

# Fermentation Process Intensification

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## Process Intensification

- **Colin Ramshaw** is widely acknowledged as a pioneer in the field of **Process Intensification**
- Its objective was the development of chemical plants much smaller (intensification) and therefore cheaper than the existing
- **Ramshaw** ignored the existing equipment and started from beginning.



## Process Intensification

- In Bioprocesses:
  - Reduces energy consumption;
  - Increases the bioconversion rates;
  - Decreases the production of waste;
  - Improves the step of purification;
  - Decreases the size of equipment;

### **Increases the Company Sustainability**

- The study about processes intensification requires a wide and meticulous knowledge of all phenomena involved.

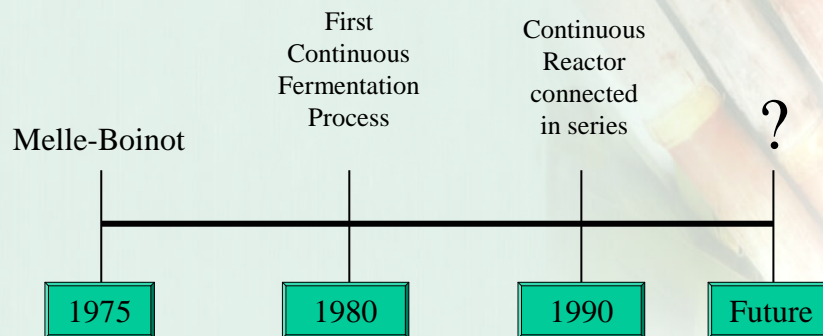


## Fermentation Process Intensification in BioEthanol Production



## Timeline

- The evolution of Brazilian Ethanol Production



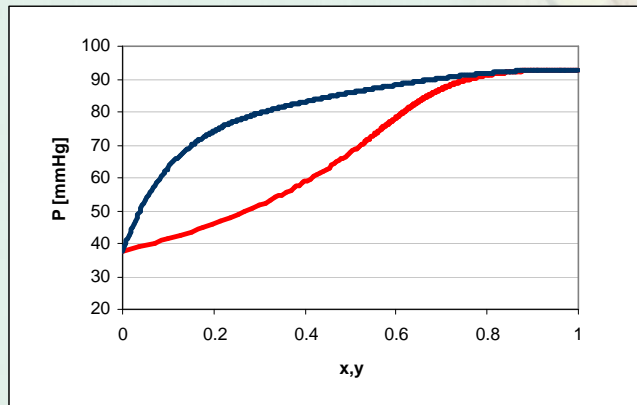
## Continuous Vacuum Extractive Process

- The ethanol is removed while it is produced;
- The ethanol concentration remains at low levels in the Fermentor;
- It reduces significantly the inhibition by ethanol concentration;
- The yeast becomes more productive due to low ethanol concentration in the medium.



