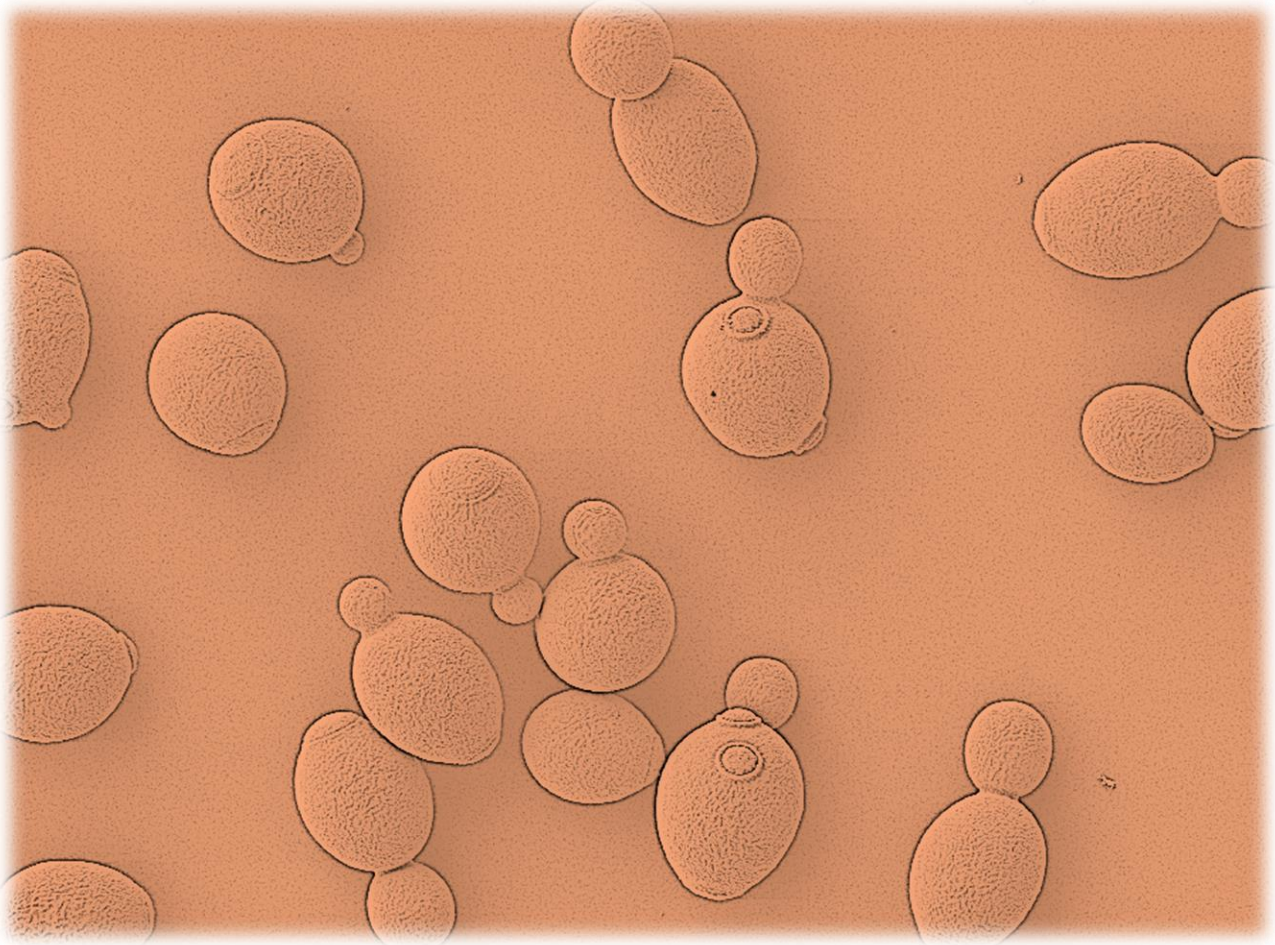
Ethanol Technology Institute

Place: Caribbean Distilling Seminar, St Lucia

Date: April 17th, 2024

# Presentation Overview

- Why are we talking about Fermentation Management and how do we do it?
- Tailoring Processes for Yeast Success:
  - Contamination and pH
  - Yeast choices based on their characteristics
  - Osmotic pressure and very stressful environments
- Putting everything together into a case study



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# The Yeast is Queen

**Yeast is critical to the production of ethanol and flavor.**

**Yeast is alive: Understanding your yeast**, its physiology, and how to optimize the environment, **is essential for optimal ethanol production.**

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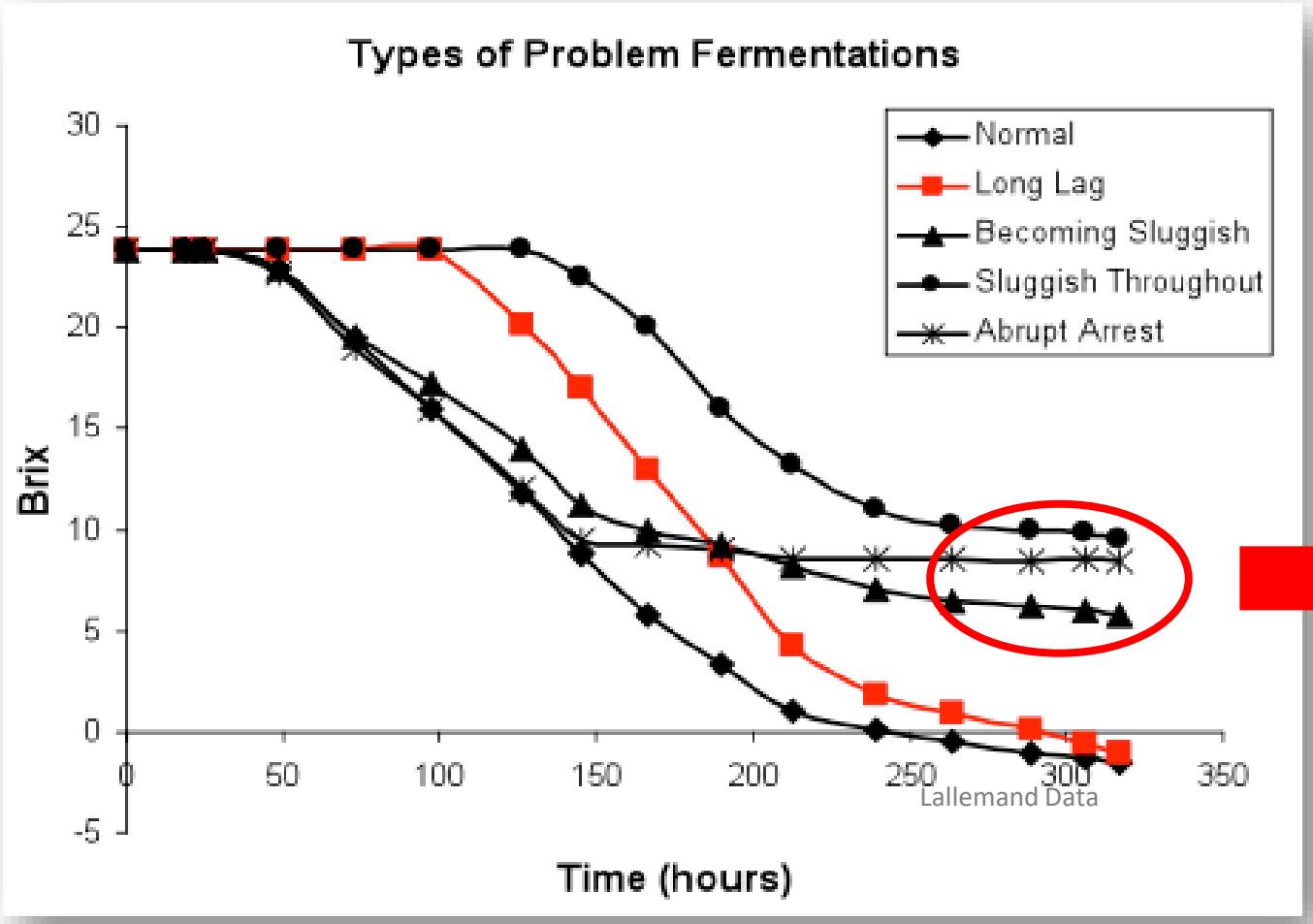
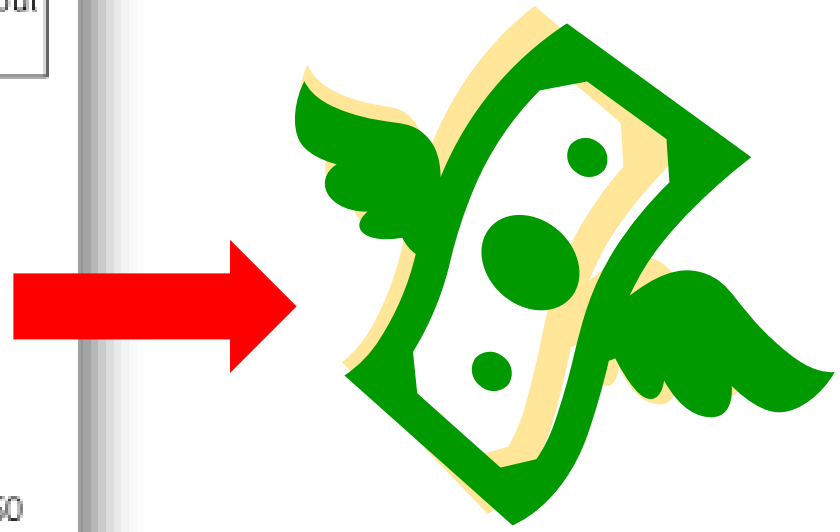
# Impacts of Poor Fermentation Management



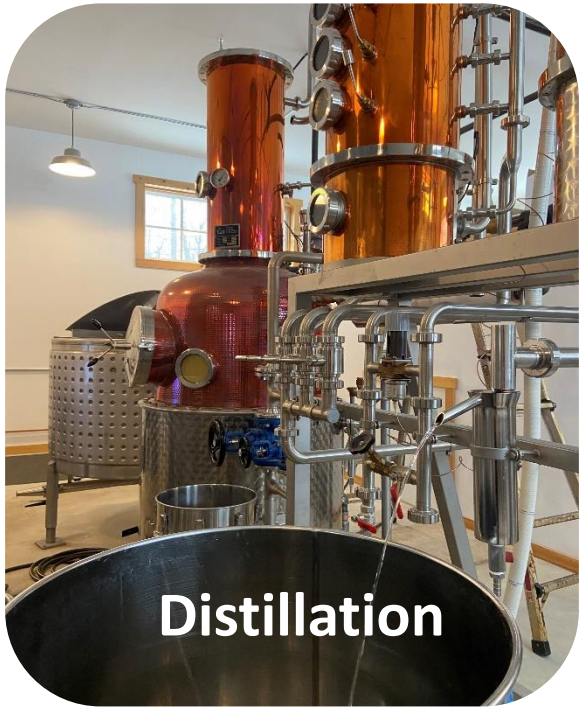



# Yield = A KPI for Everyone

**Yield** – How much “Product” we get from the “Inputs”


Starch → Sugar


Sugar → Ethanol




Recovery

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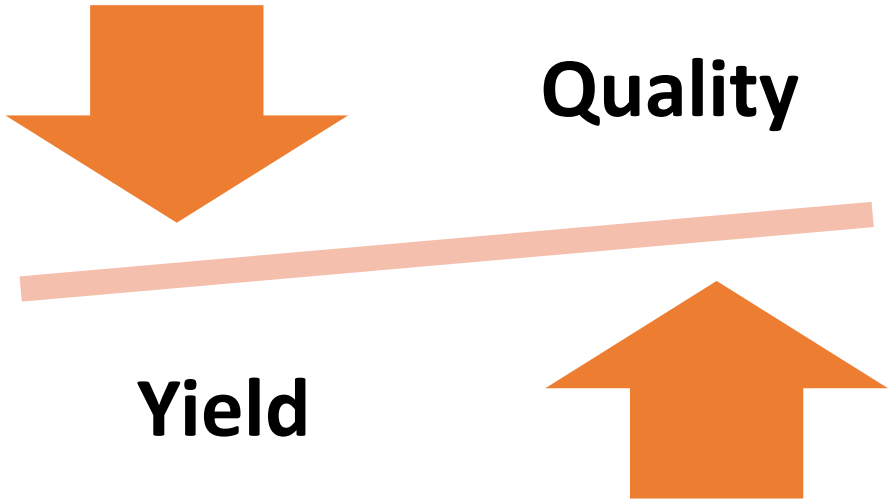
# Why Do We Need to Calculate Our Yields?

How efficiently do we work? What is the impact on the quality of the spirit?

Room for improvements

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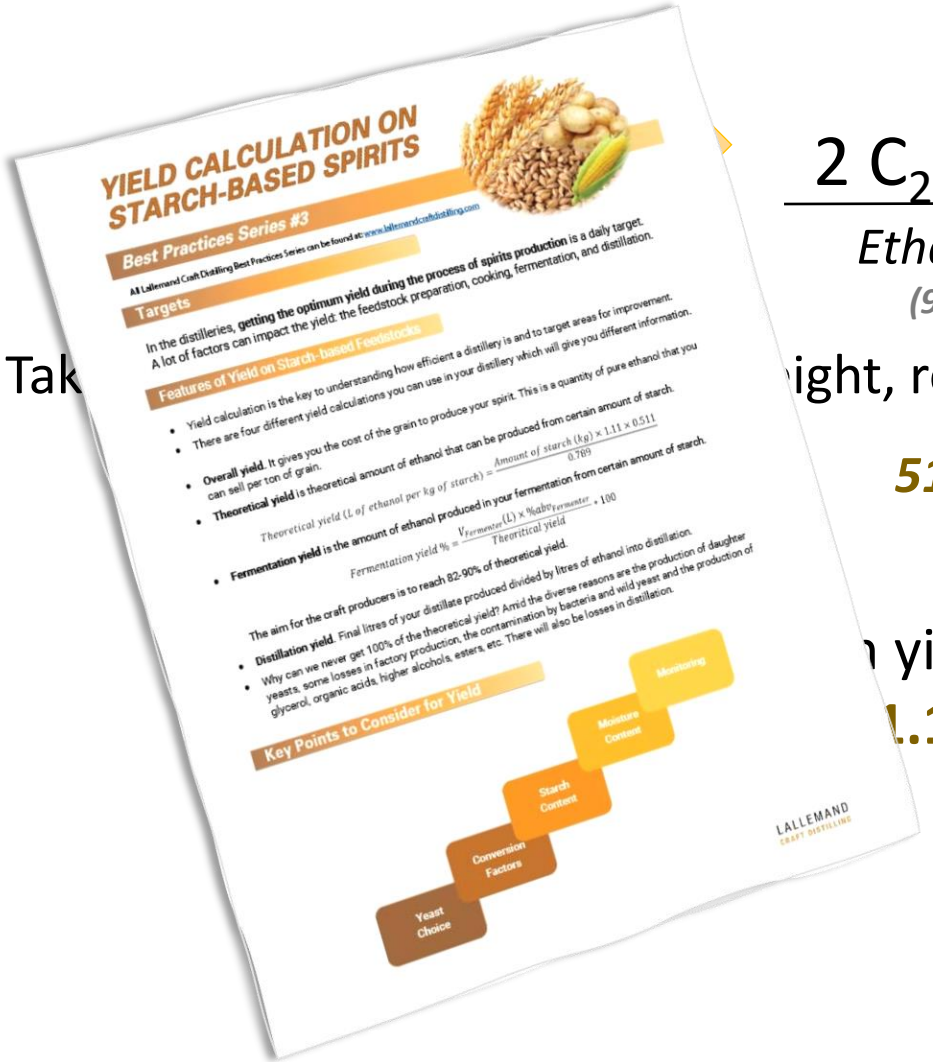
# Ethanol Yields From Glucose



YIELD CALCULATION ON STARCH-BASED SPIRITS

Best Practices Series #3

All Lallemand Craft Distilling Best Practices Series can be found at: www.lallemandcraftdistilling.com

Targets

In the distilleries, **getting the optimum yield during the process of spirits production** is a daily target. A lot of factors can impact the yield: the feedstock preparation, cooking, fermentation, and distillation.

