

Temperature Dependence and Nutrient Use Efficiency of Chemostat Reaction

Austin Joseph Dias and Sahil Patel

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BIOL 388-01

Outline

- Background information on Tai et al. (2007) paper
- Chemostat conditions established in Tai et al. (2007)
- Our modeling objectives
- Methods for accomplishing our objectives
- Description of parameters used in differential equations within model
- Solving for activation energy and frequency factor constant
- Evaluating and modeling efficiency as a function of residual glucose
- Discuss implications of findings
- Reflect on experimental process and results

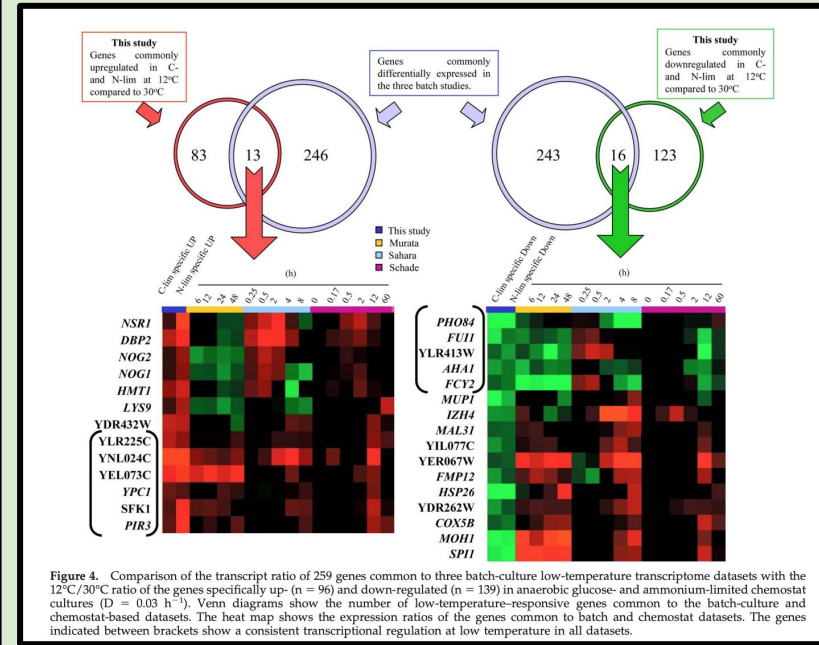
Tai et al. (2007) Background Information

- Evaluated gene transcriptional response to low temperature in *Saccharomyces cerevisiae* using chemostate method
- Stated that chemostat was more effective for this study
 - Transcriptional responses to low temperature and low specific growth rate can be separated by using chemostat cultures instead of batch cultures



Tai et al. (2007) Main Findings and Conclusions

- The only indistinguishable group of genes that was similarly regulated in low-temperature chemostats and batch culture studies on low-temperature adaptation were related to lipid metabolism
- Trehalose is not involved in steady-state low-temperature adaptation
- Transcript levels of environmental stress response genes were reduced at 12 C
- It is important to differentiate phases of physiological adaptation in response to environmental change
- Response to low temperatures by *S. cerevisiae* is not entirely dependent on changes in transcription



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Tai et al. (2007) Chemostat Conditions