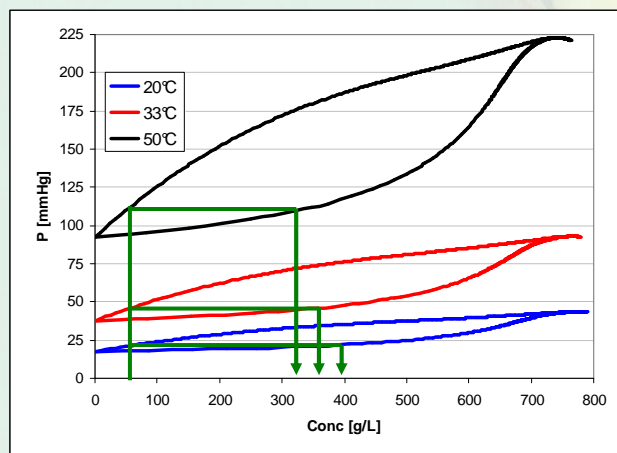
# Principle

- Liquid -Vapor Equilibrium Data (LVE) at 33°C



# Principle

- Liquid -Vapor Equilibrium Data (LVE) at 33°C



# The kinetics of fermentation

- From kinetic models with inhibition

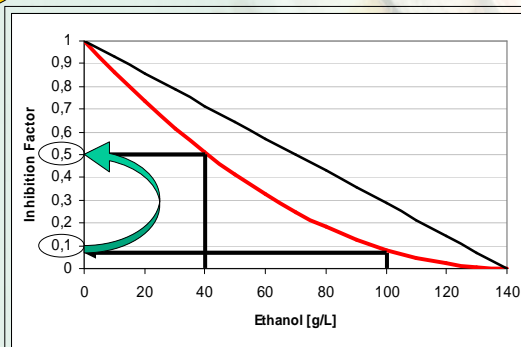
$$\mu = \mu_o \cdot \left( \frac{S}{Ks + S} \right) \cdot \left( 1 - \frac{P}{Pm} \right)^n \cdot \left( 1 - \frac{X}{Xm} \right)^m \cdot \exp(-Ki \cdot S)$$

$$IF = \left( 1 - \frac{P}{Pm} \right)^n$$

Pm=140 g/L

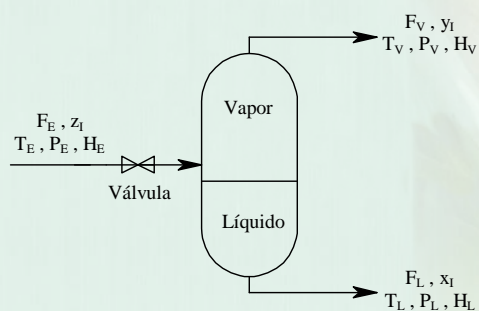
n=2.0 (red)

n=1.0 (dark)