Features of Yield on Starch-based Feedstocks

- Yield calculation is the key to understanding how efficient a distillery is and to target areas for improvement.
- There are four different yield calculations you can use in your distillery which will give you different information.
- **Overall yield.** It gives you the cost of the grain to produce your spirit. This is a quantity of pure ethanol that you can sell per ton of grain.
- **Theoretical yield** is theoretical amount of ethanol that can be produced from certain amount of starch.

$$Theoretical\ yield\ (L\ of\ ethanol\ per\ kg\ of\ starch) = \frac{Amount\ of\ starch\ (kg) \times 1.11 \times 0.511}{0.789}$$

- **Fermentation yield** is the amount of ethanol produced in your fermentation from certain amount of starch.

$$Fermentation\ yield\ \% = \frac{V_{Fermenter}(L) \times \%abv_{Fermenter.} \times 100}{Theoritical\ yield}$$

The aim for the craft producers is to reach 82-90% of theoretical yield.

- **Distillation yield.** Final litres of your distillate produced divided by litres of ethanol into distillation.
- Why can we never get 100% of the theoretical yield? Amid the diverse reasons are the production of daughter yeasts, some losses in factory production, the contamination by bacteria and wild yeast and the production of glycerol, organic acids, higher alcohols, esters, etc. There will also be losses in distillation.

Key Points to Consider for Yield



LALLEMAND CRAFT DISTILLING

$$2\ C_2H_5OH + 2\ CO_2$$

*Ethanol* (92) *Carbon dioxide* (88)

Tak ight, reactant weights would be:

***51.1*** **48.9**

yield of

**1.1%** from

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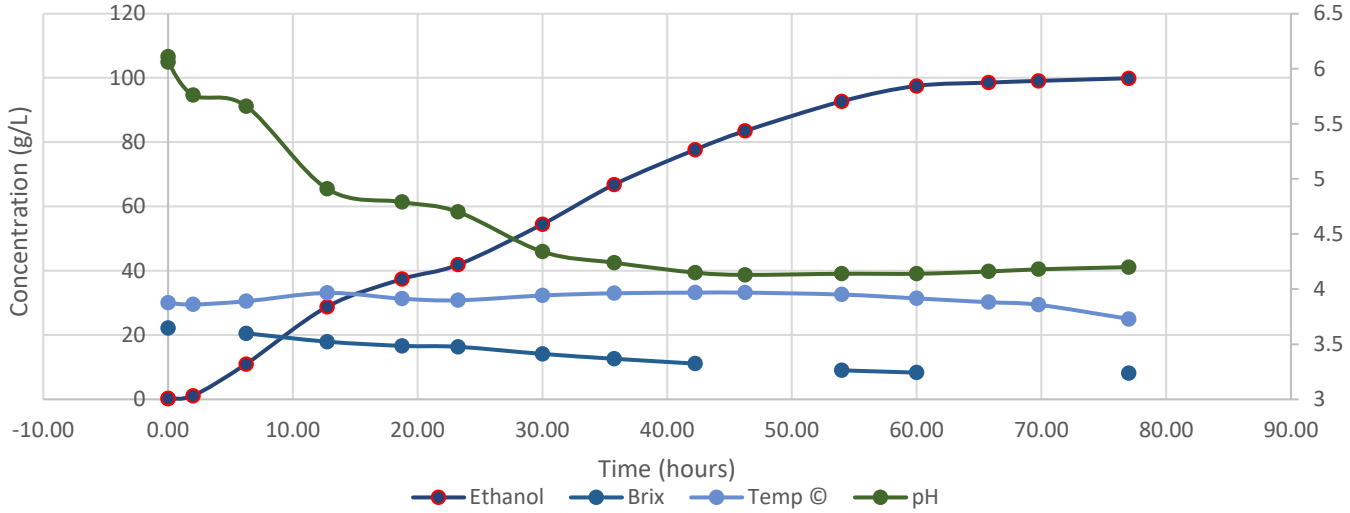
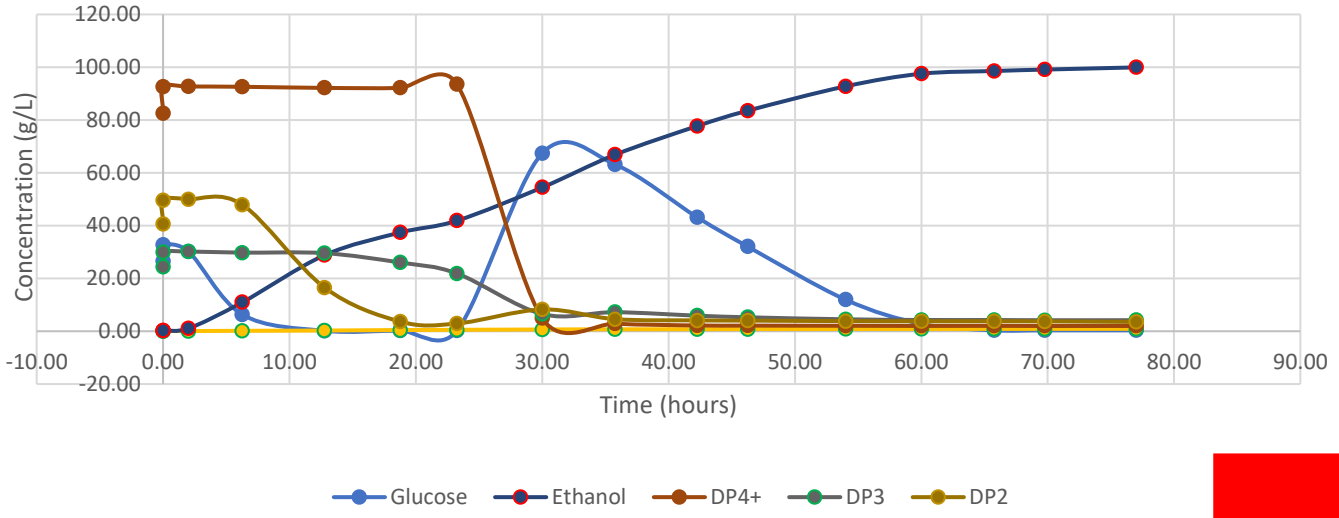
# Tracking Information!




**Considerations:**

- Substrate addition
- Yeast cell counts
- Fermentation rate
- Gravity / Brix drop
- Carbohydrate depletion
- Alcohol formation
- pH, acidity: Indicators of sanitation control
- Temperature
- Time to completion

**What's your corrective action plan?**

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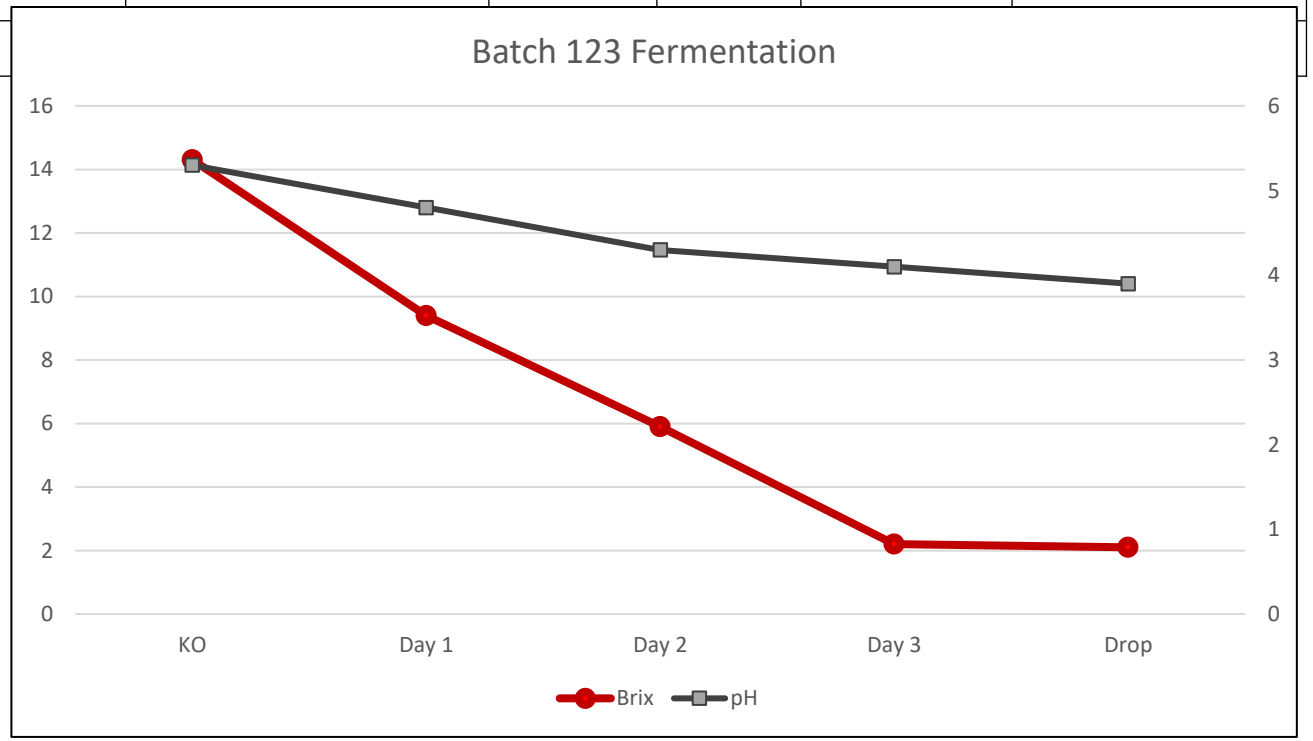
# Example of a Fermentation Tracking Sheet

| Date | Time | Batch # | Tank # | Stage | Temperature (F) | Brix | pH | Initals | Notes |
|---|---|---|---|---|---|---|---|---|---|
| 1/31/24 | 8:27 | 123 | FV1 | KO | 76 | 14.3 | 5.3 | HC | |
| 2/1/24 | 9:15 | 123 | FV1 | Day 1 | 81 | 9.4 | 4.8 | HC | |
| 2/2/24 | 9:00 | 123 | FV1 | Day 2 | 82 | 5.9 | 4.3 | HC | |
| 2/3/24 | 10:15 | 123 | FV1 | Day 3 | 80 | 2.2 | 4.1 | HC | |
| 2/4/24 | 8:45 | 123 | FV1 | Drop | 78 | 2.1 | 3.9 | HC | |
| | | | | | | | | | |
| | | | | | | | | | |

Simple datasets can inform powerful decision making!

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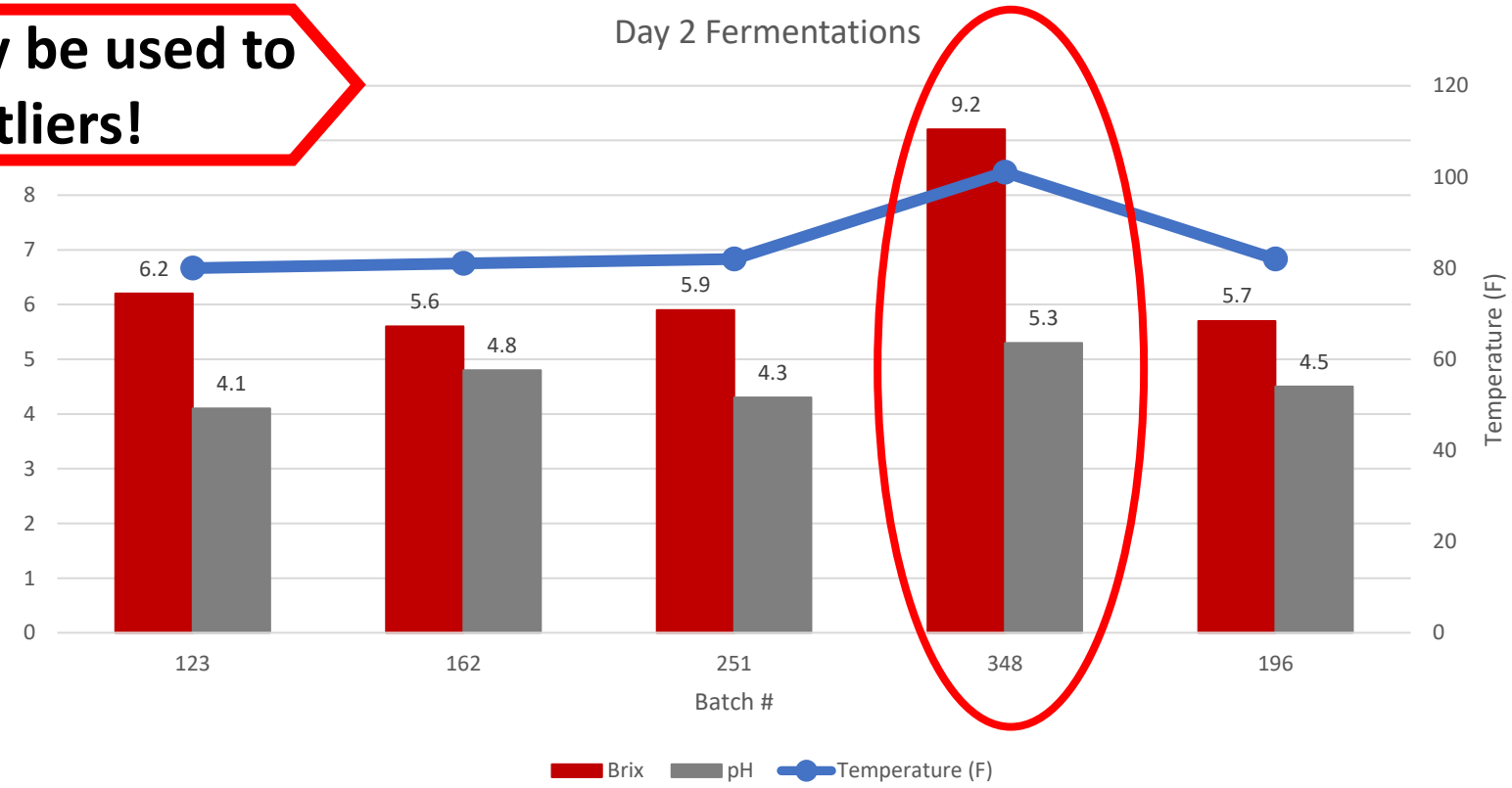
# Example of a Fermentation Tracking Sheet