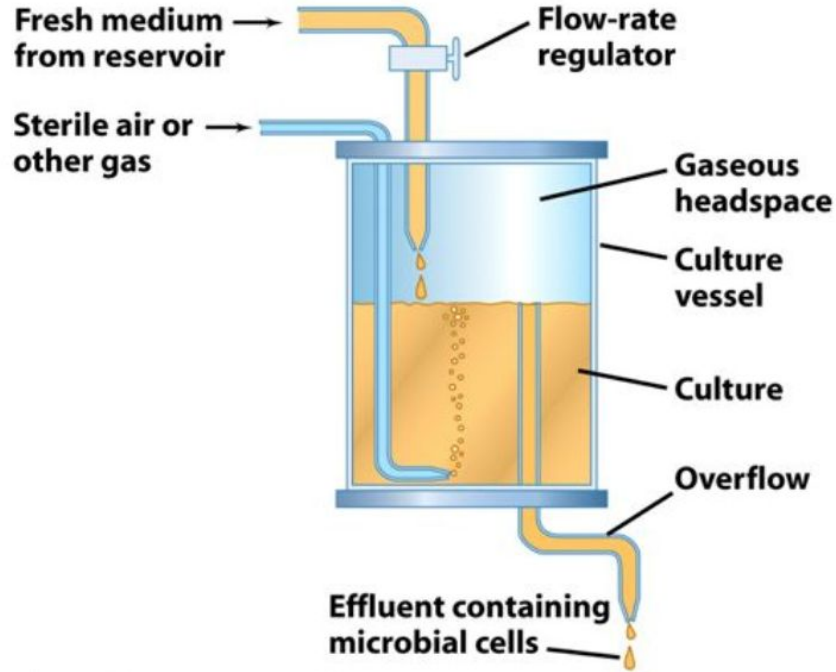


Figure 6-13 Brock Biology of Microorganisms 11/e
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- Anaerobic conditions
- 1 L culture solution
- Allowed system to reach steady state before collecting data

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Modeling Objectives

1. Identify the activation energy 'b' and frequency factor constant 'a' using the arrhenius equation:

$$r = ae^{-\frac{b}{RT}}$$

2. Determine if efficiency of nutrient to biomass conversion is dependent on residual glucose. If so, construct a function of efficiency in terms of residual glucose

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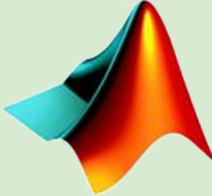
Methods

Obtained parameters
from Tai et al. (2007)

Established model for two
nutrient chemostat and
input parameters from Tai
et al. (2007)

$$\begin{aligned} r_y &= r^*(y/(K+y))*(z/(L+z)) \\ dxdt &= (r_y)*x - q*x \\ dydt &= q*(u - y) - ep*r_y*x \\ dzdt &= q*(v - z) - fp*r_y*x \end{aligned}$$

Solved for activation energy
and frequency factor constant
to find specific growth rate
using arrhenius equation at
15, 20, and 25 C



MATLAB

Developed function for
efficiency of glucose
conversion to biomass
as a function of residual
glucose, to determine if
there was any change
from the original model

