Industrial Yeast Production with Corn Derived Sugars

DEPARTMENT OF CHEMICAL & BIOMOLECULAR ENGINEERING

Team 2

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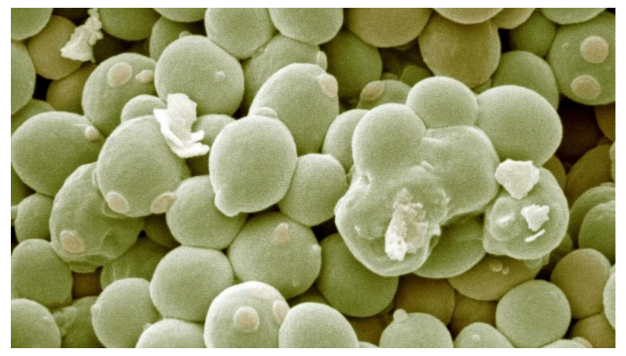
Introduction

- Food insecurity is a widespread issue with few solutions
- Yeast-based foods provide a cost-effective yet nutritious solution.
- Yeast bioreactors typically use molasses as a sugar source which must be imported from other countries to the United States
- Corn is the most widely produced crop in the United States



***Saccharomyces cerevisiae* (Baker's Yeast)**

Objective: Process corn for use as a sugar source for industrial yeast production

Equations and Models

Kinetic rate laws used in the bioreactor model

- r1 = Sugar Fermentation
- r2 = Ethanol Oxidation
- r3 = Sugar Oxidation

$$r_1 = \mu_{1,max} \frac{e_1}{e_{1,max}} \frac{S_1}{K_1 V_L + S_1}$$

$$r_2 = \mu_{2,max} \frac{e_2}{e_{2,max}} \frac{S_2}{K_2 V_L + S_2} \frac{Ox}{K_{Ox} + Ox}$$

$$r_3 = \mu_{3,max} \frac{e_3}{e_{3,max}} \frac{S_1}{K_3 V_L + S_1} \frac{Ox}{K_{Ox} + Ox}$$

$$\frac{dX}{dt} = (\sum_i (r_i v_i))X$$

$$\frac{dS_1}{dt} = F_{in} s_1^0 - (\frac{r_1 v_1}{Y_1} + \frac{r_3 v_3}{Y_3})X$$

$$\frac{dS_2}{dt} = (\phi_1 \frac{r_1 v_1}{Y_1} - \frac{r_2 v_2}{Y_2})X$$

$$\frac{dV_L}{dt} = F_{in}$$

Mass Balances for sugar, ethanol, and total liquid volume

where:
X = yeast mass
ri = rate of enzyme i
vi = enzyme concentration

$$\frac{d(e_1/e_{1,max})}{dt} = (\mu_{1,max} + \beta)(1 - \varepsilon + \varepsilon u_1 \frac{S_1}{K_1 V_L + S_1}) - (\sum_{j=1,3} r_j v_j + \beta)(\frac{e_1}{e_{1,max}})$$

