Investigating the Possible Correlation between Nitrogen Concentration and CO_2 Production

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BIOL398-05/MATH388-01
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Outline

- The Environment Affects Fermentation
- Hypothesis: Nitrogen Concentration and Fermentation are Positively Correlated
- Model Attempts to Relate ter Schure et al. (1995) and Albertin et al. (2011)
- CO_2 May Not Directly Correlate With Nitrogen
- Re-evaluated Equations are Needed For This Population

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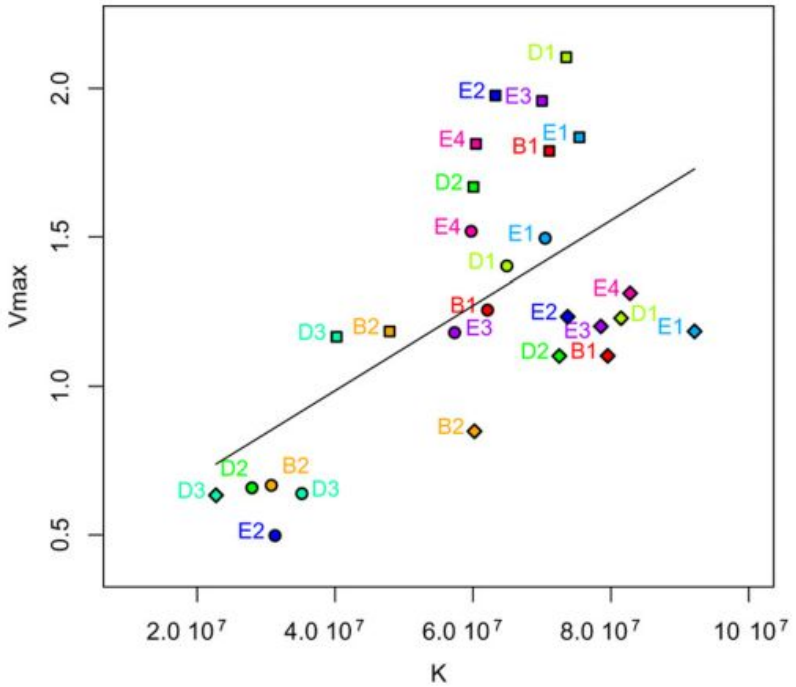
The Environment is the Main Factor Shaping Alcoholic Fermentation

- **In their study, Albertin et al. (2011) found positive correlations between V_{max} (maximal CO2 production rate) and carrying capacity (K), nitrogen consumption and K, and biomass and K.**



Albertin et al. (2011) *Applied and Environmental Microbiology* 77(8)

Population Size Drives *S. Cerevisae* Fermentation

- **Albertin et al. (2011) also found that increasing the carrying capacity, thus increasing the yeast biomass, increases the fermentative ability of the yeast.**
  - **This then leads to increased CO2 production and increased glucose/nitrogen consumption**

Image courtesy of: https://ntgreenchemblog.wordpress.com/2013/10/14/lesson-5-bioethanol-and-biodiesel/

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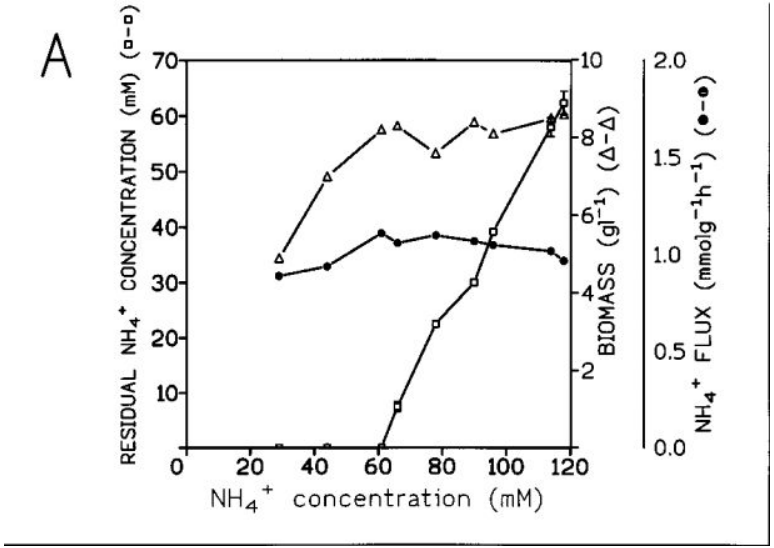
Positive Correlation Between Nitrogen Concentration and Fermentation