**Data can easily be used to catch outliers!**

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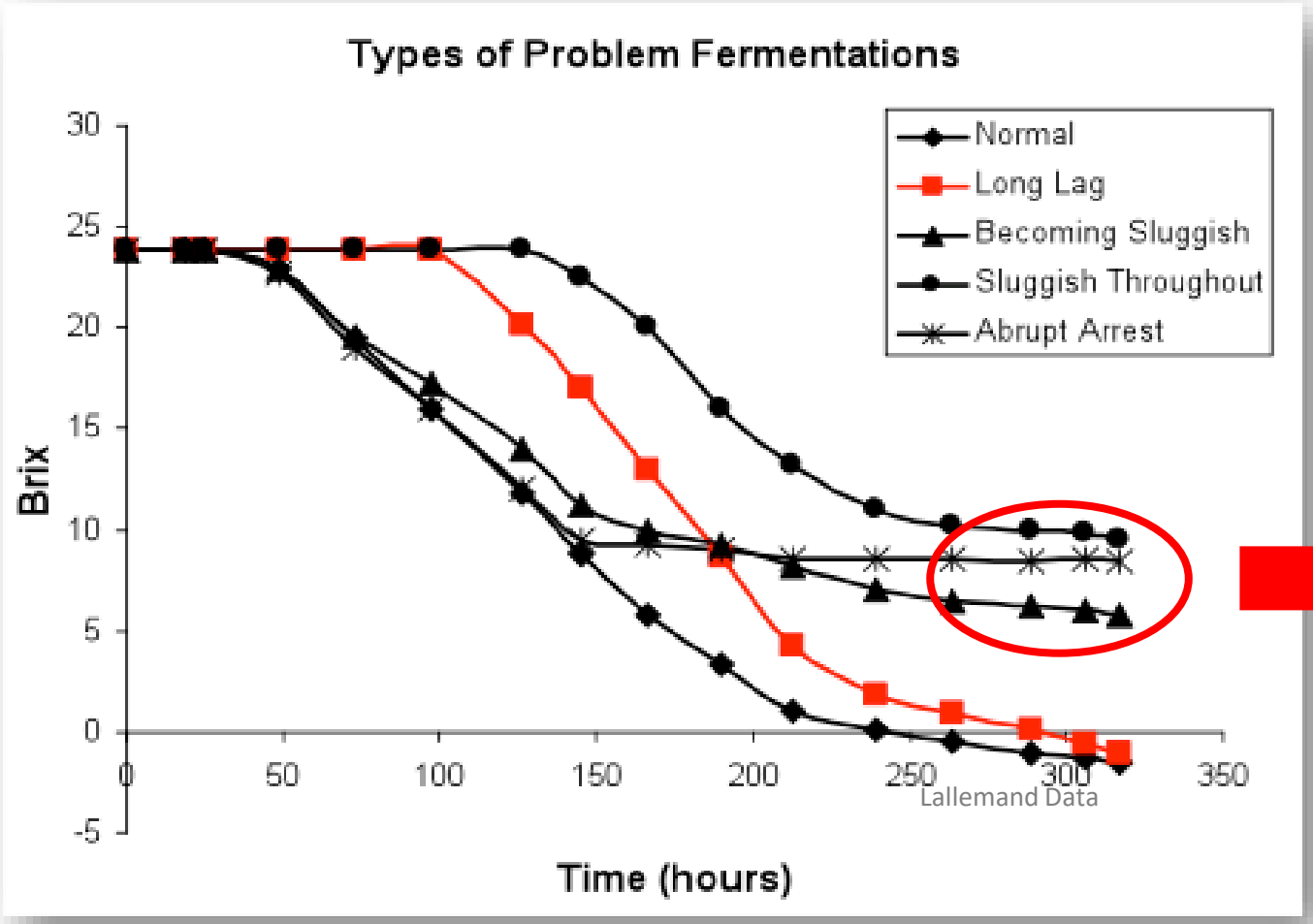
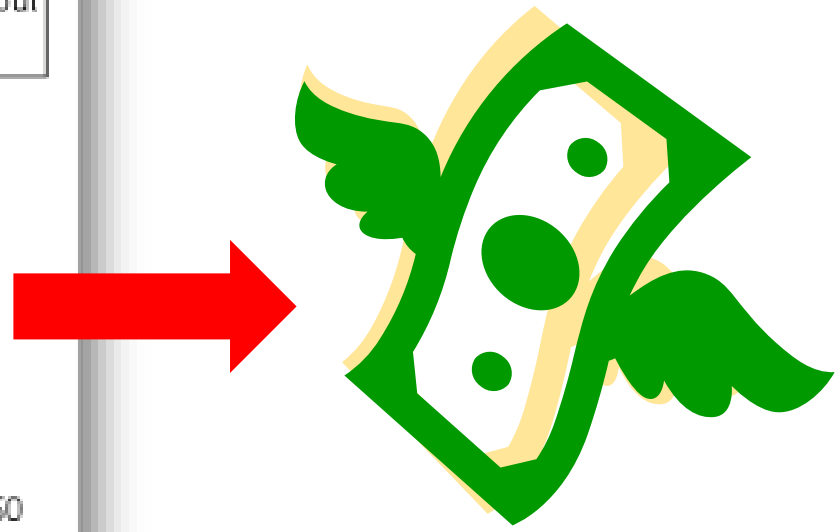
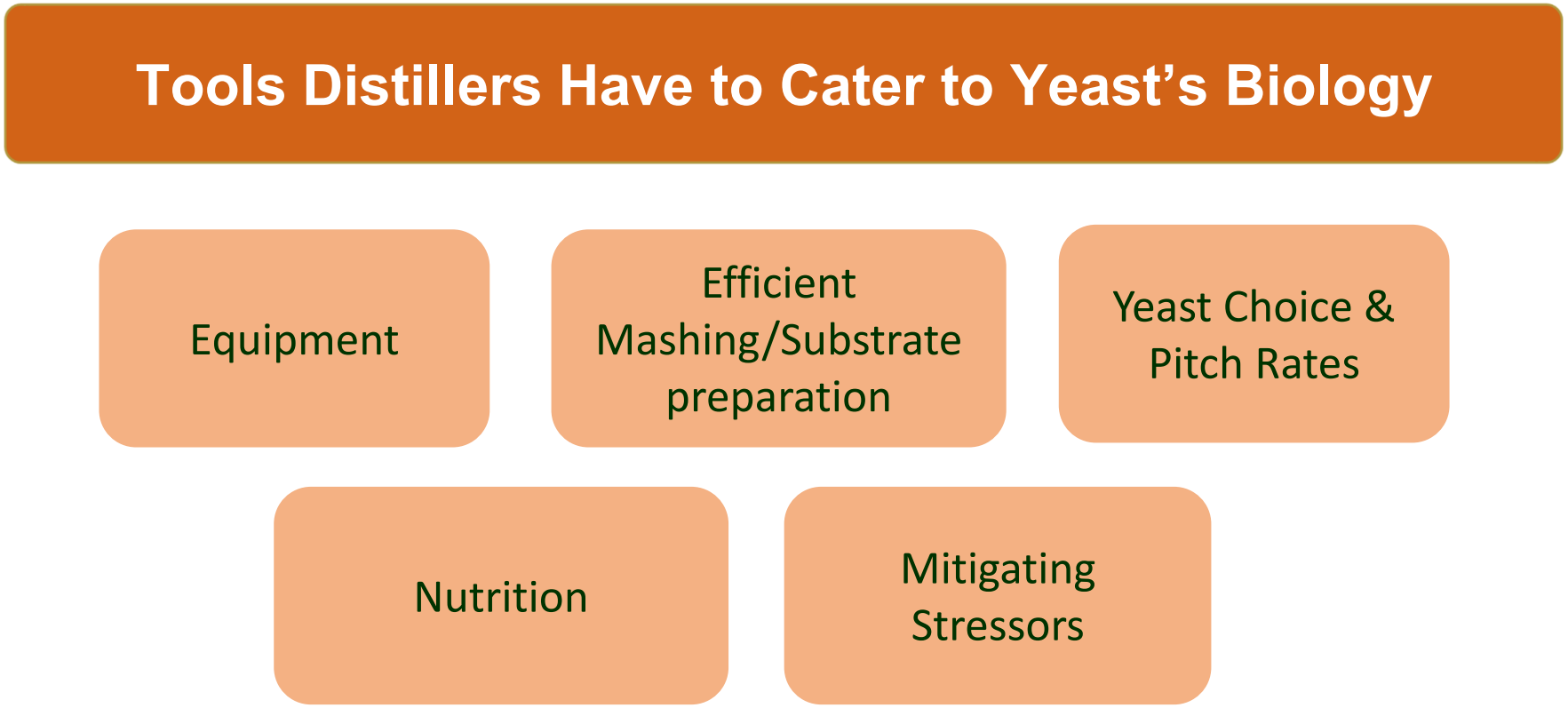
# Impacts of Poor Fermentation Management



# Tailoring Processes for Yeast Success

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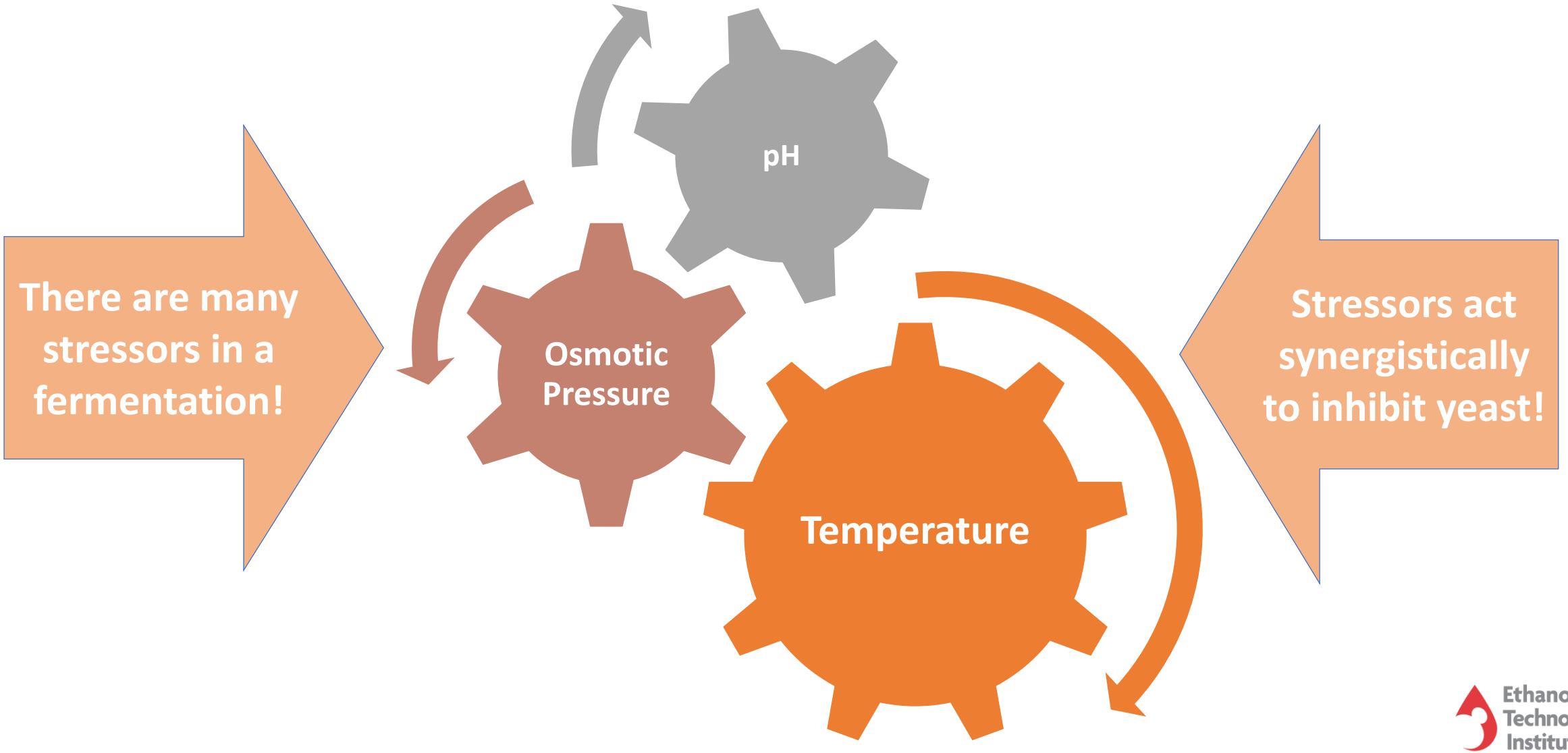
# Yeast Stress