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Parameter Descriptions

$r \rightarrow$ specific growth rate

$E \rightarrow$ efficiency of conversion from glucose to biomass

$F \rightarrow$ efficiency of conversion from ammonia to biomass

$q \rightarrow$ dilution rate

$u \rightarrow$ glucose feed concentration

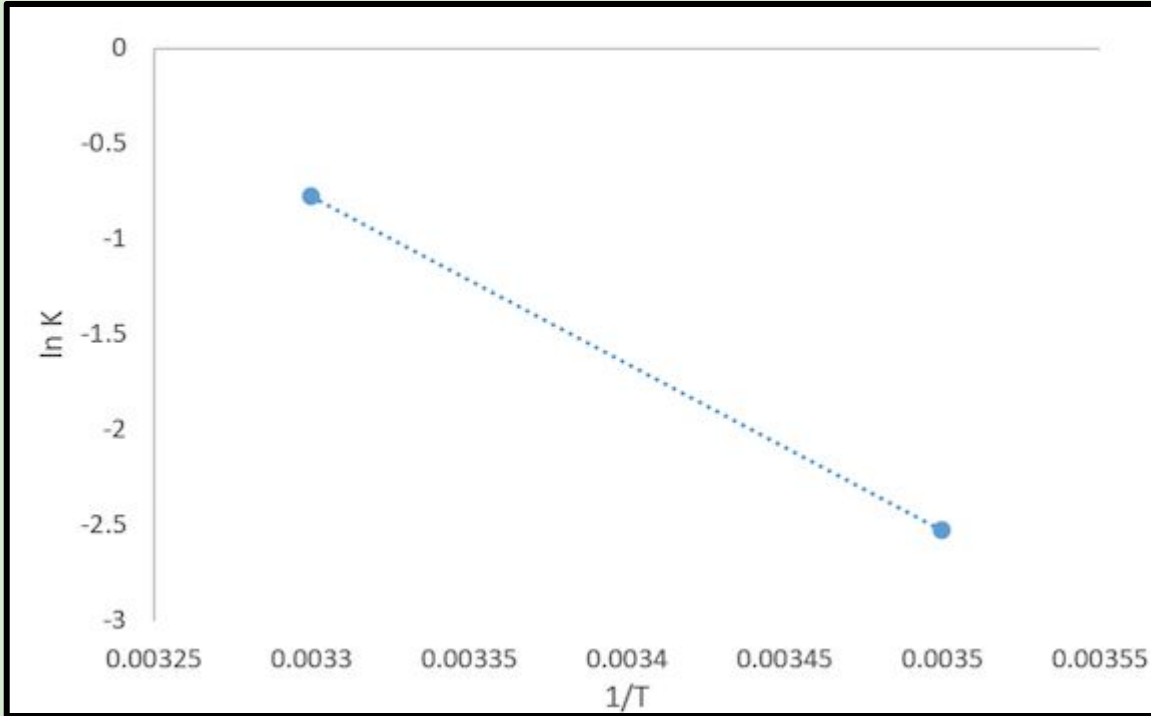
$v \rightarrow$ ammonium feed concentration

$K, L \rightarrow$ substrate concentration when the reaction velocity is equal to 1/2 of the max velocity for the reaction

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Solving for Ea ('B') and Frequency Factor Constant ('A')



Slope of $\ln k$ vs $1/T = -8400.36$

Slope = $-E_a/R = B/R$

$B = 69,840.59$

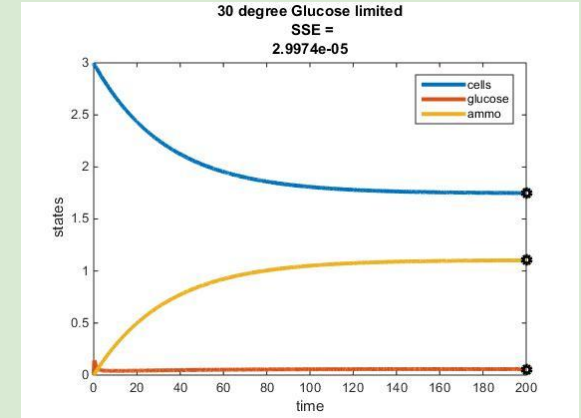
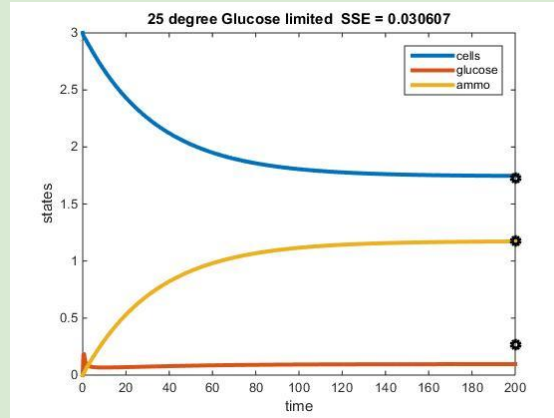
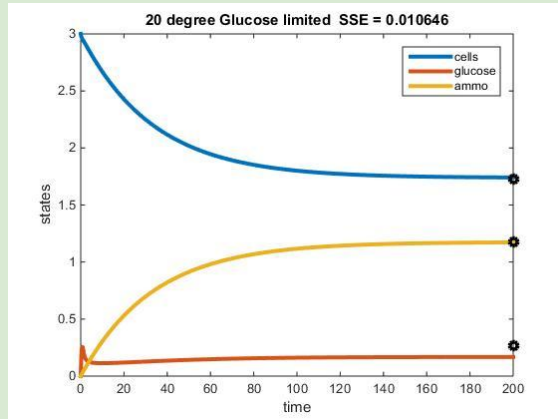
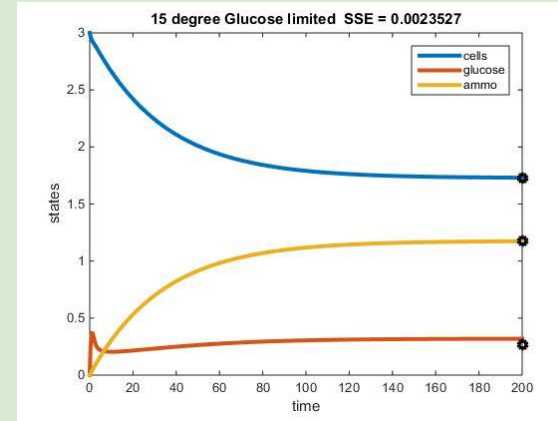
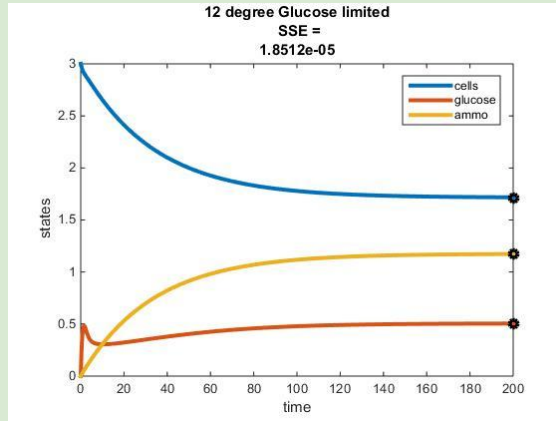
rate = $ae^{-\frac{b}{RT}}$