- As in ter Schure et al. (1995), increasing the concentration of ammonia (nitrogen) will increase the biomass of the yeast.
  - The increase in yeast biomass will lead to the increase in CO_2 production (fermentation) seen in Albertin et al. (2011).



ter Schure *et al.* (1995) *J. Bacteriology* 177(22)

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Other Environmental Factors are Excluded

- **The main simplifying assumption is that the fermentative ability (CO_2 production) is directly affected by nitrogen concentration, glucose concentration, the rate of CO_2 production, and biomass.**
  - **All other factors were excluded from the model for simplification purposes**

Model Attempts to Visualize Relationship Between Variables

- q = Dilution rate
- u1 = [nitrogen fed into reactor]
- u2 = [glucose fed into reactor]
- K = metabolic constant
- V = volume
- Z = CO2 production rate
- y = concentration of yeast (Biomass)
- c1 = [nitrogen]
- c2 = [glucose]

Ammonia Concentration (g/L)

$$\frac{dc_1}{dt} = qu_1 - qc_1 - yV\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right)$$

Glucose Concentration (g/L)

$$\frac{dc_2}{dt} = qu_2 - qc_2 - yV\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right)$$

Biomass (g/L)

$$\frac{dy}{dt} = yR\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right) - qy$$

CO_2 Production Rate (g L-1 h-1)

$$\frac{dV}{dt} = Z\left(1 - \frac{Z}{y}\right)V$$

Steady State Indicates Equilibrium

- **These equations indicate the steady states equilibrium values of the system.**
  - **The state variables are constant.**

Ammonia Concentration (g/L)

$$c_1^* = u_1 - \frac{V}{R} y^*$$

Glucose Concentration (g/L)

$$c_2^* = u_2 - \frac{V}{R} y^*$$

Biomass (g/L)

$$\frac{q}{R} = \frac{c_1}{K_1 + c_1} \frac{c_2}{K_2 + c_2}$$

CO_2 Production Rate (g L-1 h-1)