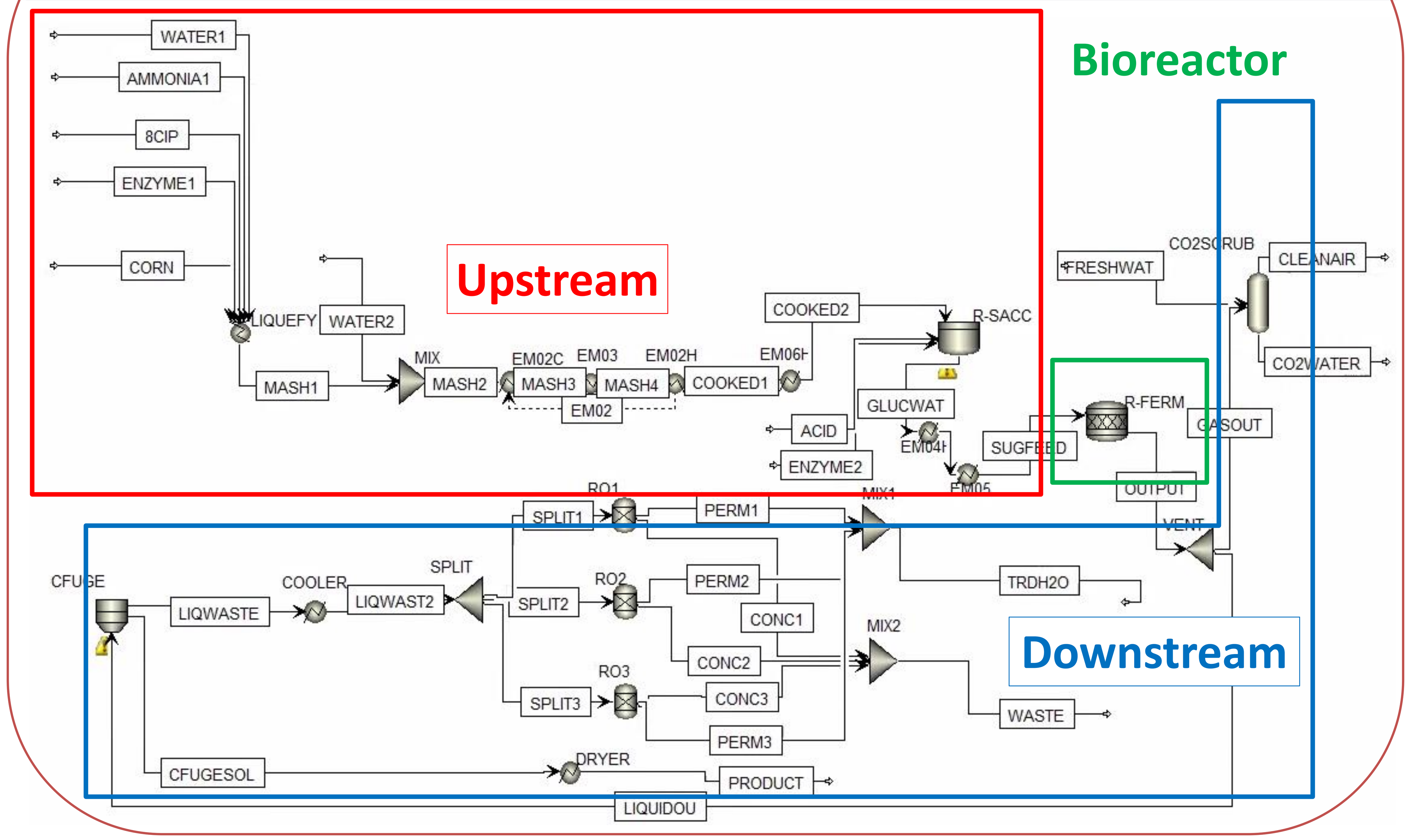
$$\frac{d(e_2/e_{2,max})}{dt} = (\mu_{2,max} + \beta)(1 - \varepsilon + \varepsilon u_2 \frac{S_2}{K_2 V_L + S_2} \frac{Ox}{K_{Ox} + Ox}) - (\sum_{j=1,3} r_j v_j + \beta)(\frac{e_2}{e_{2,max}})$$

$$\frac{d(e_3/e_{3,max})}{dt} = (\mu_{3,max} + \beta)(1 - \varepsilon + \varepsilon u_3 \frac{S_1}{K_3 V_L + S_1} \frac{Ox}{K_{Ox} + Ox}) - (\sum_{j=1,3} r_j v_j + \beta)(\frac{e_3}{e_{3,max}})$$

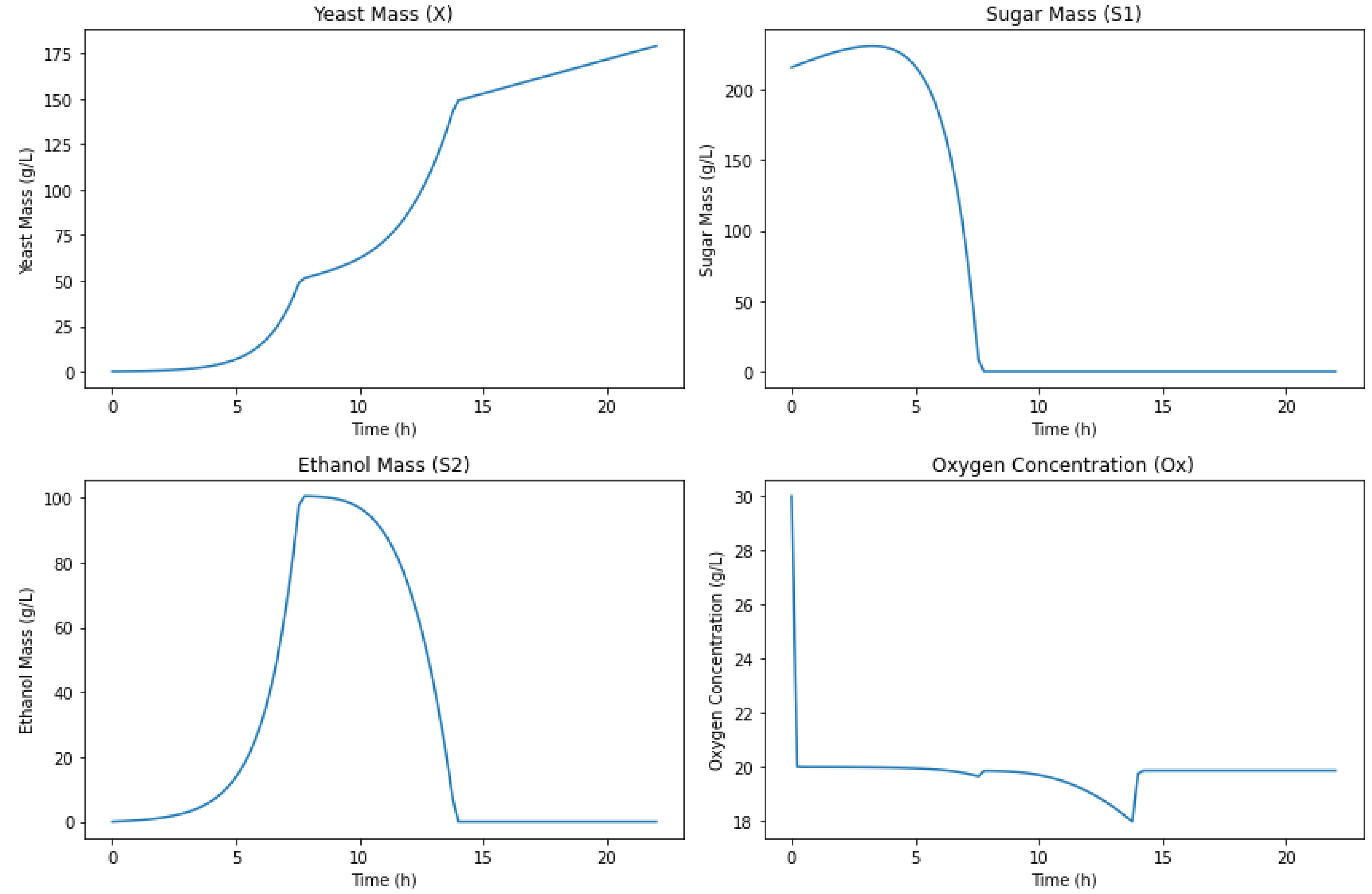
$$\frac{dOx}{dt} = k_L a(Ox^* - Ox) - (\phi_2 \frac{r_2 v_2}{Y_2} + \phi_3 \frac{r_3 v_3}{Y_3}) \frac{X}{V_L}$$

