Investigating the Temperature Dependency and Efficiency of *S. cerevisiae* Using MatLab

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Biology 388
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Outline

- Introduction of the chemostat problem of Tai et al (2007)

- Data extracted from the Tai paper (2005) & (2007)

- Methods used to investigate the model

- Temperature investigation

- Efficiency/waste investigation

- Conclusions

Chemostats are Useful for Controlling Variables

- "The chemostat is an experimental apparatus where the chemical environment can be maintained static and nutrient availability can be controlled by the experimenter." -ScienceDirect
- Chemostats can be used to investigate the differential utilization of fermentation at different metabolic rates.
- Tai paper experimented with a limiting nutrient- either Glucose (Carbon) or Ammonium (Nitrogen).
- Tai experiment done under anaerobic conditions.
- It is not possible to only change a single parameter without having an effect on any others, even using the chemostat culture approach rather than the batches.

Feed   Effluent
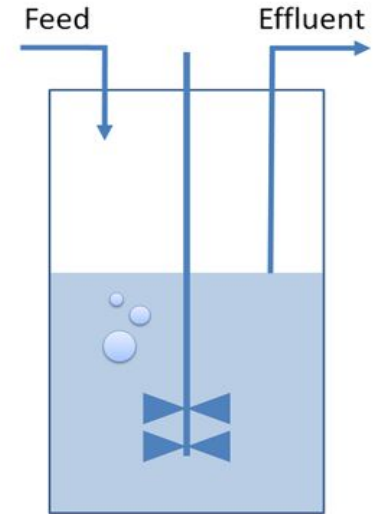
Inflow = outflow

Parameters Included in Tai et al

Table 1. Physiological characteristics of *S. cerevisiae* grown in ammonium- and glucose-limited anaerobic chemostat cultures

Limiting nutrient	Growth temperature (°C)	$Y_{Glu/X}$ ($g_{DW} \cdot g_{glucose}^{-1}$)	q_{Glu}[a]	q_{EtOH}[a]	q_{CO2}[a]	Carbon recovery (%)	Residual glucose (mM)	Residual ammonia (mM)
Glucose	12	0.07 ± 0.01	−2.5 ± 0.2	3.8 ± 0.3	4.4 ± 0.3	100 ± 3	2.8 ± 1.1	65.2 ± 2.2
Glucose	30	0.07 ± 0.00	−2.3 ± 0.0	3.5 ± 0.0	3.8 ± 0.2	95 ± 1	0.3 ± 0.1	61.3 ± 4.5
Ammonium	12	0.05 ± 0.00	−3.6 ± 0.2	6.1 ± 0.3	6.0 ± 0.6	97 ± 4	90.0 ± 9.8	1.5 ± 0.2
Ammonium	30	0.04 ± 0.00	−4.0 ± 0.1	6.8 ± 0.2	7.4 ± 0.2	97 ± 2	85.1 ± 8.2	0.2 ± 0.1

Cultures were grown at 30 and 12°C ($D = 0.03 \text{ h}^{-1}$). Values represent the mean ± SD of data from three independent steady-state chemostat cultivations. $Y_{Glu/X}$, biomass yield on glucose; DW, dry weight.

[a] Values expressed as $mmol \cdot g_{DW}^{-1} \cdot h^{-1}$.

*Did not know: r,k,L,F

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Parameters from Data Used to Define Unknowns

	12C Glucose Limiting	30C Glucose Limiting	12C Ammonium Limiting	30C Ammonium Limiting
T	285K	303K	285K	303K
r	0.08	0.46	0.08	0.46
A	$4.9*10^{11}$	$4.9*10^{11}$	$4.9*10^{11}$	$4.9*10^{11}$
B	$6.98*10^{4}$	$6.98*10^{4}$	$6.98*10^{4}$	$6.98*10^{4}$
E	14.2857	14.2857	20.0000	25.000
y	0.504	0.054	16.216	15.333