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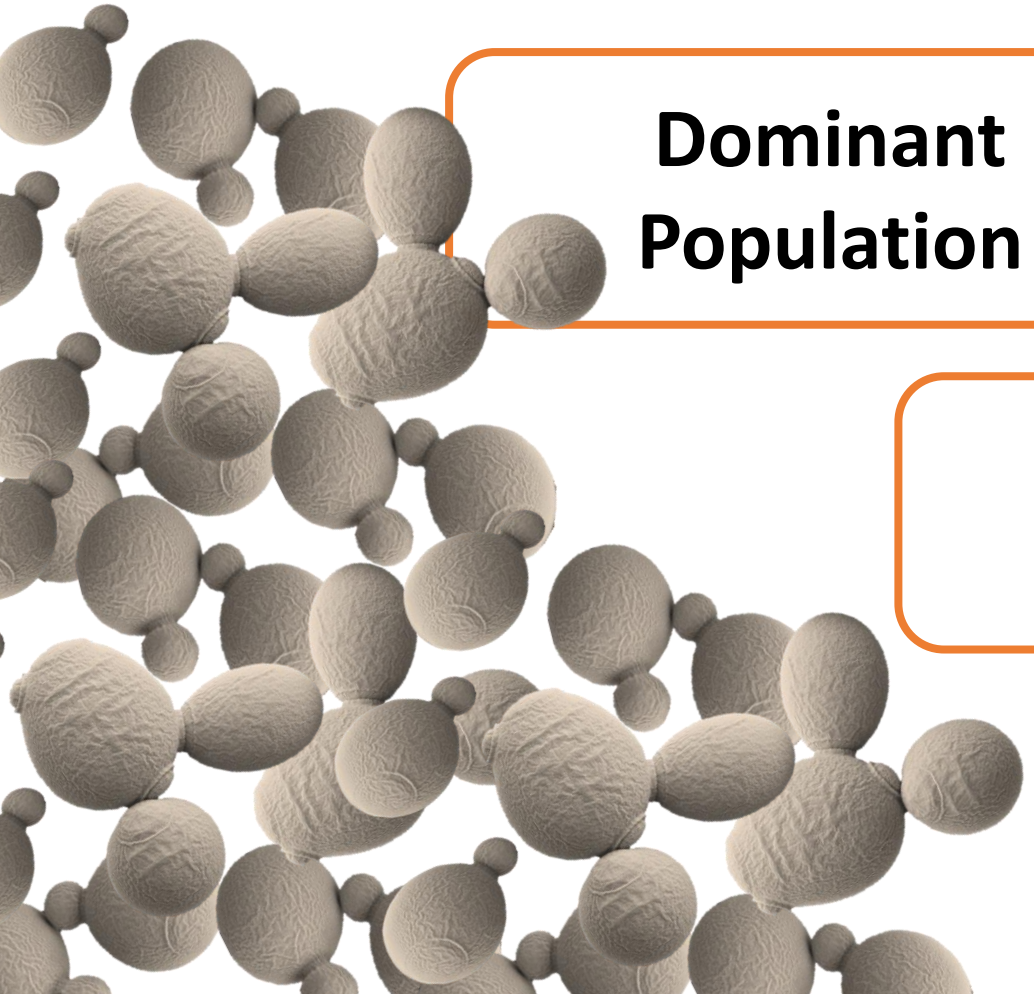
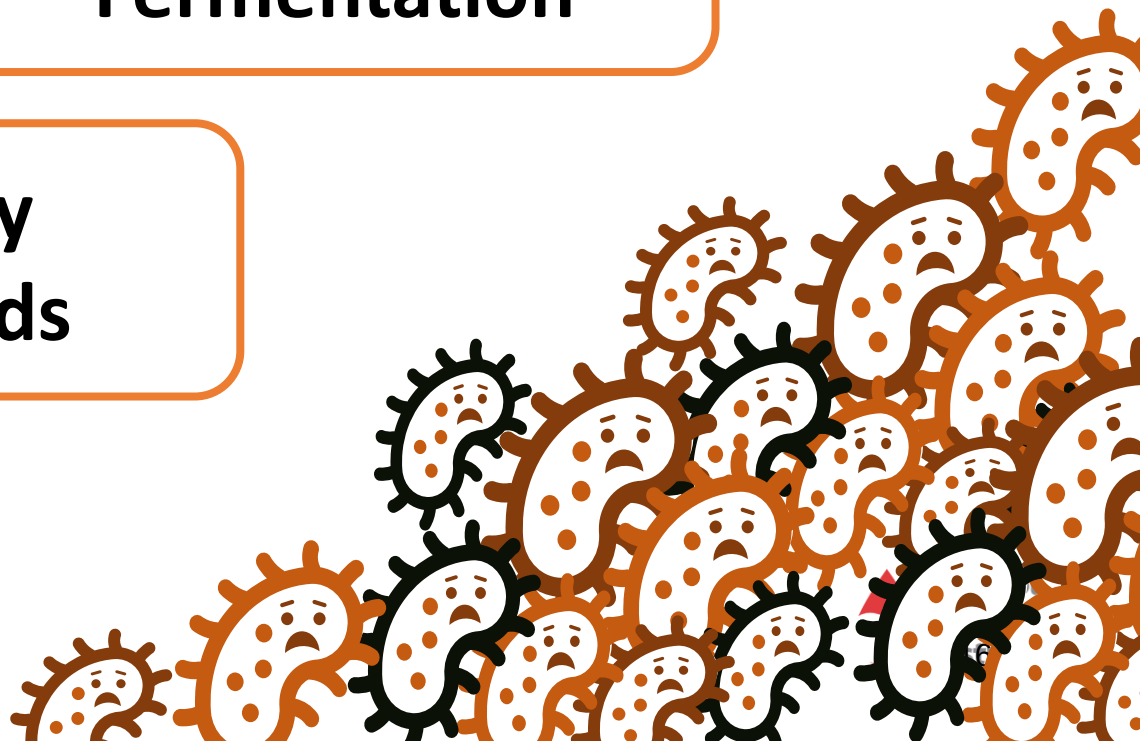
# Healthy Yeast



**Dominant Population**

**Rapid Fermentation**

**Inhibitory Compounds**



# Monitoring Fermentations

## Microscopes – Extremely powerful tools in a Distillery!

- **Direct microscopy** - will show up presence of bacteria in a sample of wort, beer or yeast
- **Gram stain** - will detect presence of either Gram positive or negative bacteria
- **Slide culture** - will show micro-colonies of yeast/bacteria after a few hours' growth on slide with thin film of agar
- **Yeast counting and viability**

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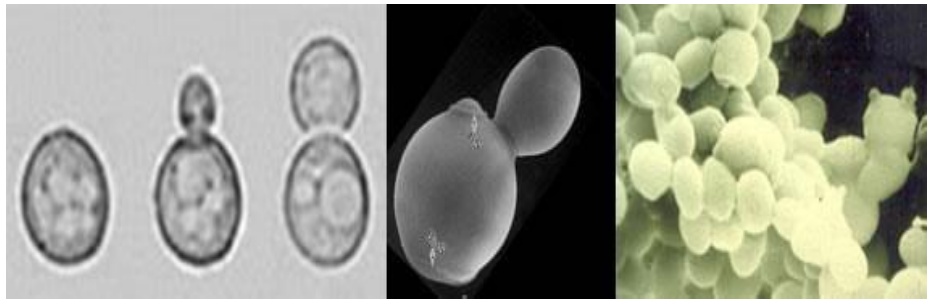
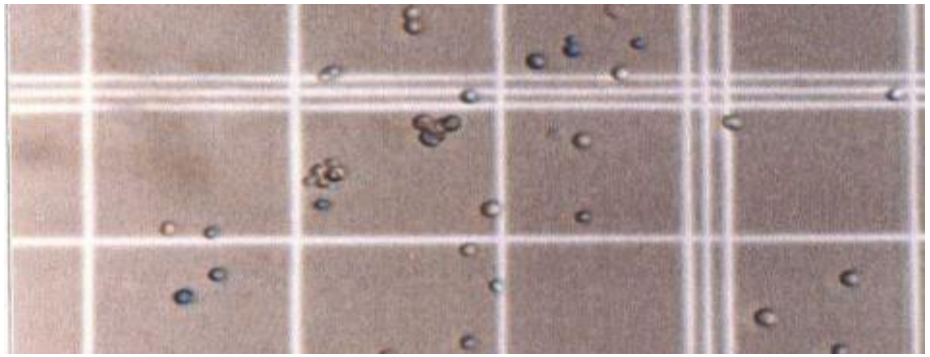
# Assessing Fermentation Progress

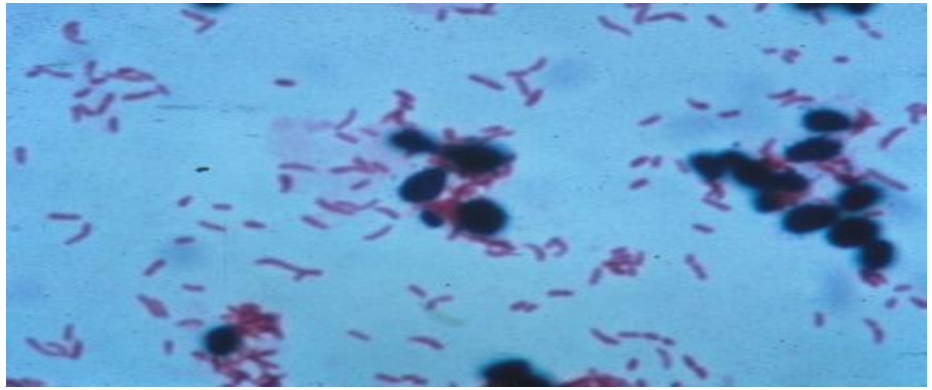
**Healthy Yeast?**



**Dead Yeast?**



**Contaminated Mash?**



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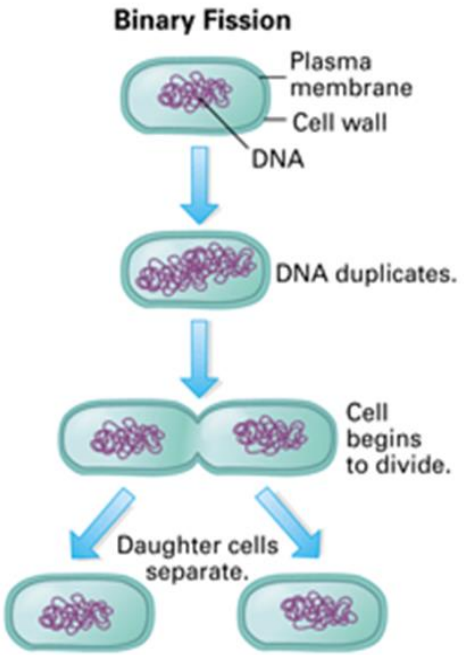
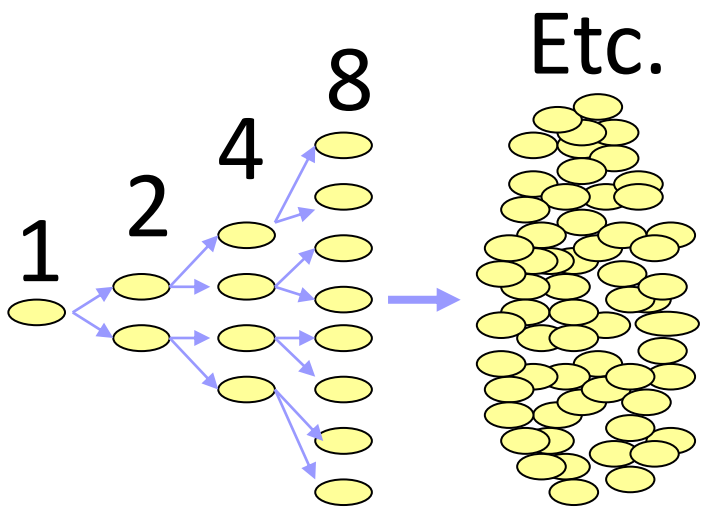
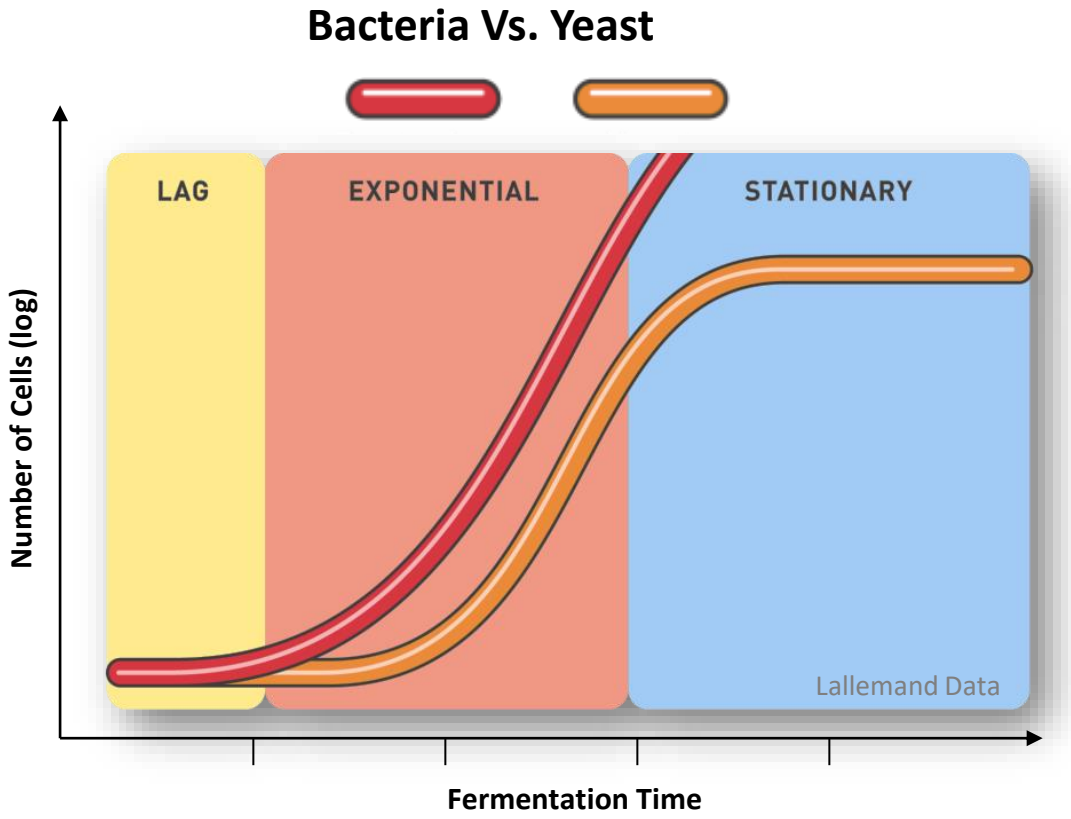
# Bacterial Reproduction – Binary Fission




**Bacteria multiplies rapidly and keeps multiplying!**

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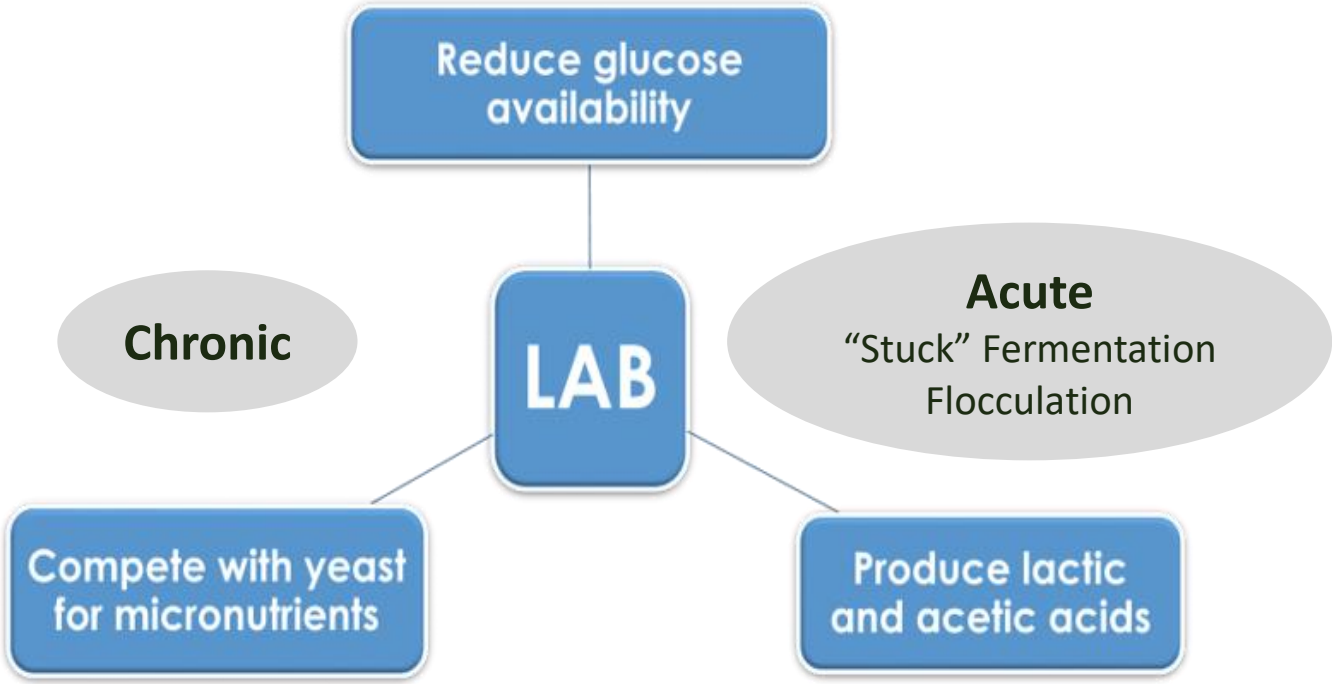
# Impacts of Contaminants