Balances for relative enzyme concentrations

Process Flow Diagram



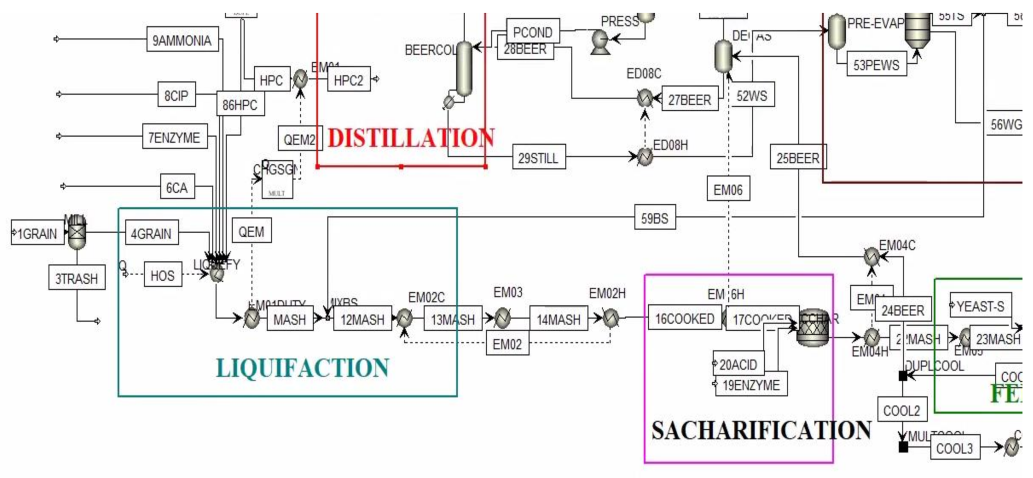
Design Calculations



Result of the Python Code model for Simulating Yeast Kinetics.

Process Description

1.) Upstream – Aspen Plus



Aspen Plus Bioethanol from Corn Model

- **Liquefaction:** Initiates breakdown of complex polysaccharides into smaller sugar chains.
- **Saccharification:** Main hydrolysis, both enzymatic and weak-acidic

2.) Yeast Bioreactor – Python

$$18.42\, O_2 + 2.24\, NH_3 + 5.42\, C_6H_{12}O_6 \rightarrow 13.17\, CH_{1.81}O_{0.51}N_{0.17} + 19.34\, CO_2 + 23.95\, H_2O$$

3.) Downstream – Aspen Plus

- **Centrifuge:** Removes yeast from growth broth
- **Filtration:** Separates yeast from any process contaminants
- **Dryer:** Removes any excess water from the final product

4.) Design Alternatives

- CO2 Absorption Column
- Corn Stover Sugar Source

Results

- 8,000 kg/hr of dry yeast using proven upstream and downstream methods
- 6,000,000 L water for CO_2 scrubbing to reduce emissions from 1.2% to 507 ppm
- Financial analysis projects a $44 million annual profit and 33% ROI

References

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4. Yeast, Explore. "What Is Saccharomyces Cerevisiae?" Explore Yeast, 4 May 2023, www.exploreyeast.com/what-is-yeast/what-is-saccharomyces-cerevisiae/.