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Investigation of Chemostat Model
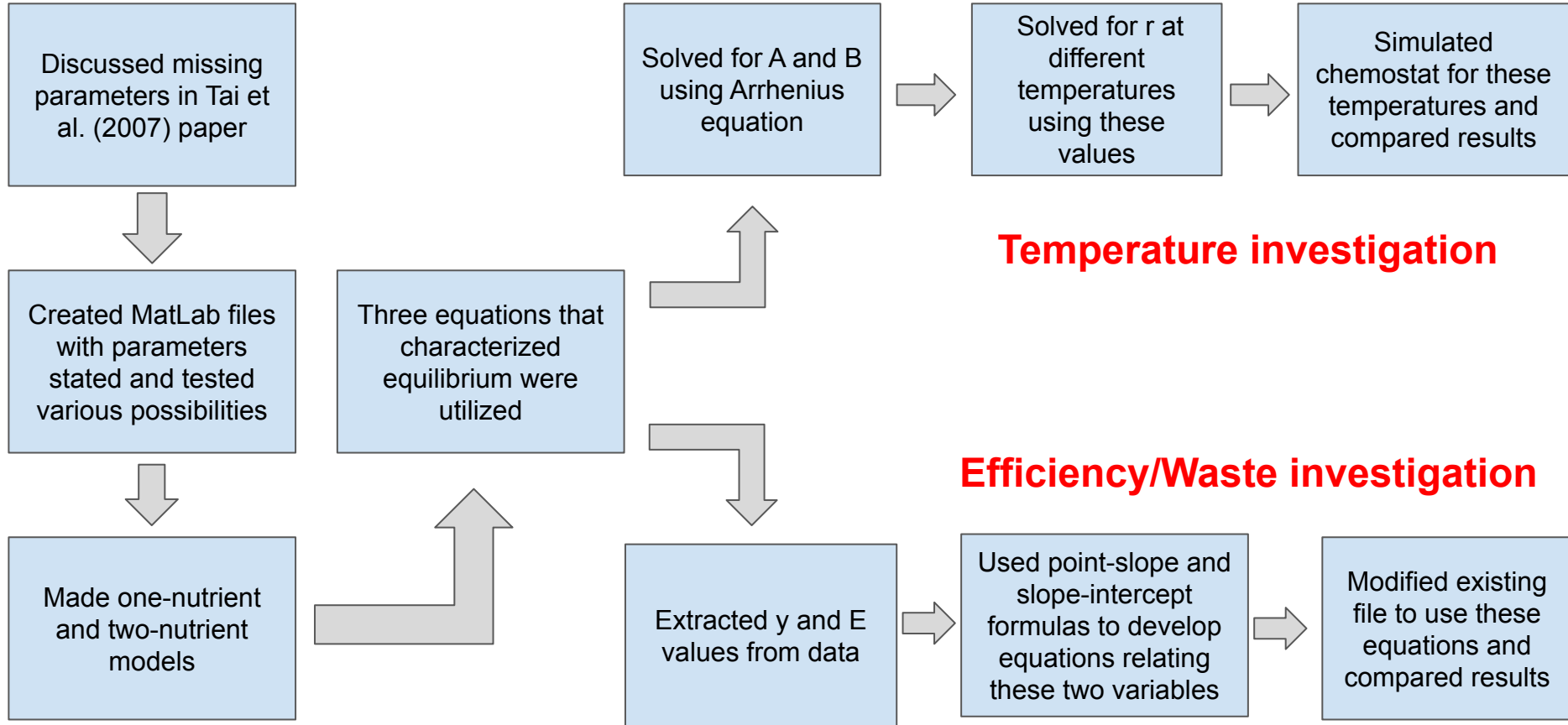
Remaining Parameters Calculated from the following

Equilibrium equations used in MATLAB:

$$y(t) = \frac{dy}{dt} = \frac{-Exryz}{(y+k)(z+L)} - qy + qu$$

$$z(t) = \frac{dz}{dt} = \frac{-Fxryz}{(y+k)(z+L)} - qz + qv$$

$$x(t) = \frac{dx}{dt} = \frac{xryz}{(y+k)(z+L)} - qx$$

Arrhenius Equation:

$$K = Ae^{-Ea/RT}$$

Point-slope Equation:

$$y - y_1 = m(x - x_1)$$

Slope-intercept Formula:

$$y = mx + b$$

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Chemostat Simulated at Different Temperatures

- Used Glucose-limited condition
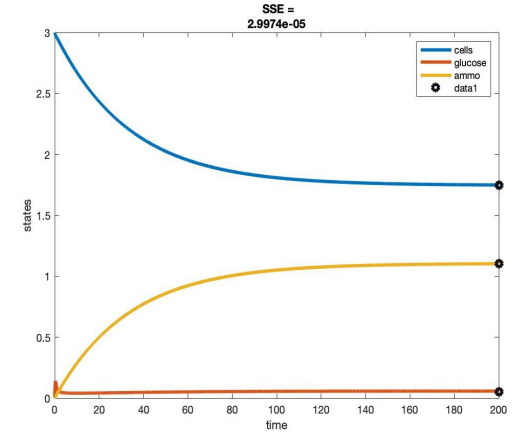- Calculated rates using Arrhenius equation