***Contamination events occur when bacterial populations in fermentation outgrow a healthy yeast population.***

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# Toxicity of Acetic Acid

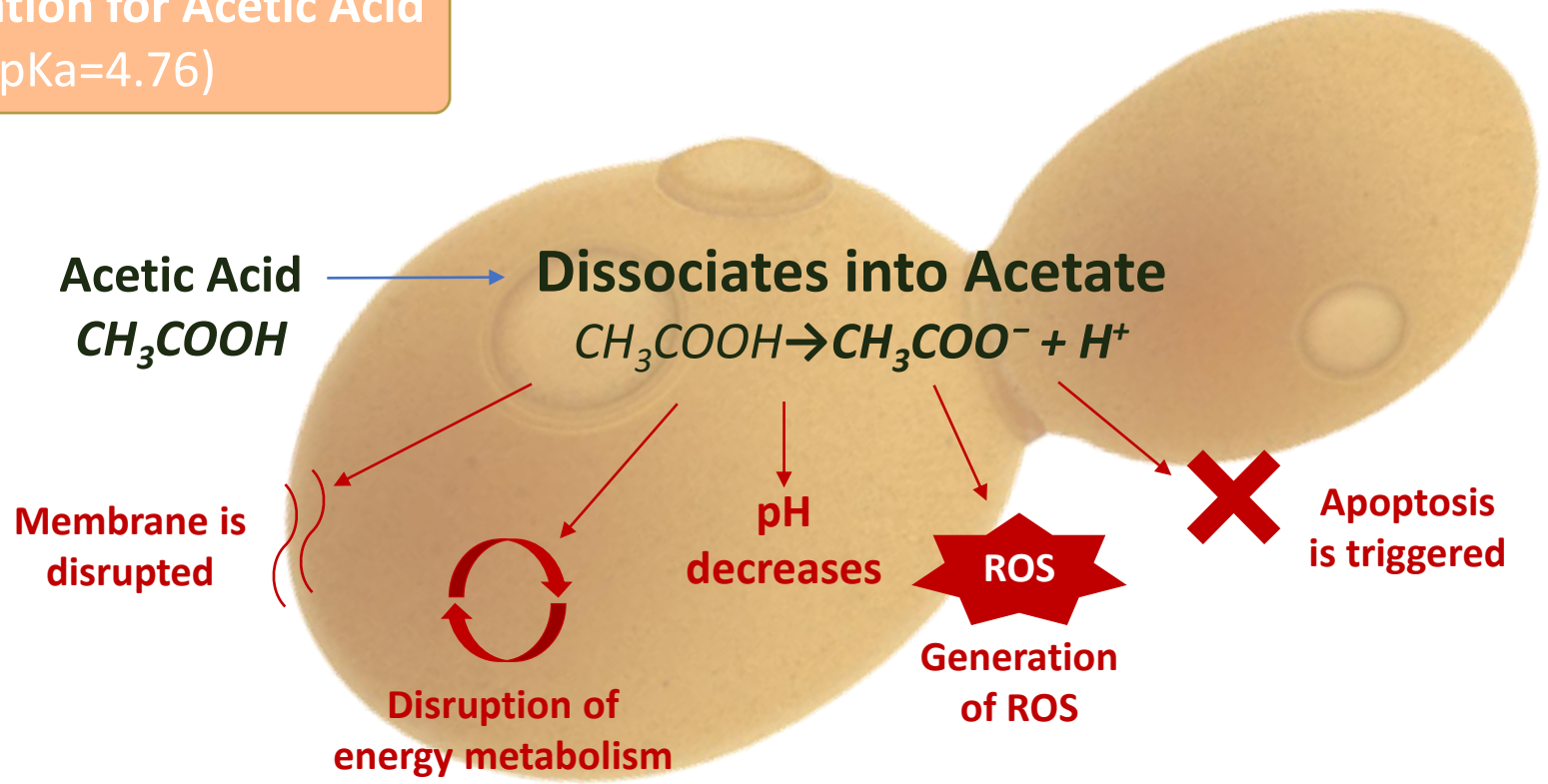
**Generic Dissociation Equilibrium Equation for Acetic Acid**

$CH_3COOH \leftrightarrow CH_3COO^- + H^+$ (pKa=4.76)

**Undissociated weak acids passively diffuse into the cell**

**0.8%** w/v Lactic acid

**0.05 - 0.1%** w/v Acetic acid

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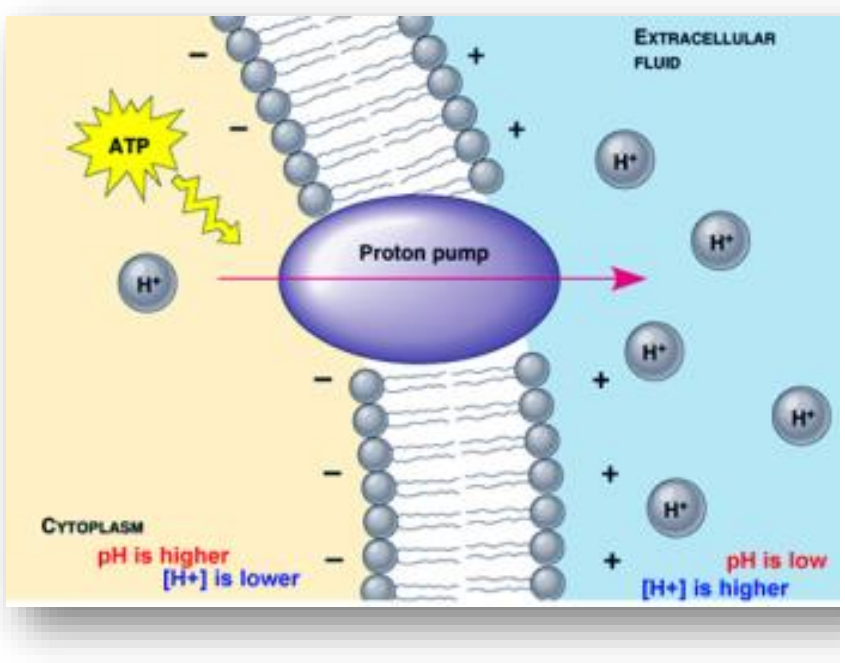
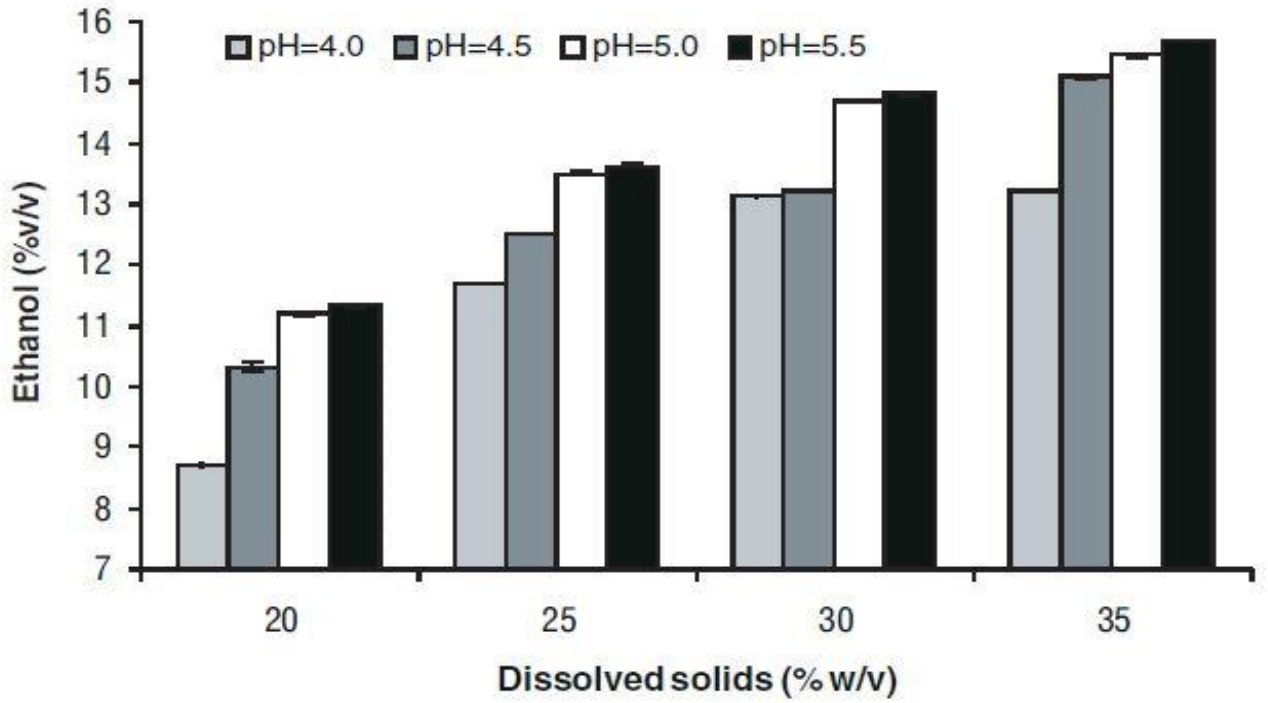
# pH Stress

**Yeasts have an *ideal* pH range**

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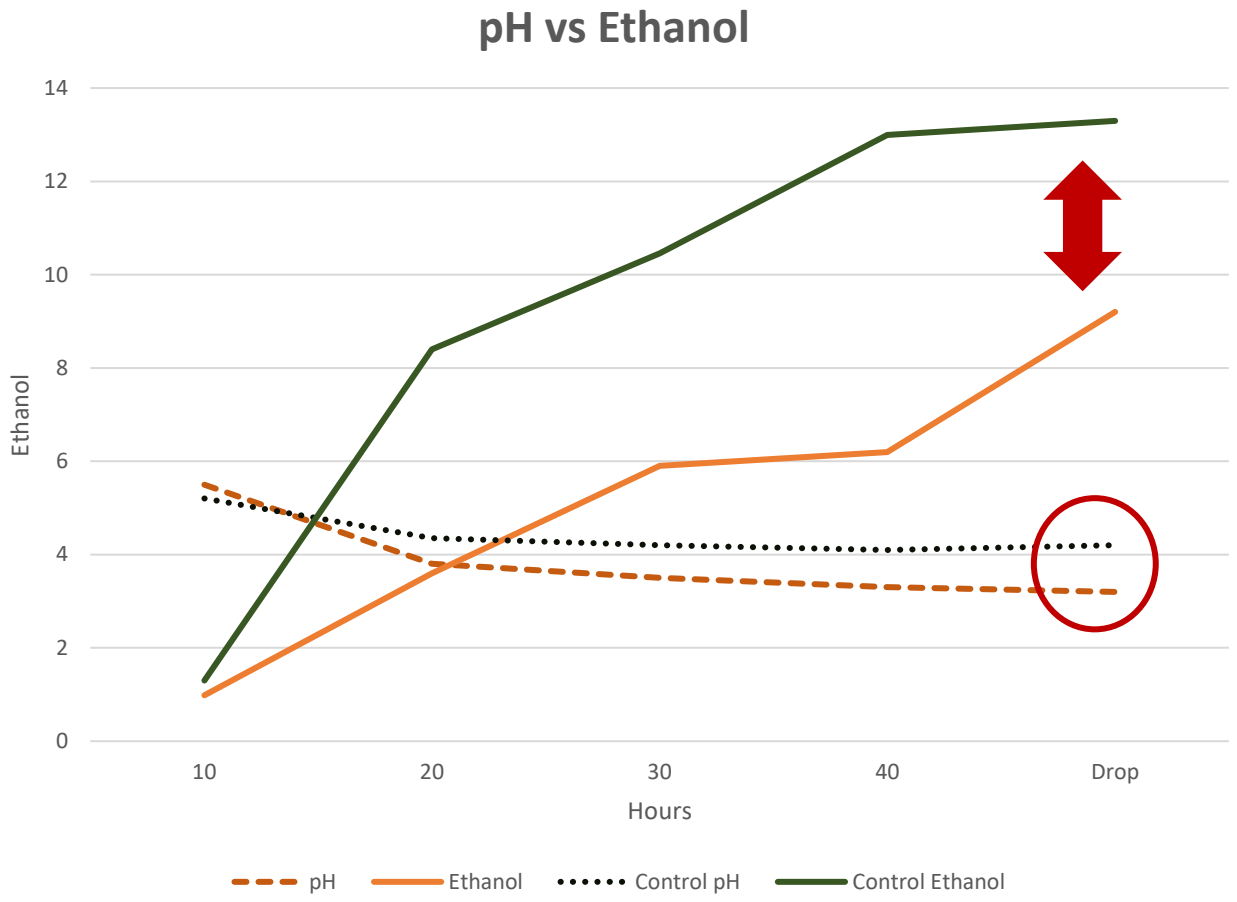
# Managing pH




Lallemand Data

**It's important to understand how you can impact the pH of your fermentations:**

- Keep acid additions to a minimum
- Try to edge up pH
- ***Reduce the production of organic acids through good hygiene practices***