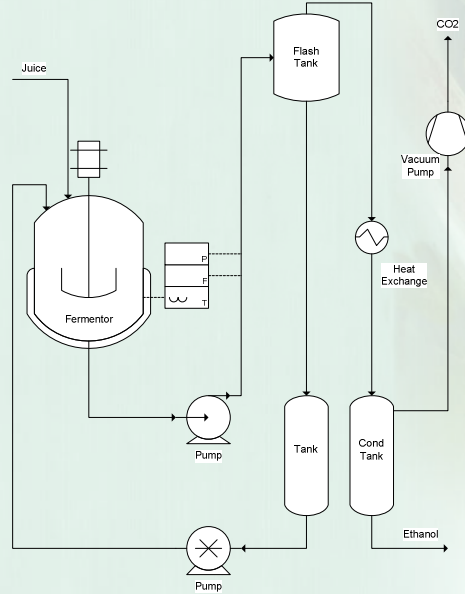


# Vacuum Flash Tank

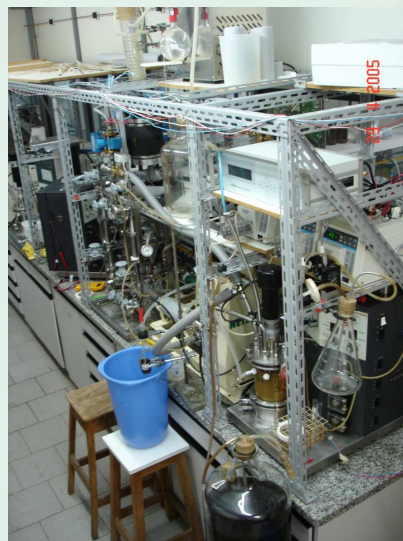
- Principle of Operation



# Prototype Developed



# Prototype Developed

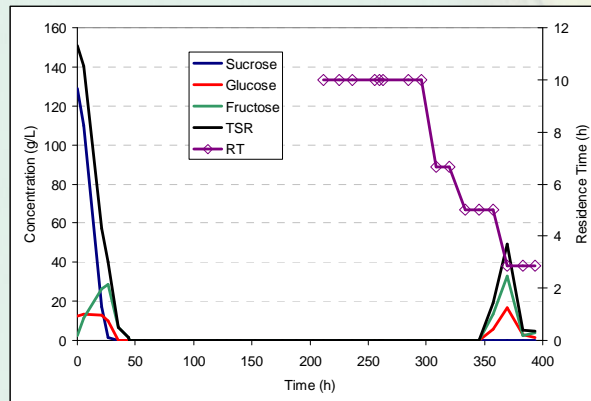


Laboratory Scale  
Unicamp



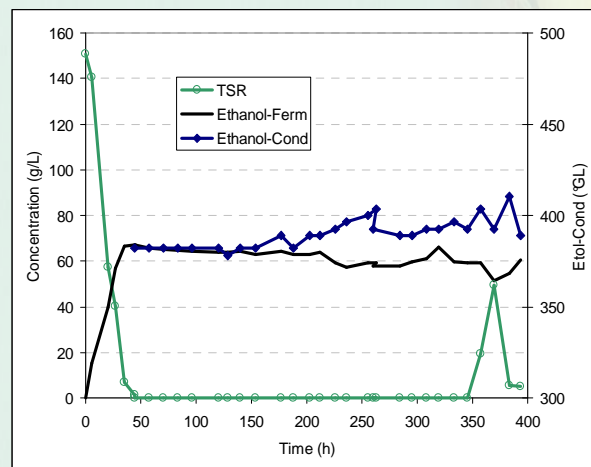
## Experimental Trials

- Sucrose, glucose, fructose, TSR, RT



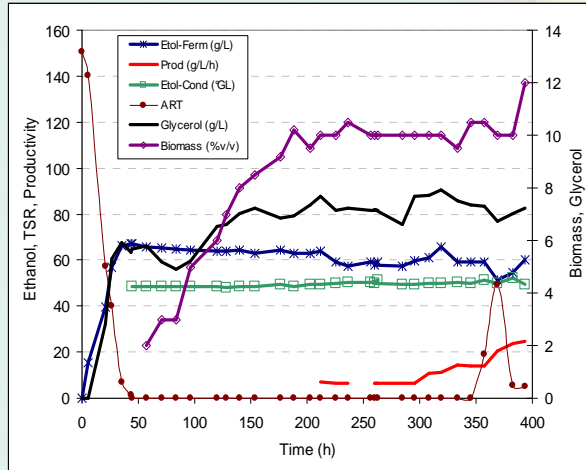
## Experimental Trials

- Ethanol



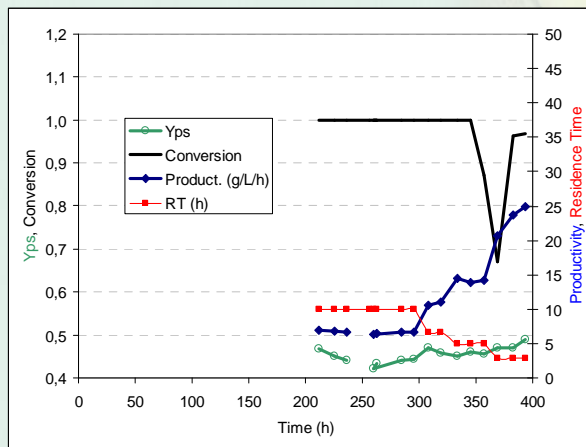
# Experimental Trials

- General Overview



# Experimental Trials

- Conversion, Yield and Residence Time



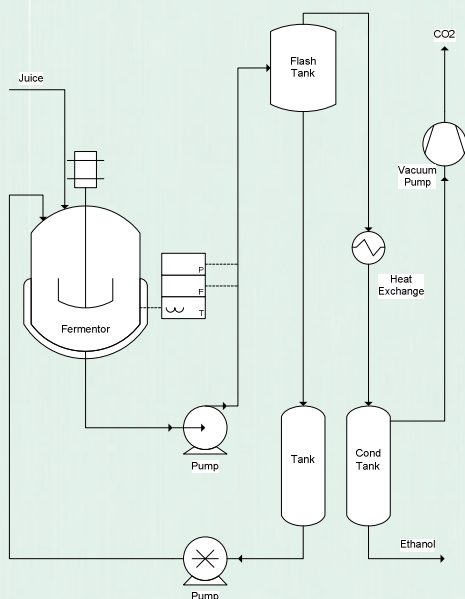


## Positive Aspects

- The juice can be feed in the Fermentor at least 3 times more concentrated;
- More productive process: at least 3 times;
- Reduction of vinasse (waste) production ;
- More compact and economical Plants;
- Reduction or Elimination of heat exchangers;
- Alcohol Production of 50°GL from vapor phase condensation implies in eliminating one distillation column.
- Equivalent to a traditional process with an alcohol content of 20° GL