Temperature	Rate
15°	0.1087
20°	0.1787
25°	0.289

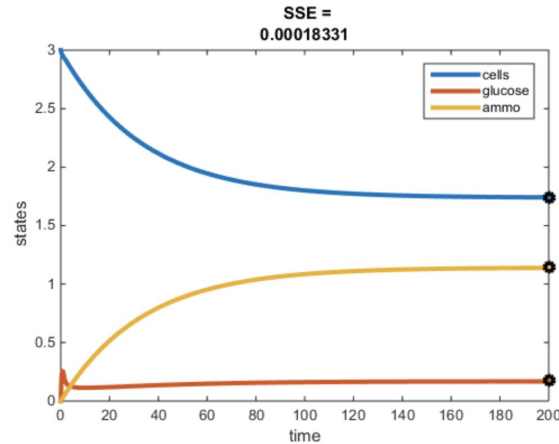# Glucose Steady States Remained the Same

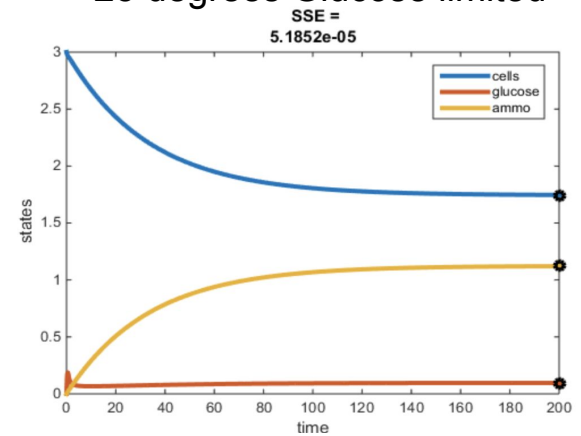12 degrees Glucose limited
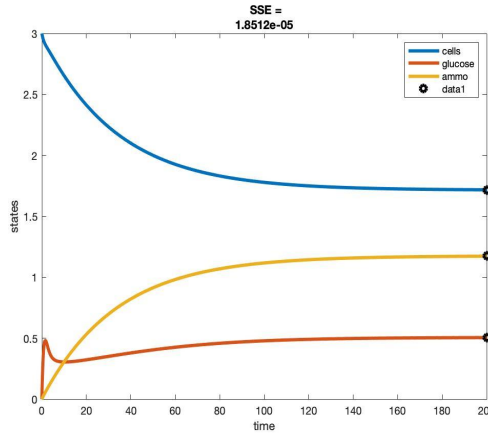
30 degrees Glucose limited

15 degrees Glucose limited
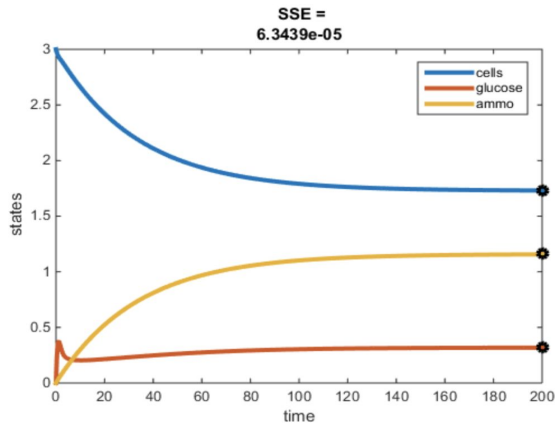
20 degrees Glucose limited

25 degrees Glucose limited

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Investigating E as a Variable Versus a Constant