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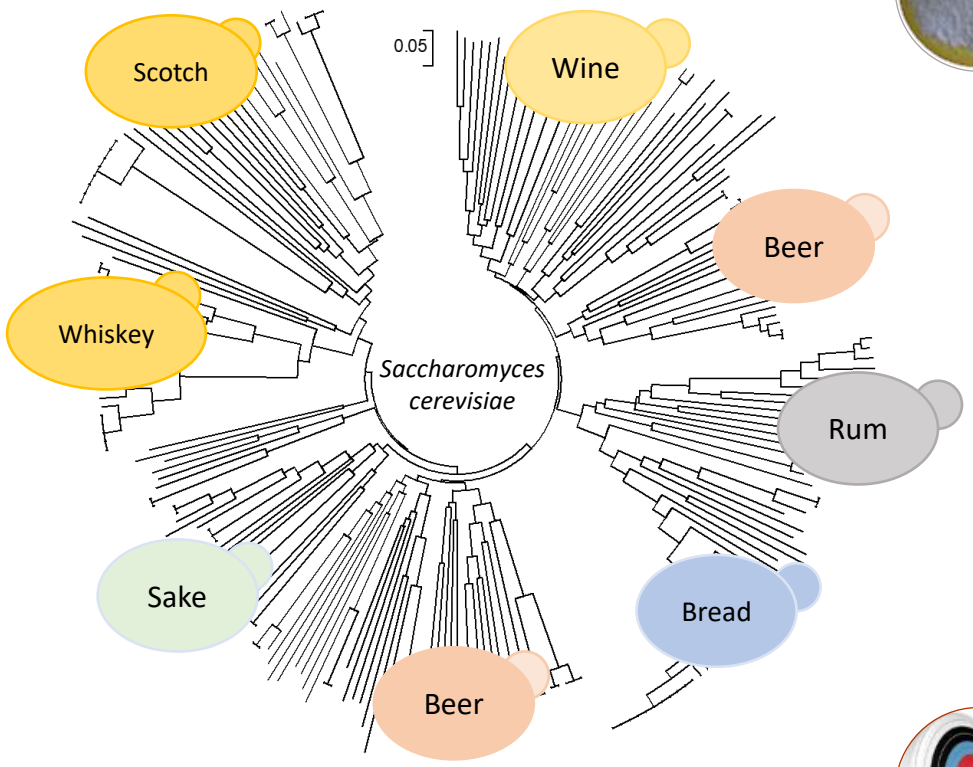
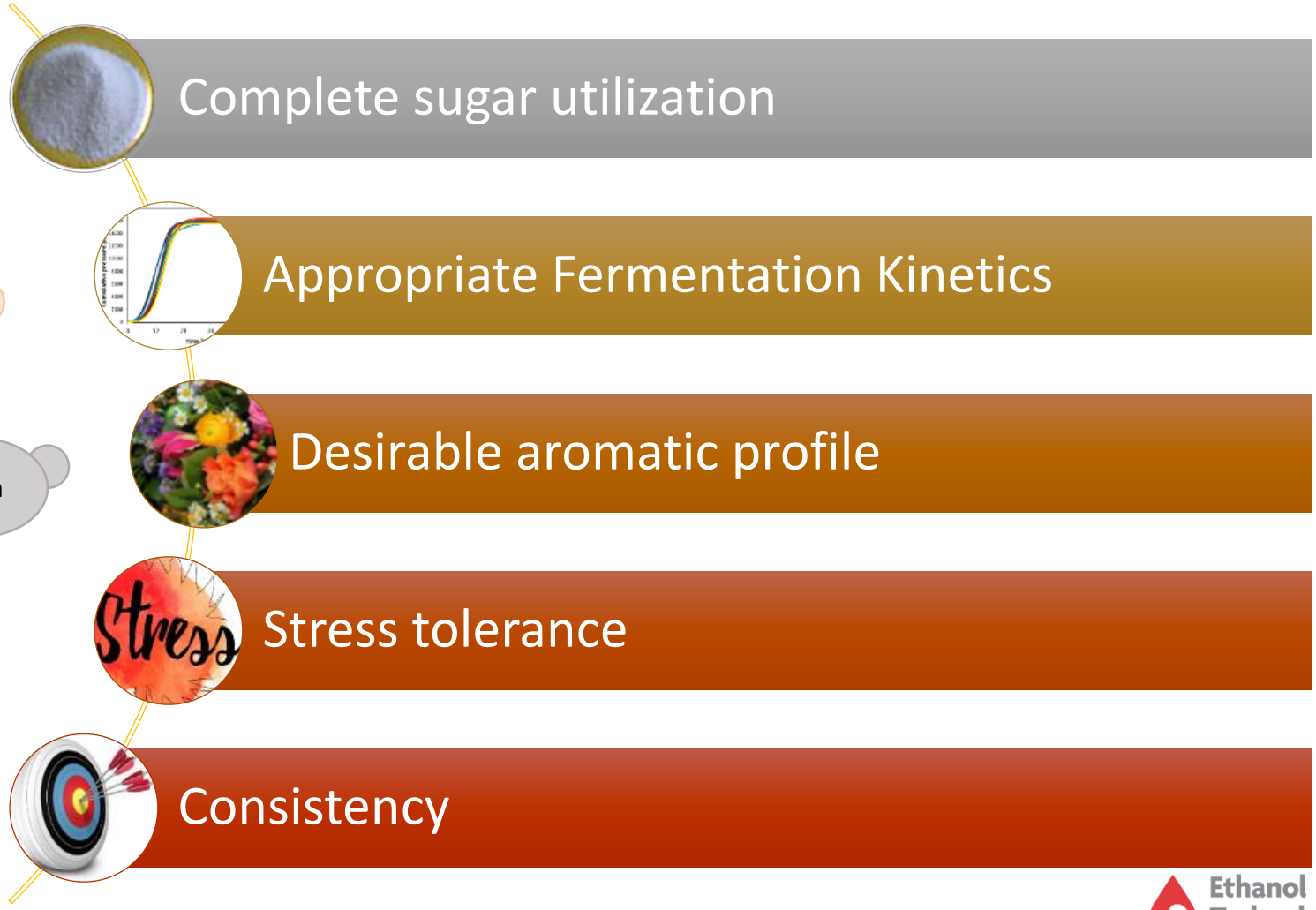
# But What is the Right and Most Efficient Yeast Strain?

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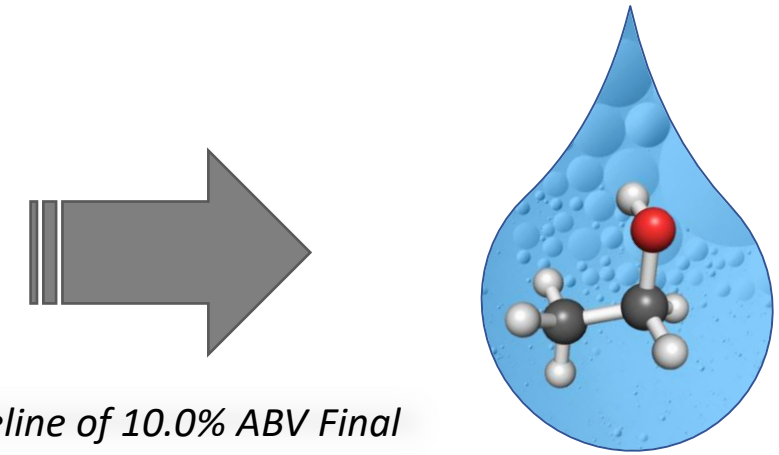
# Profitability Calculations

Assumptions

20,000
Liters Ferm

x14
Ferms/week for 48 weeks

*Baseline of 10.0% ABV Final



**1,344,000 LAA/yr**

*Not factoring in Distillation Recovery %

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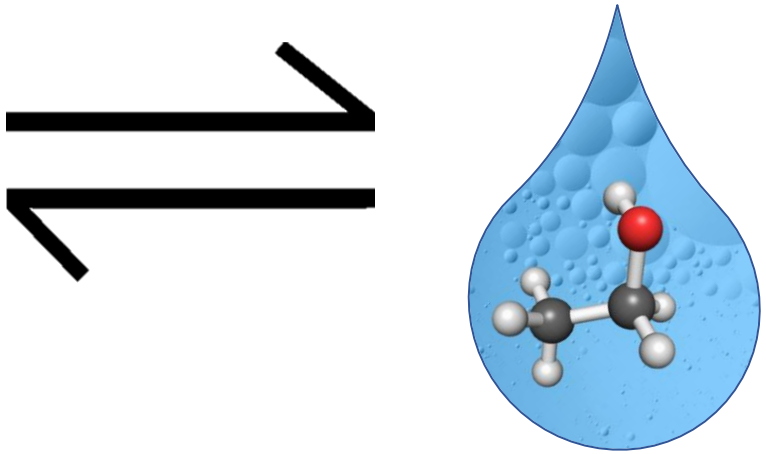
# Profitability Calculations

**4,475,000 Bottles**


**1,344,000 LAA/yr**



**Not factoring in Distillation Recovery %*

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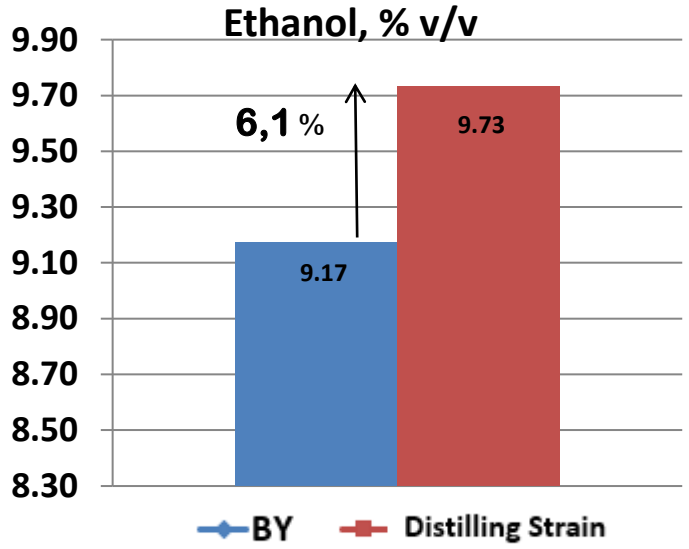
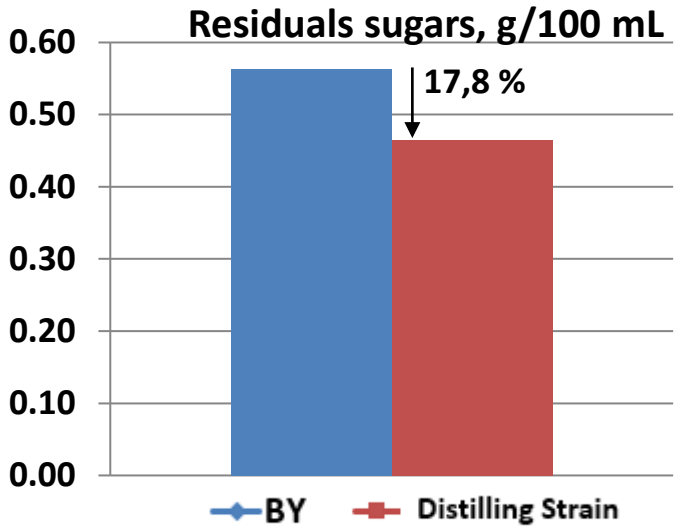
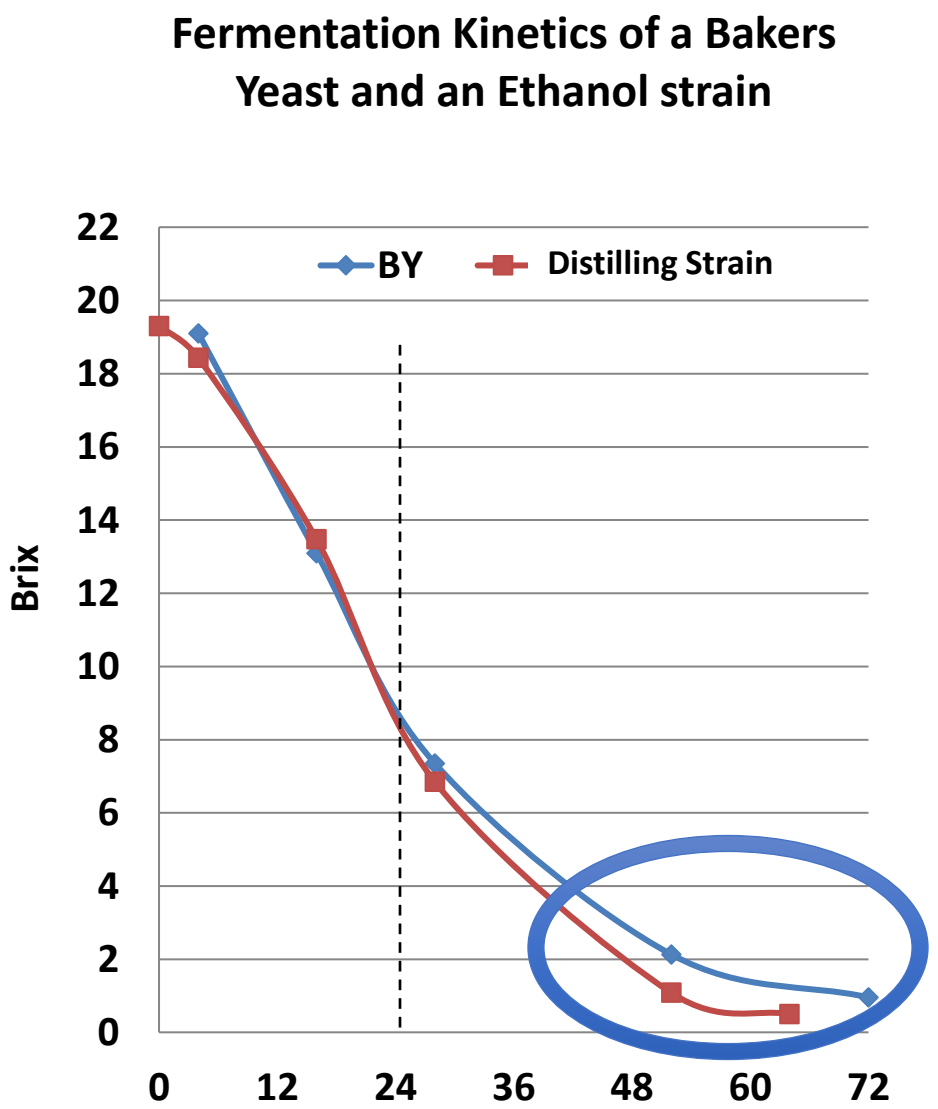
# Yeast and Substrate Choice = Potential Benefits

**~251K extra bottles**


Lallemand Trials, 2017

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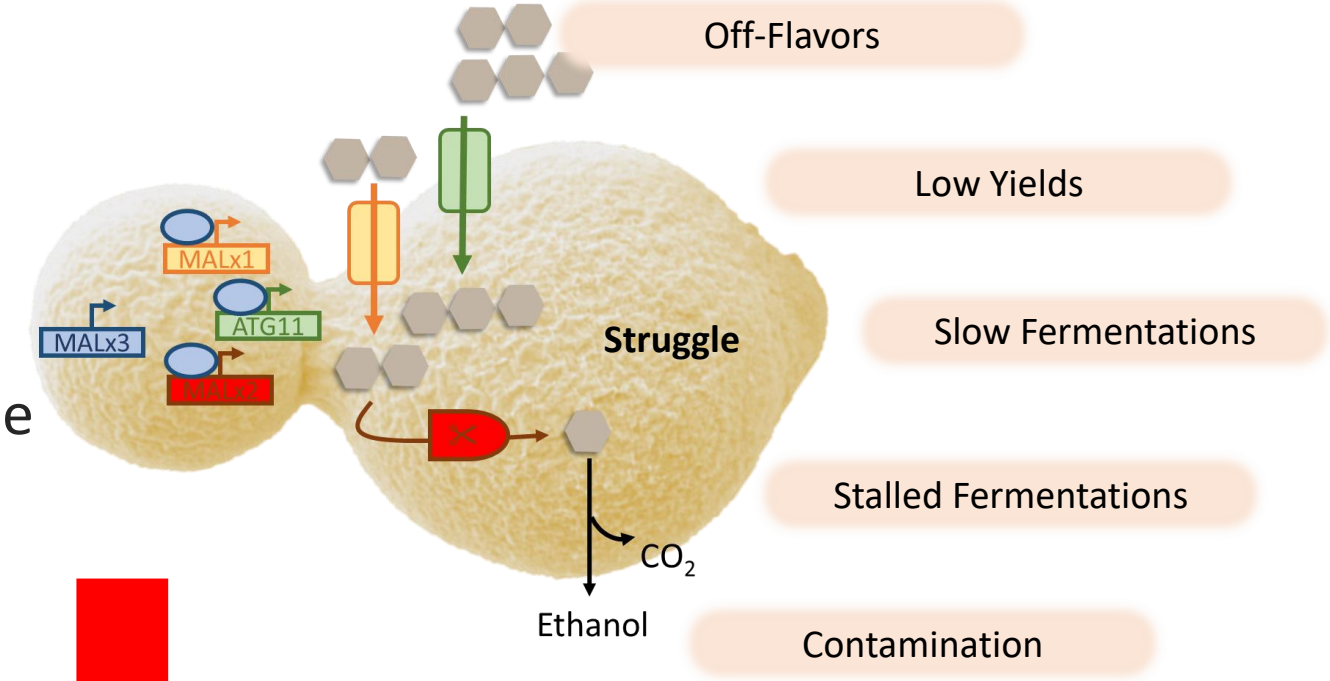
# Fermentation Temperatures