$A = 4.979 \times 10^{11}$

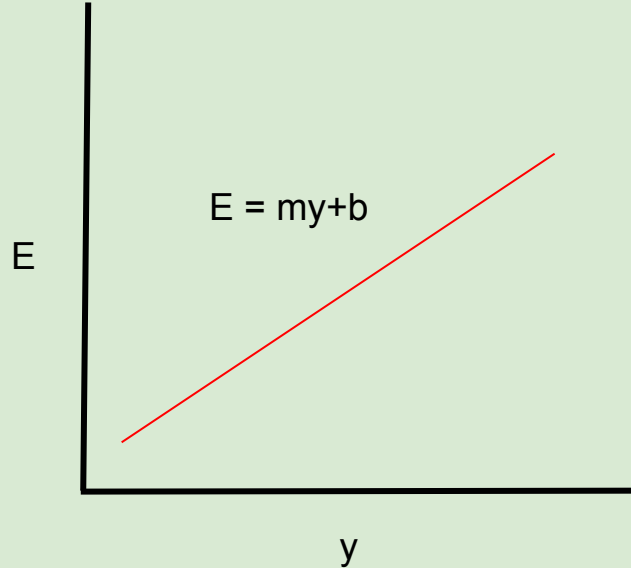
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Applying Growth Rates for Glucose Limited at Varying Temperature



Efficiency as a Function of 'y' (Residual Glucose)



- Assumed relationship between efficiency and residual glucose was linear
- Used point slope formula to solve for slope
- Inputted back into y - intercept formula to solve for b