- Calculated y values by multiplying residual glucose (rG) by the conversion factor to grams
- Used point-slope and slope-intercept formulas to develop equations that match both (y,E) points for each temperature
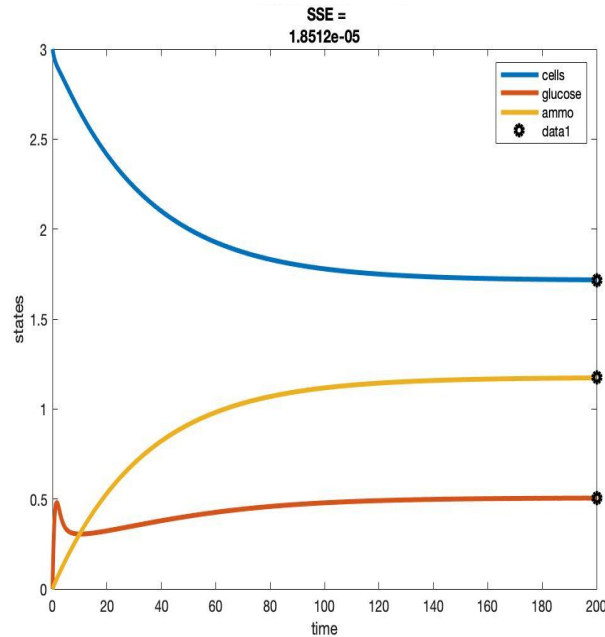
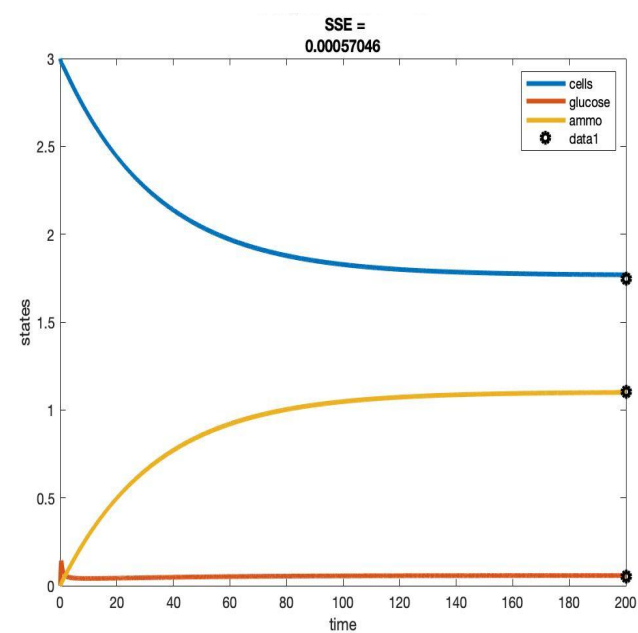| Temperature	Function
12°C	E = 0.3637y + 14.1022
30°C	E = 0.7012y + 14.2483

Using the 12°C Equation Steady States Varied

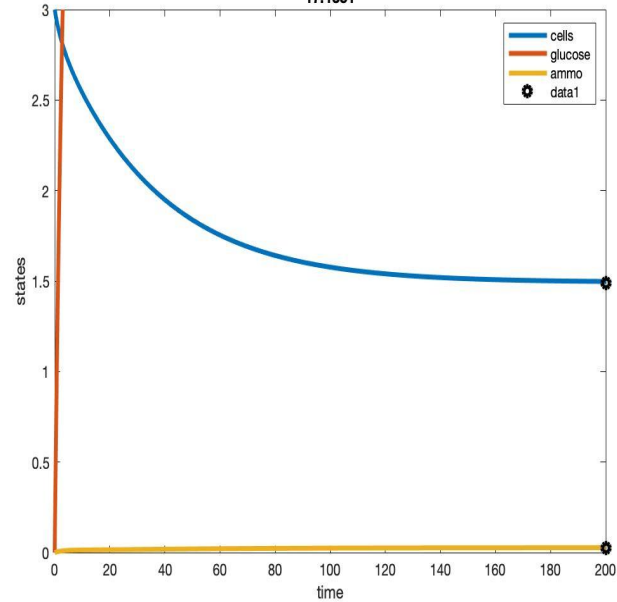12 degrees Glucose limited adjusted
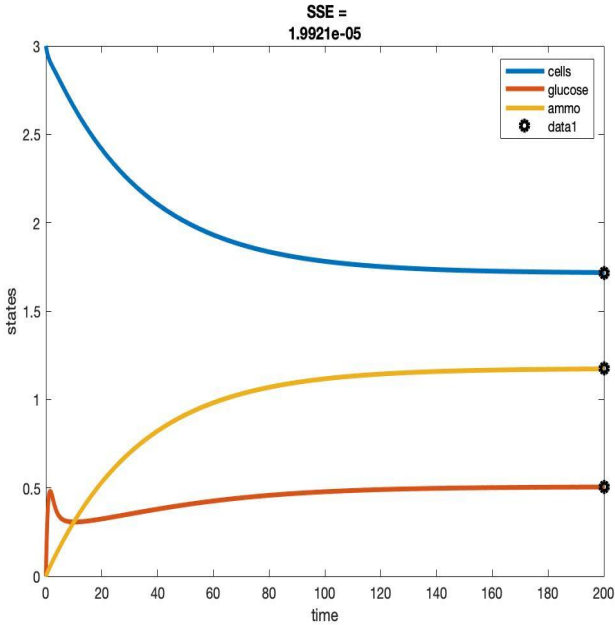
12 degrees Glucose limited