**Yeast has an ideal temperature window 24˚- 34˚C** (75 ˚- 95 ˚F)

- **Temperatures above or below the window will impact yeast health and flavor**

**High temperature stress leads to:**

- Alteration to the cell membrane
- Loss of enzyme activity
- Shift of metabolites towards defense
- Increased sensitivity to ethanol
- Stress responses




**Yield** **Flavor**

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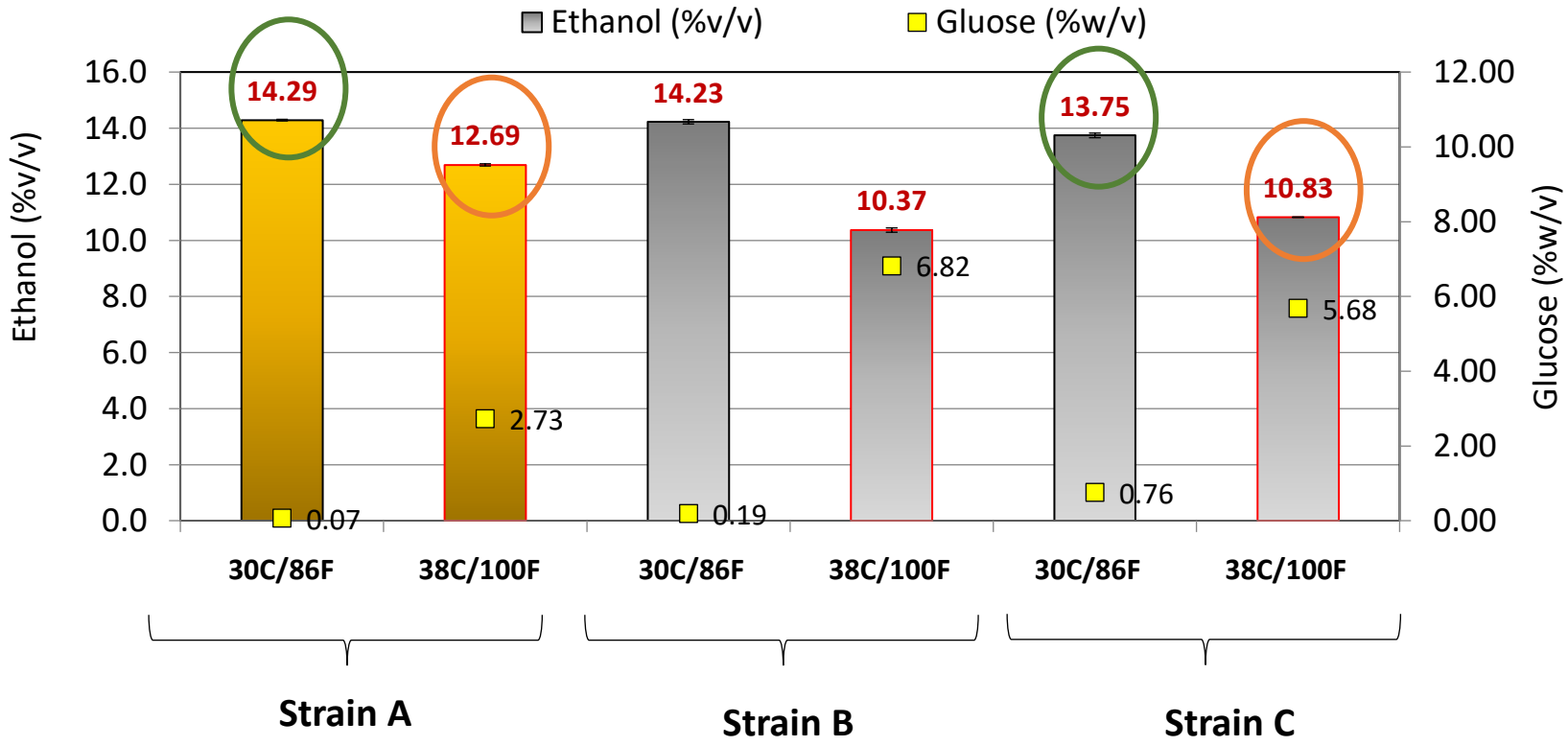
# Consider Your Fermentation Environment and Stress Factors

This will impact flavor too!





**~833k less bottles**

**~242K extra bottles**

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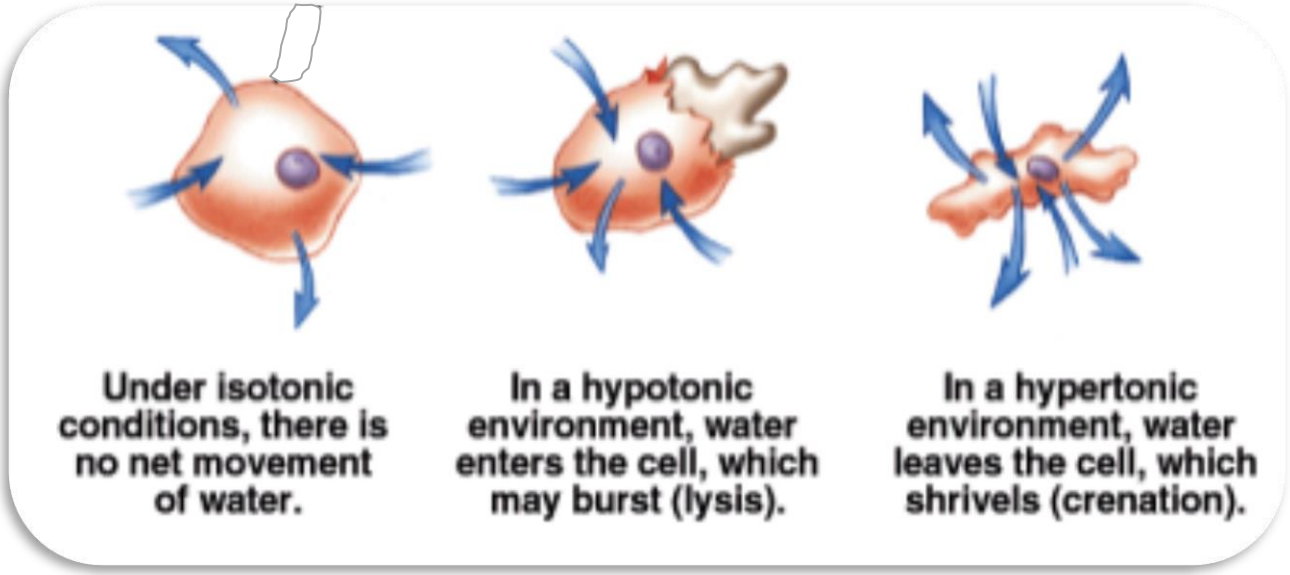
Lallemand Trials, 2019

# Osmotic Stress

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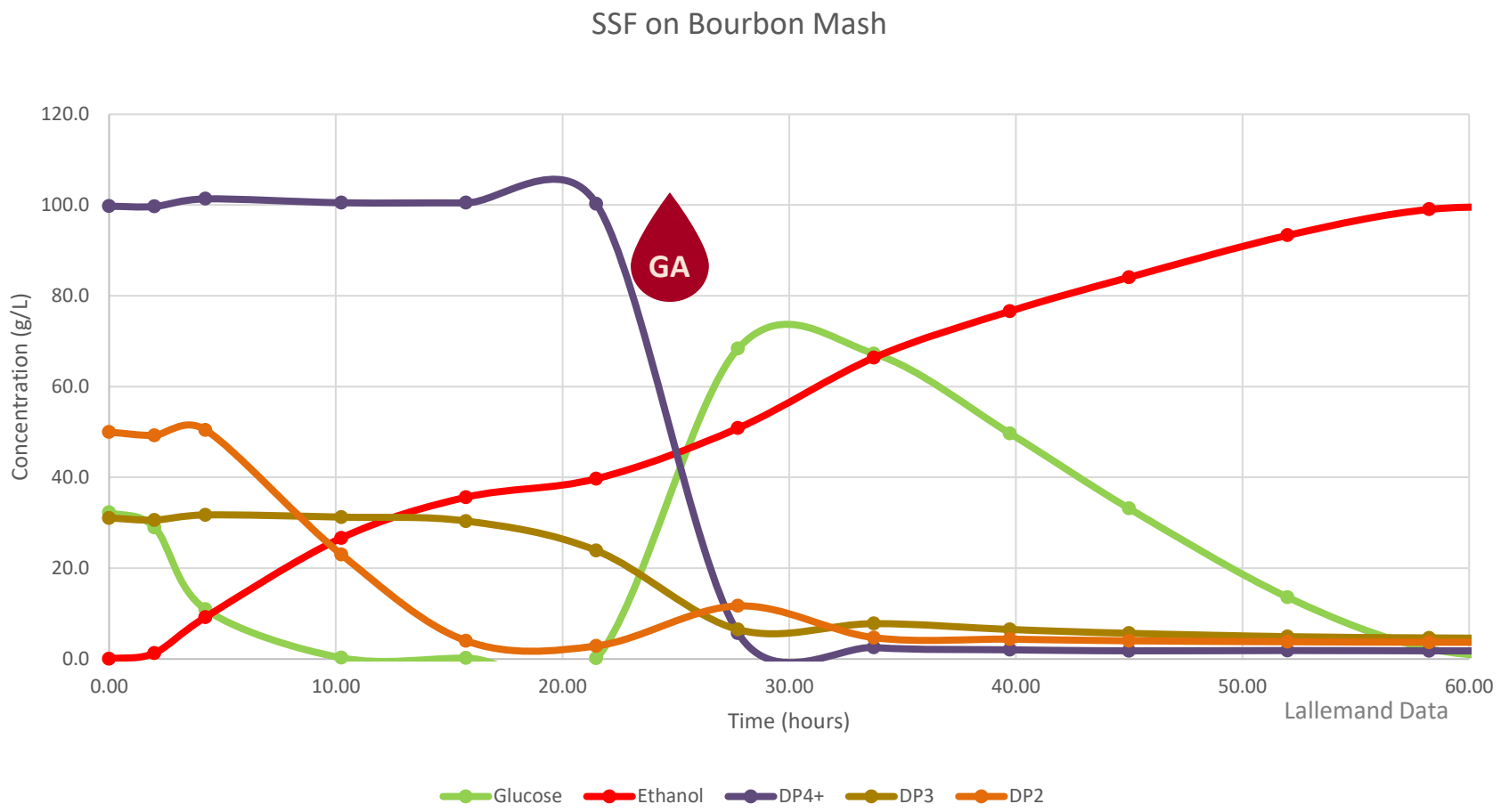
# Managing Osmotic Stress – In Starch Substrates

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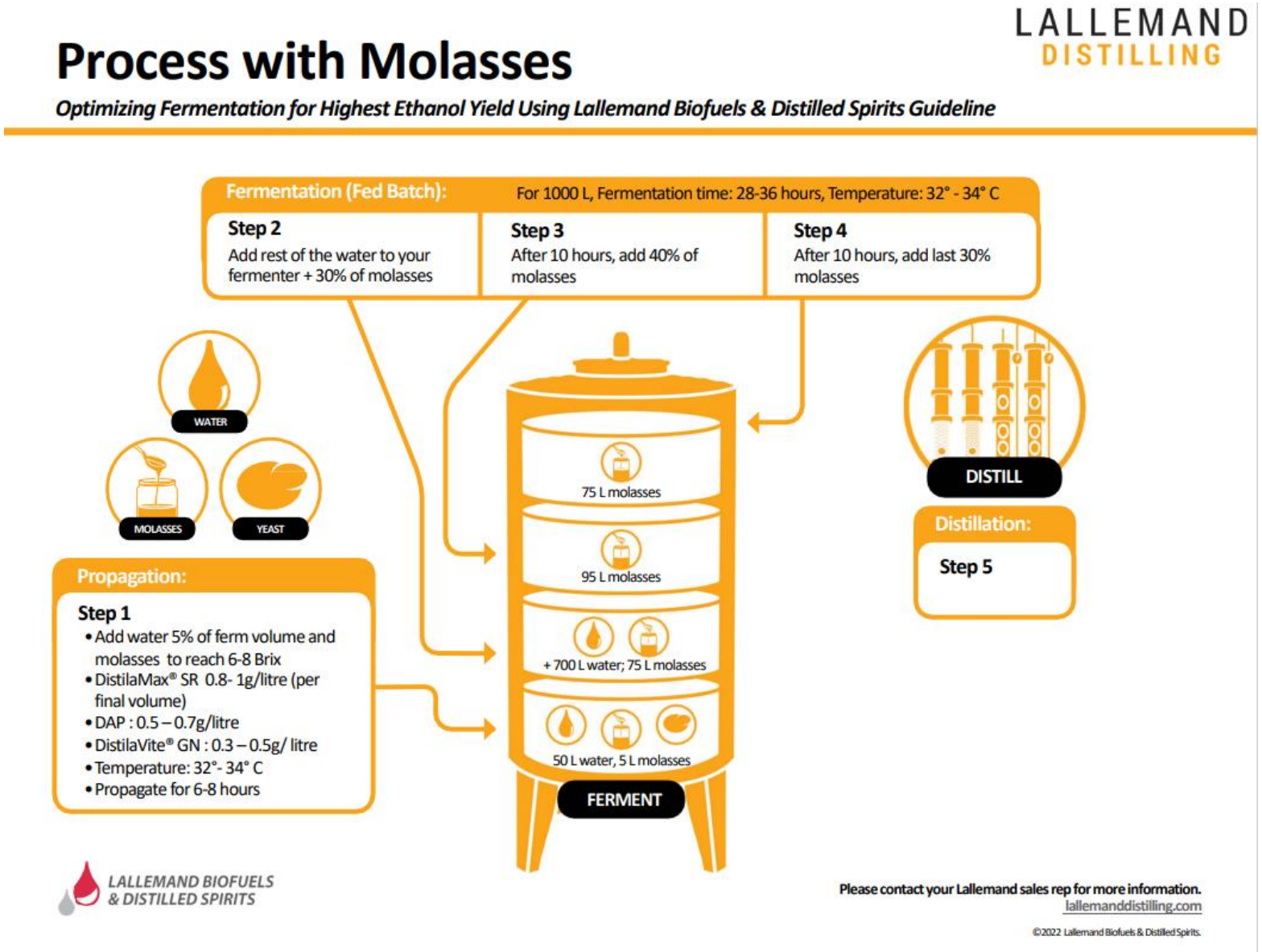
# Managing Osmotic Stress – In Molasses/Syrup Substrates