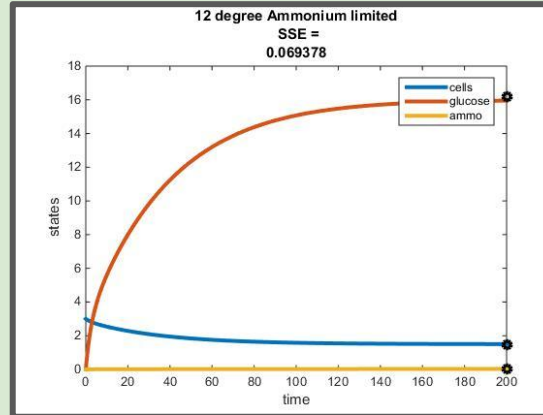
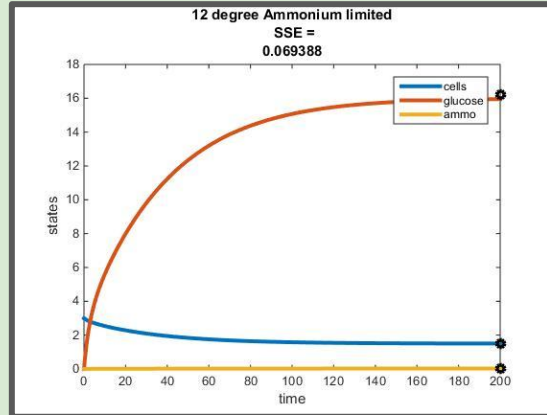
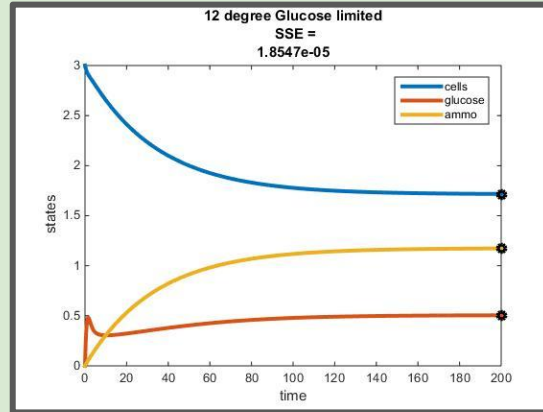
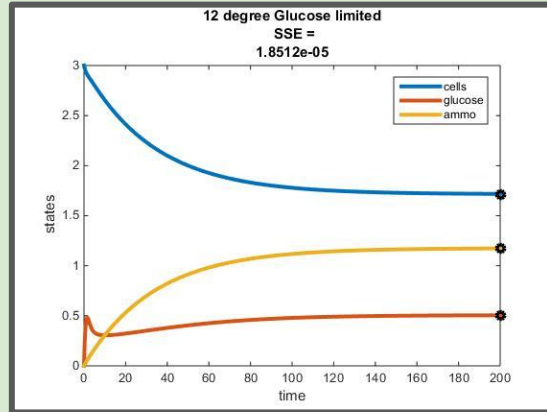
12 C