## Pilot Plant – Pedra Mill



# Process Intensification

19<sup>th</sup> European Symposium on Computer Aided Process Engineering – ESCAPE19  
J. Jezowski and J. Thullie (Editors)  
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## Simulation and optimization of the continuous vacuum extractive fermentation for bioethanol production and evaluation of the influence on distillation process

Tassia L. Junqueira,<sup>a</sup> Marina O. S. Dias,<sup>a</sup> Maria R. W. Maciel,<sup>a</sup> Rubens Maciel Filho,<sup>a</sup> Carlos E. V. Rossell,<sup>b</sup> Daniel I. P. Atala<sup>c</sup>

<sup>a</sup> School of Chemical Engineering, State University of Campinas, UNICAMP, P. O. Box 6066, 13083-970, Campinas – SP, Brazil, [tassia@eq.unicamp.br](mailto:tassia@eq.unicamp.br)

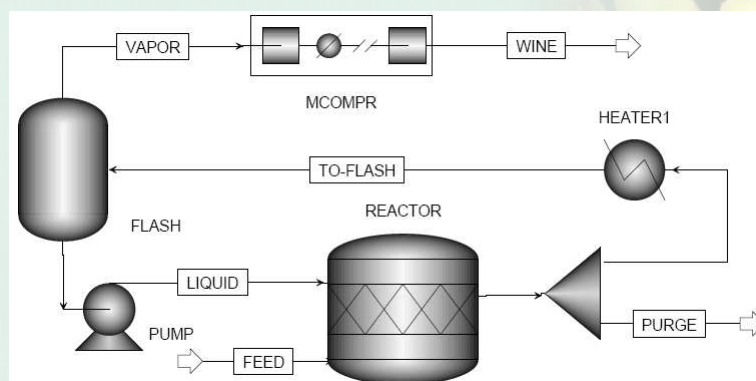
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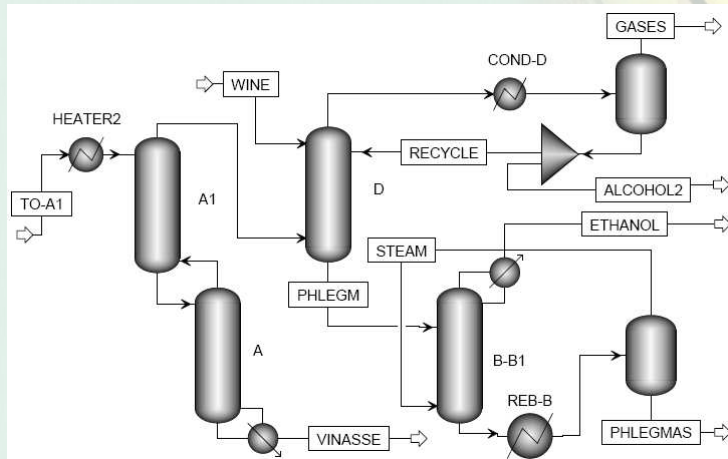
# Process Intensification

ASPEN simulation



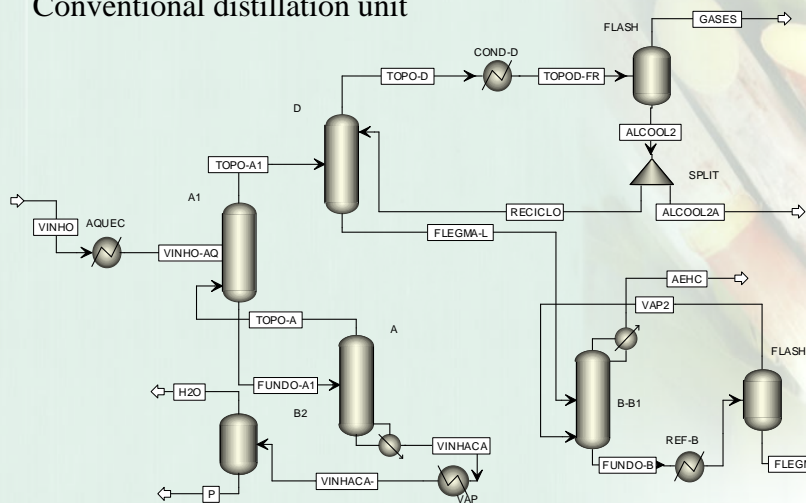
# Process Intensification

Integrated with distillation unit



# Process Intensification

Conventional distillation unit



# *Process Intensification*

## Energy Balance

Vacuum Extractive fermentation		Conventional process	
Equipment	Energy (MJ/h)	Equipment	Energy (MJ/h)
Heater2	10.0	Heater2	128.1
Column A reboiler	22.7	Column A reboiler	236.2
Column B reboiler	120.4	Column B Reboiler	149.0
Heater1	117.0	Evaporator	907.8
Total	270.1	Total	1421.1
<b>Energy Savings</b>	<b>80%</b>		