$$Z = y$$

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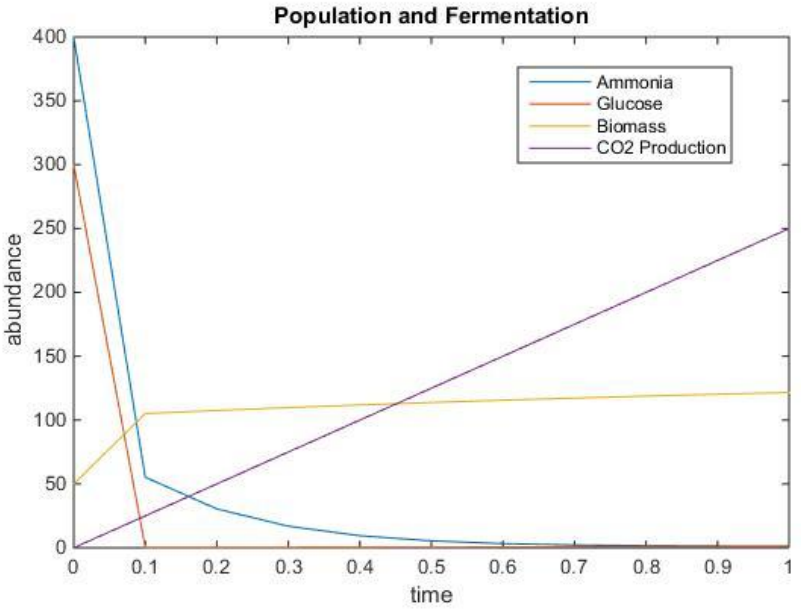
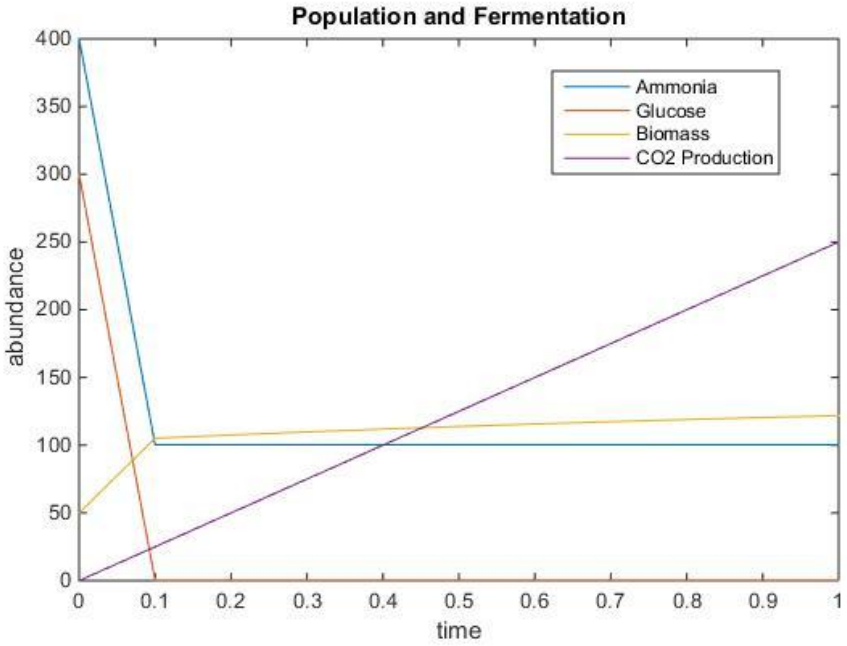
Hypothesis Appears to be Accurate at First Glance

- As the biomass (yeast population) increases, the CO_2 production increases.
  - The correlation found by Albertin et al. (2011) is modeled.
- What happens when the nitrogen concentration (u_1) is doubled?



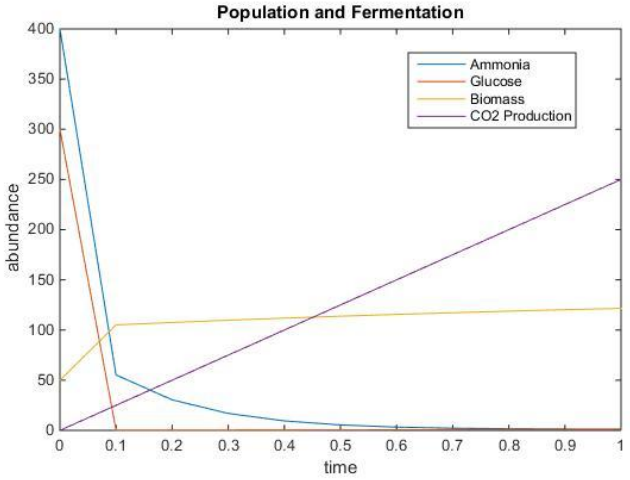
Doubling the Nitrogen Concentration Does Not Affect CO_2 Production