- $E = 0.363y + 14.107$

30 C

- $E = 0.7004y + 14.252$

Comparing Adjusted Efficiency to Original Model at 12 C

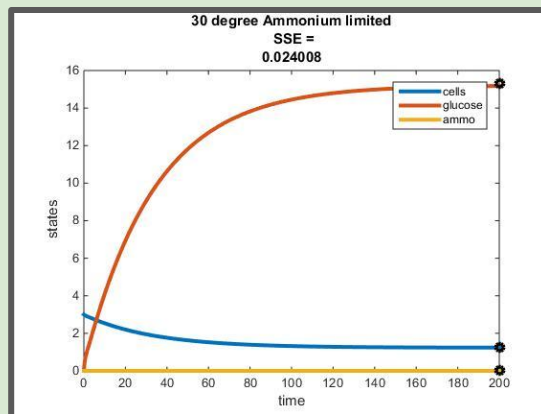
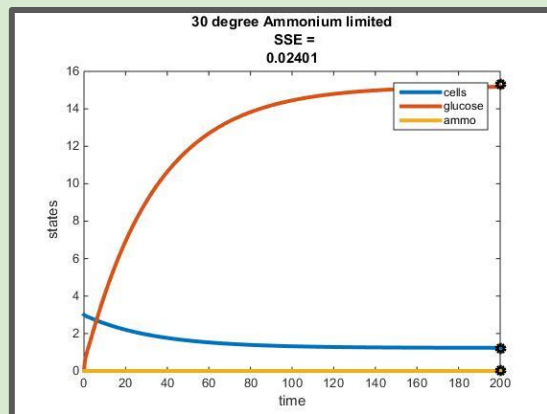
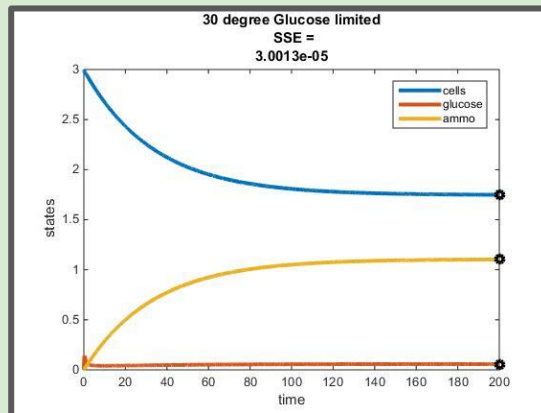
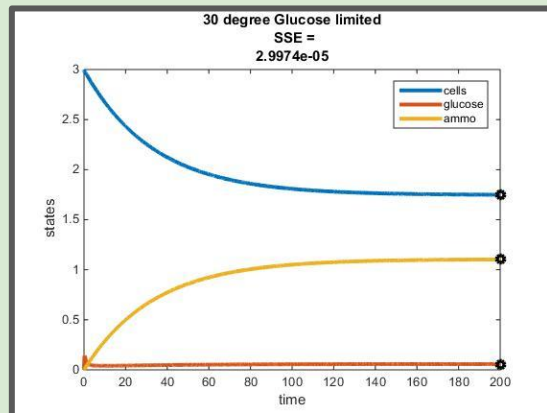


Original

Adjusted

- No significant difference between original model with E denoted as $1/Y$ compared to E as a function residual glucose at 12 C

Comparing Adjusted Efficiency to Original Model at 30 C



Original

Adjusted

- No significant difference between original model with E denoted as $1/Y$ compared to E as a function residual glucose at 30 C

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Discussion

- Both original and adjusted model show steady state being reached after 100 hours, contradicting our initial calculation
- Defining efficiency of the conversion of glucose to biomass as a function of residual glucose did not improve the accuracy of the model
- The sharp increase in glucose concentration upon starting the chemostat followed by an abrupt decrease in the glucose limited culture may reflect fast rate of glucose consumption followed by slower consumption as glucose levels decrease
- When glucose is in excess, glucose consumption rate does not reduce the concentration of glucose, as in glucose limited conditions
 - Suggests glucose is a more valuable nutrient for yeast utilization

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Reflection

- Tai et al. (2007) did not provide sufficient information to model the chemostat conditions used to obtain their results
 - Did not specify maximum growth rate (r) which was required for our model
- Include equations for carbon dioxide and ethanol to determine if they have an effect on efficiency of conversion of nutrients to biomass\
- Investigate sharp increase in glucose concentration upon starting the chemostat followed by an abrupt decrease in the glucose limited culture at 30C

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References

Activation Energy. (n.d.). Retrieved from <https://www.chem.fsu.edu/chemlab/chm1046course/activation.html>

Dahlquist, K. and Fitzpatrick, B. (2019). BIOL388/S19:Week 14/15. [online] openwetware.org. Available at: [\[\[BIOL388/S19:Week 14/15|Week 14/15 Assignment Page\]\]](#) [Accessed 21 Apr. 2019].

Tai, S. L., Boer, V. M., Daran-Lapujade, P., Walsh, M. C., de Winde, J. H., Daran, J. M., & Pronk, J. T. (2005). Two-dimensional transcriptome analysis in chemostat cultures combinatorial effects of oxygen availability and macronutrient limitation in *Saccharomyces cerevisiae*. *Journal of Biological Chemistry*, 280(1), 437-447.

Tai, S. L., Daran-Lapujade, P., Walsh, M. C., Pronk, J. T., & Daran, J. M. (2007). Acclimation of *Saccharomyces cerevisiae* to low temperature: a chemostat-based transcriptome analysis. *Molecular Biology of the Cell*, 18(12), 5100-5112.