# Rethinking the process

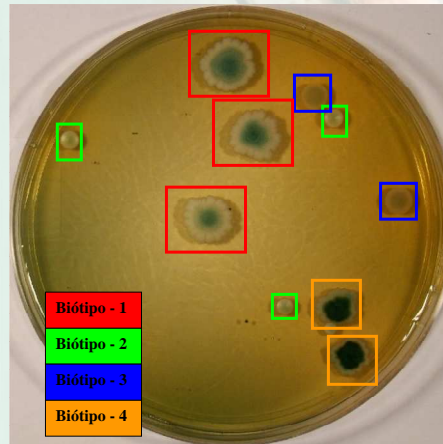
New Challenges!



## CTC Culture Collection



Over 1200 yeast strain  
Over 700 bacteria strain



## FAPESP – BIOEN

- The contributions of microwave energy and ultrasound in the improvement of ethanol industrial production process from sugarcane
  - Prof. Dr. Antonio Marsaioli Junior (coordinator)
    - GEPC/ITAL;
    - CTC



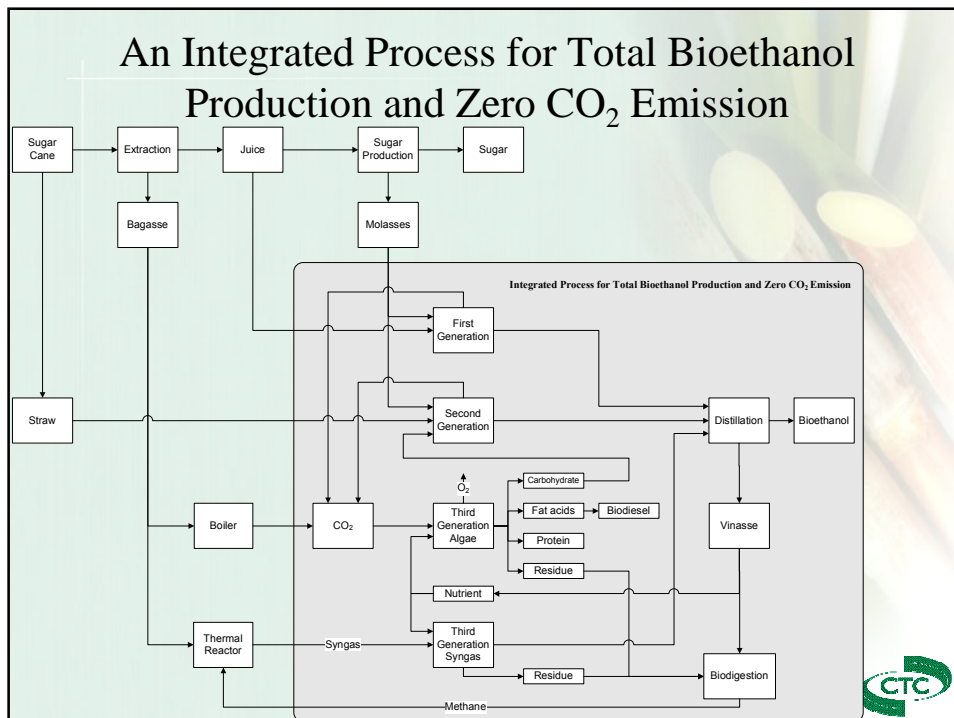


## FAPESP – BIOEN (PRONEX)

- An Integrated Process for Total Bioethanol Production and Zero CO<sub>2</sub> Emission

– Prof. Dr. Rubens Maciel Filho (coordinator)

- FEQ/Unicamp;
- FEA/Unicamp;
- FURG;
- Unesp Araraquara
- CTC



Thank You!

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