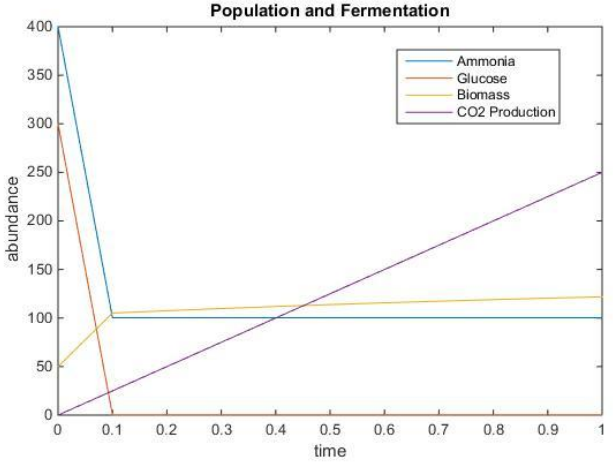
- When u_1 is doubled from 100 to 200, there is no change in CO_2 production, or anything else.
- The model may not be accurate.



The Model Does Not Align With ter Schure et al. (1995) as Hypothesized

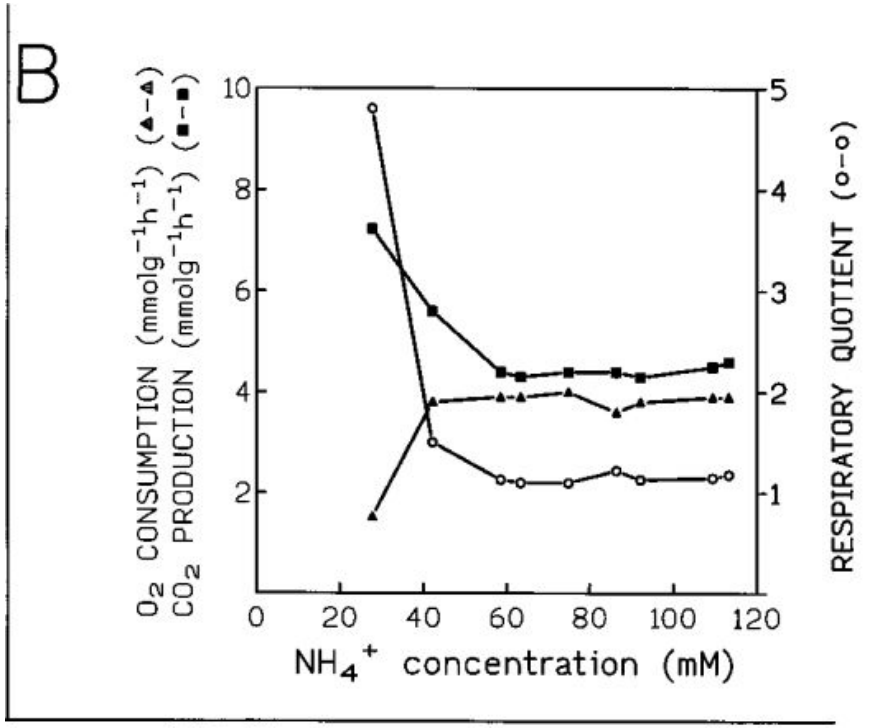
- Increasing the nitrogen concentration has no effect on the biomass.
  - This is contrary to what ter Schure et al. (1995) observed.





CO2 Production Activity Resembles ter Schure et al.

- ter Schure et al. (1995): CO_2 production did not change with increasing ammonia.
- Albertin et al. (2011): Increasing biomass increases CO_2 production
- The link between ammonia and biomass perhaps cannot be made.



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Re-Evaluation of Equations May Improve Model

- **Further studies may be required in order to improve understanding of the model.**
  - **How exactly does CO_2 fit in with ammonia and glucose?**

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$$\frac{dc_1}{dt} = qu_1 - qc_1 - yV\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right)$$

Glucose Concentration (g/L)

$$\frac{dc_2}{dt} = qu_2 - qc_2 - yV\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right)$$

Biomass (g/L)

$$\frac{dy}{dt} = yR\left(\frac{c_1}{K+c_1}\frac{c_2}{K+c_2}\right) - qy$$

CO_2 Production Rate (g L-1 h-1)

$$\frac{dV}{dt} = Z\left(1 - \frac{Z}{y}\right)V$$

Acknowledgements

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References

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