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# Glycerol = $

## Assumptions

**~56K more bottles**

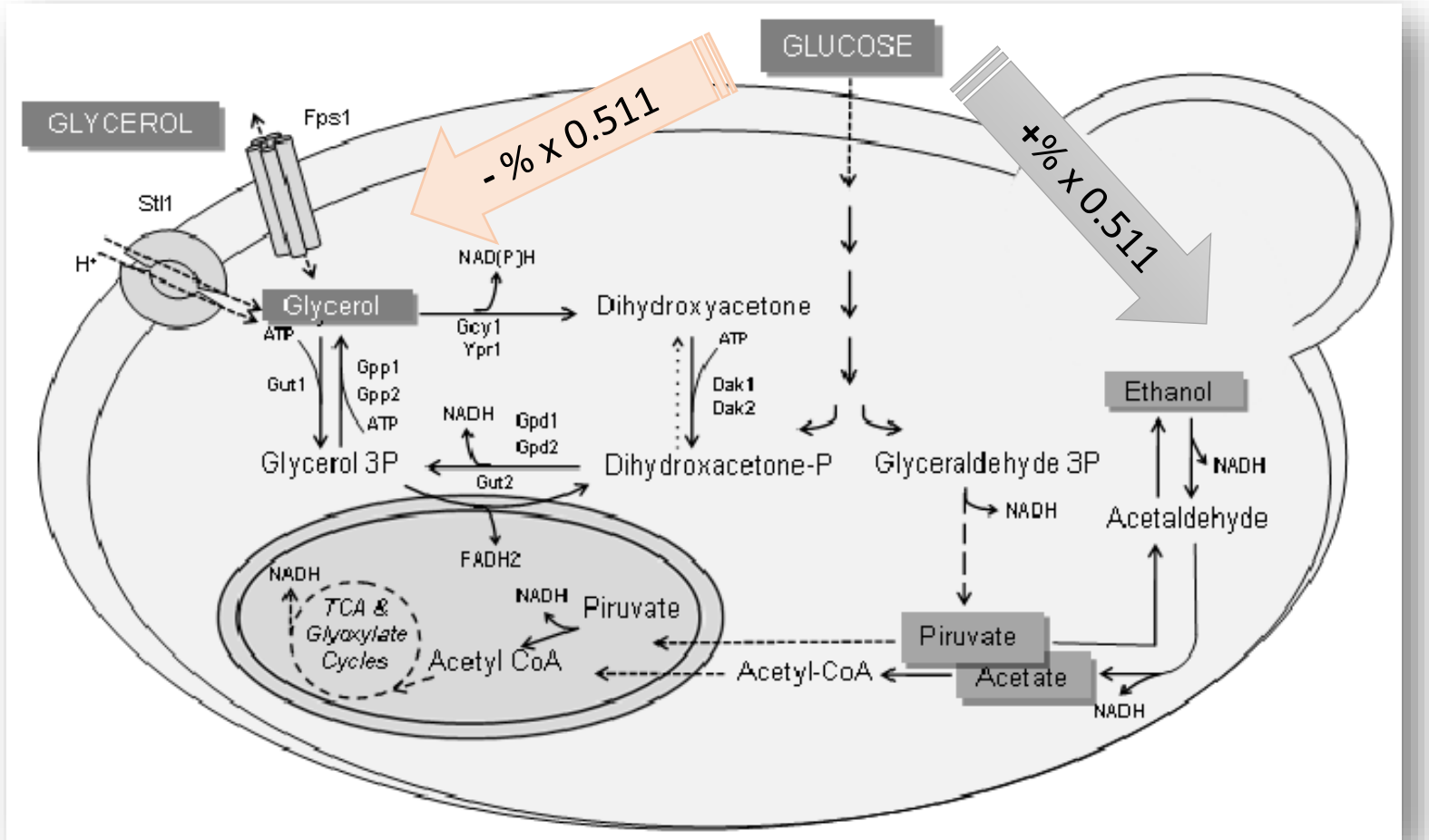
Lower limit glycerol = 1.0 %w/v

Average glycerol = 1.2 %w/v

Upper limit glycerol = 1.4 %w/v

**~56k less bottles**

Yeast, the man's best friend. Joana Tulha et al., 2012

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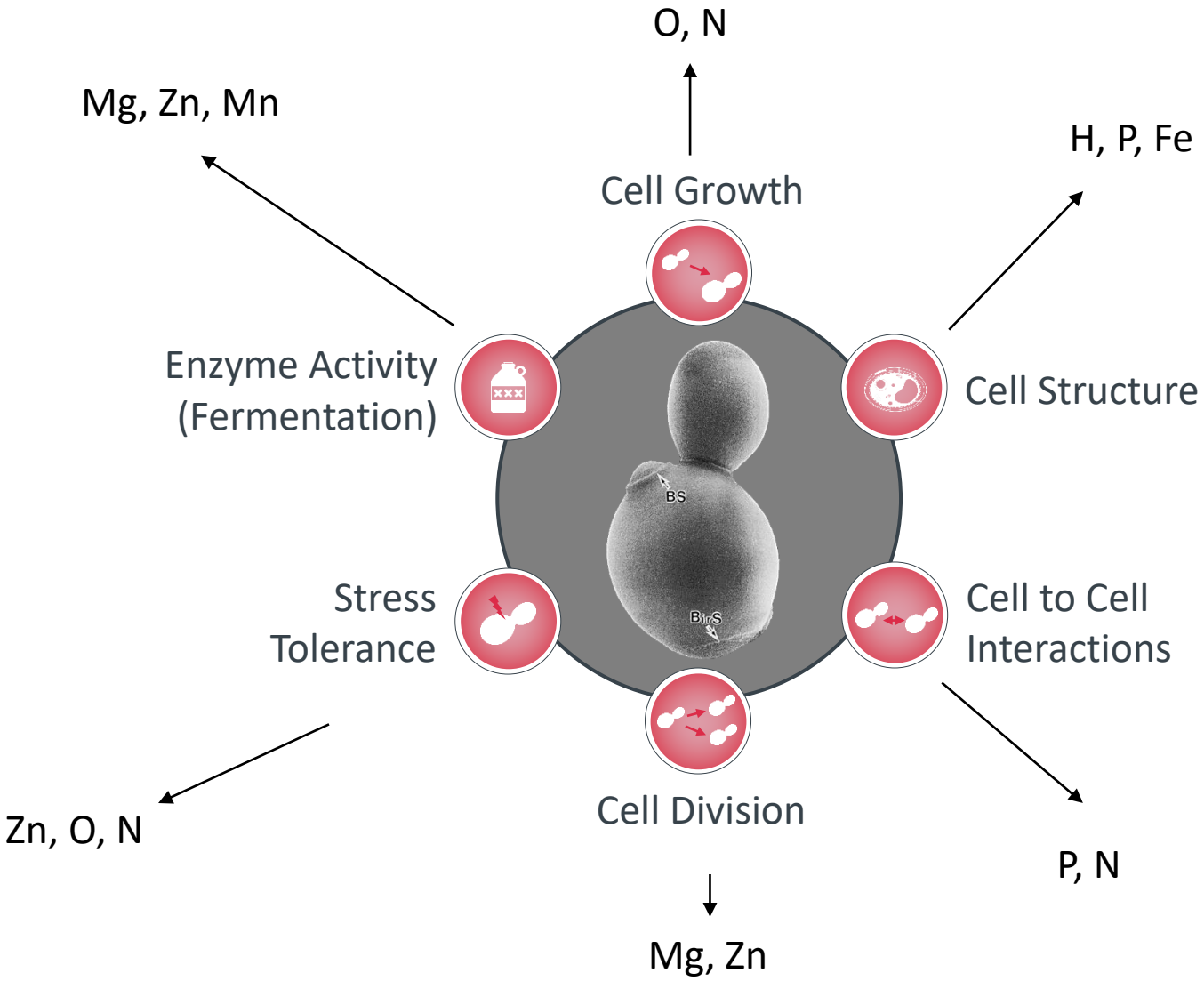
# Why Do Yeast Need Nutrition?

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# What are the Economical Justifications?

| | Ferm Hours | #Ferms/Year | %ABV Drop | Liters EtOH/Year* | Increase Liters/Year |
|---|---|---|---|---|---|
| **Plant 1** | 55h | 1000 | 10,0% | 10,000,000 L | NA |
| **Nutrient gain** | **50h** | **1100** | 10,0% | **11,000,000 L** | **1,000,000 L** |
| **Plant 2** | 70h | 1000 | 10,0% | 10,000,000 L | NA |
| **Nutrient gain** | **60h** | **1167** | 10,0% | **11,666,667L** | **1,666,667 L** |
| **Plant 3** | 80h | 1000 | 10,0% | 10,000,000 L | NA |
| **Nutrient gain** | **56h** | **1429** | 10,0% | **14,285,714 L** | **4,285,714 L** |
| **Plant 4** | 70h | 1000 | 10,0% | 10,000,000 L | NA |
| **Nutrient gain** | 70h | 1000 | **10,5%** | **10,500,000 L** | **500,000 L** |
| **Plant 5** | 70h | 1000 | 10,0% | 10,000,000 L | NA |
| **Nutrient gain** | **60h** | **1167** | **10,5%** | **12,250,000 L** | **2,250,000 L** |

*Assuming working fermenter volume of 100,000L

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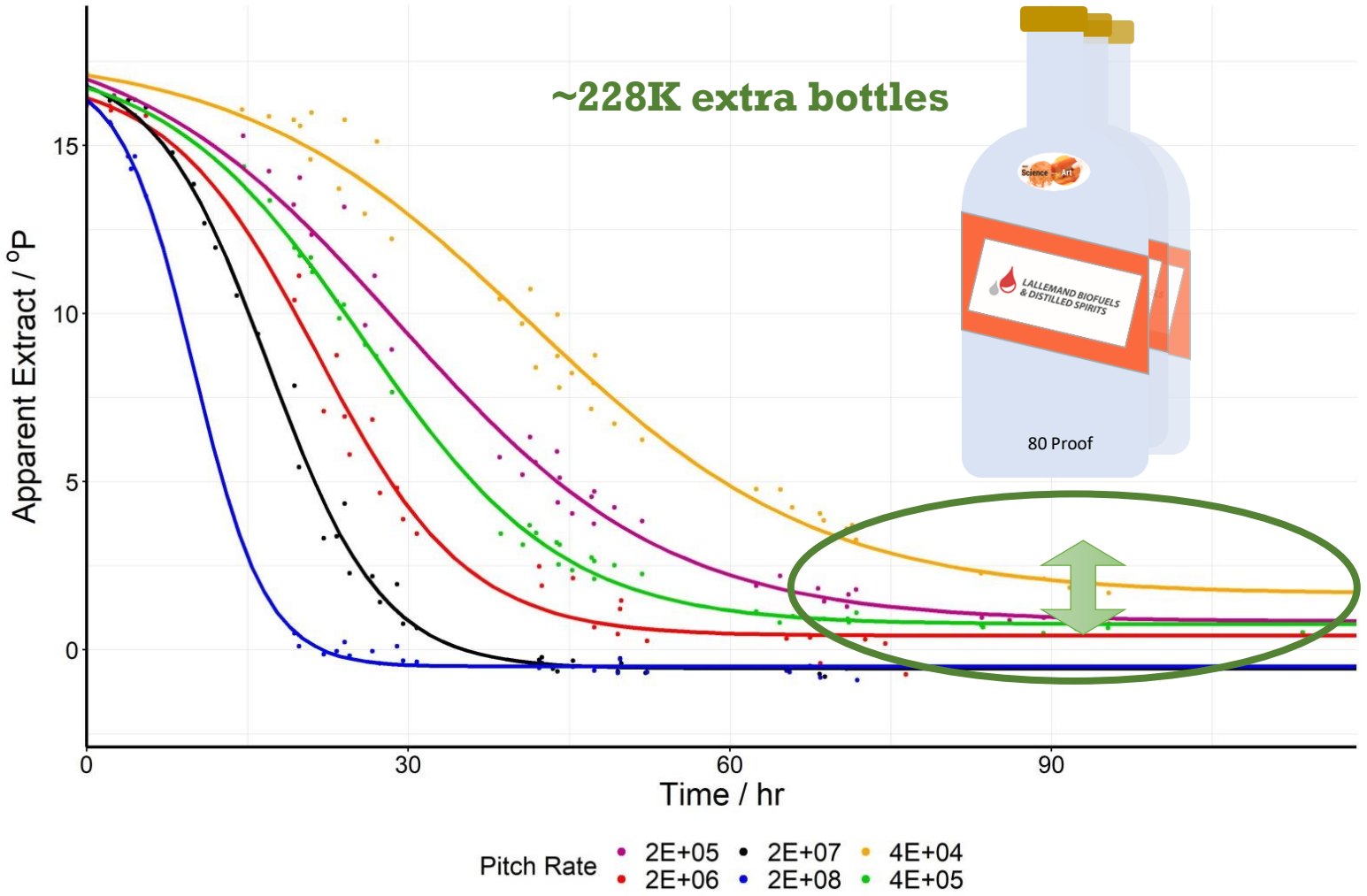
# Effect of Pitching Rate on Kinetics

| Liquid | |
|---|---|
| Most underpitched | 4 x$10^4$ cells $mL^{-1}$ |
| Very underpitched | 2 x$10^5$ cells $mL^{-1}$ |
| More underpitched | 4 x$10^5$ cells $mL^{-1}$ |
| Underpitched | 2 x$10^6$ cells $mL^{-1}$ |
| Control | 2 x$10^7$ cells $mL^{-1}$ |
| Overpitched | 2 x$10^8$ cells $mL^{-1}$ |

Increasing pitch-rate



# Fermentation Case Study

American Agave Fermentation

- **Going from a typical 5% to 12% abv fermentation**

- **How was this achieved? → Cater to the Biology**
  - Protocol Adjustments – Innovative protocol
  - Heavy nutrient loading
  - Heavy yeast loading (Correct strain had **huge** impacts here)
  - Treat our yeast well!
  - pH adjustments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# Fermentation Case Study

**Going from a typical 5% to 12% abv fermentation**

**Typical American Agave Ferm…**

- 2-3 wks long - High Labor and Overhead Cost + Energy
- 5-6% ABV, maybe 7% - High water and energy use per Liter EtOH
- Low efficiency Yield - Our input doesn't go as far.

**Charleston Distilling Agave Ferm…**

- 1wk long - <1/4 the labor/overhead per liter EtOH
- 12% ABV - <1/2 the water and energy use per L EtOH
- High Efficiency Yield - Input gets utilized to full potential

# Conclusion: Opportunities For Efficient Fermentation Management

**Distillers Can Cater to Yeast's Biology By Considering The Yeast Environment!**

- Equipment
- Efficient Mashing/Substrate preparation
- Yeast Choice & Pitch Rates
- Nutrition
- Mitigating Stressors

**Track your data!**

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# Thank you!

## Questions?

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