30 degrees Glucose limited adjusted
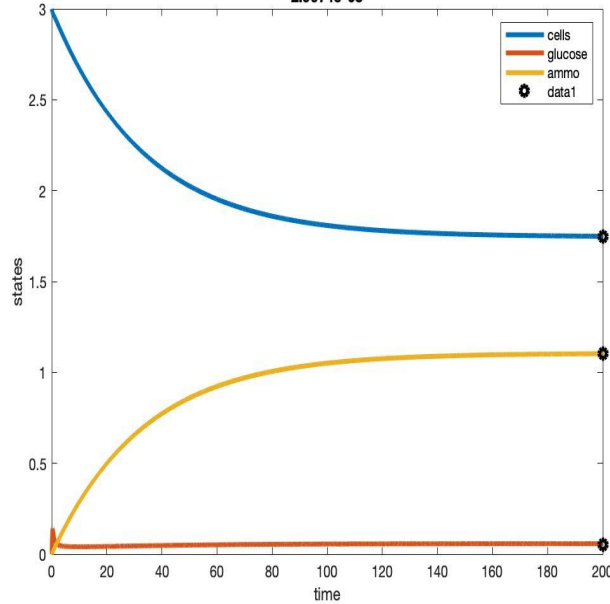
The 30°C Equation Produced Similar Results
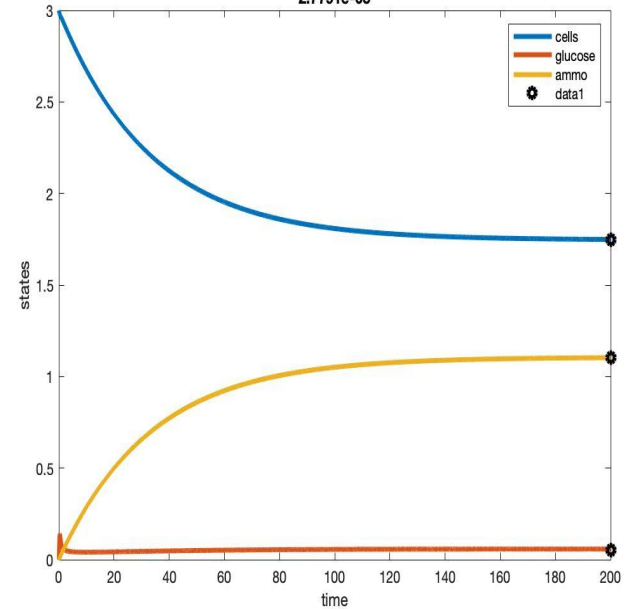
12 degrees Glucose limited adjusted

30 degrees Glucose limited

30 degrees Glucose limited adjusted

Conclusions

- Changing the temperature did not affect the steady states

- Glucose levels decreased as temperature levels increased

- The Efficiency (E) did not change with temperature

Future Directions

- Include temperatures outside of the 12 and 30 degree range and see if that makes a bigger difference than using the intermediary 15, 20, 25 degrees.
- Investigate a different nutrient's steady state over time, such as Trehalose.

Acknowledgments

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References

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    https://openwetware.org.wiki/BIOL388/S19:Week_14/15

2. 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. DOI: 10.1091/mbc.e07-02-0131

3. Tai, S. L., Boer, V. M., Daran-Lapujade, P., Walsh, M. C., de Winde, J. H., Daran, J. M., and Pronk, J. T. (2005). Two-dimensional transcriptome analysis in chemostat cultures: combinatorial effects of oxygen availability and macro- nutrient limitation in Saccharomyces cerevisiae. J. Biol. Chem. 280, 437–447.