Computational Modeling of Fed-Batch Bioreactor Processes using Monod Kinetics

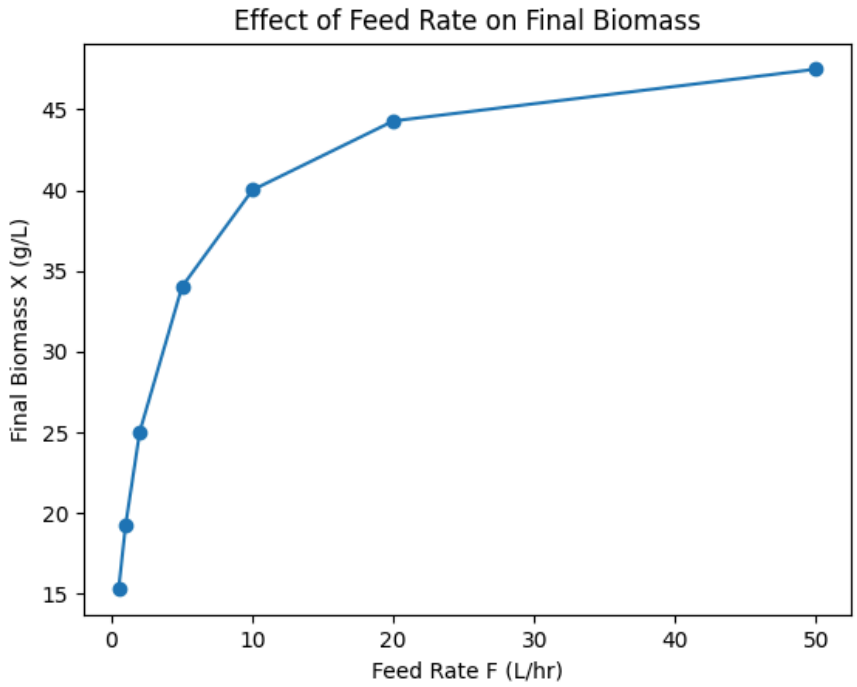
Fed-batch fermentation is widely used to achieve high product yields by adding nutrients gradually, which helps prevent substrate inhibition commonly associated with high initial substrate concentrations in batch cultures.

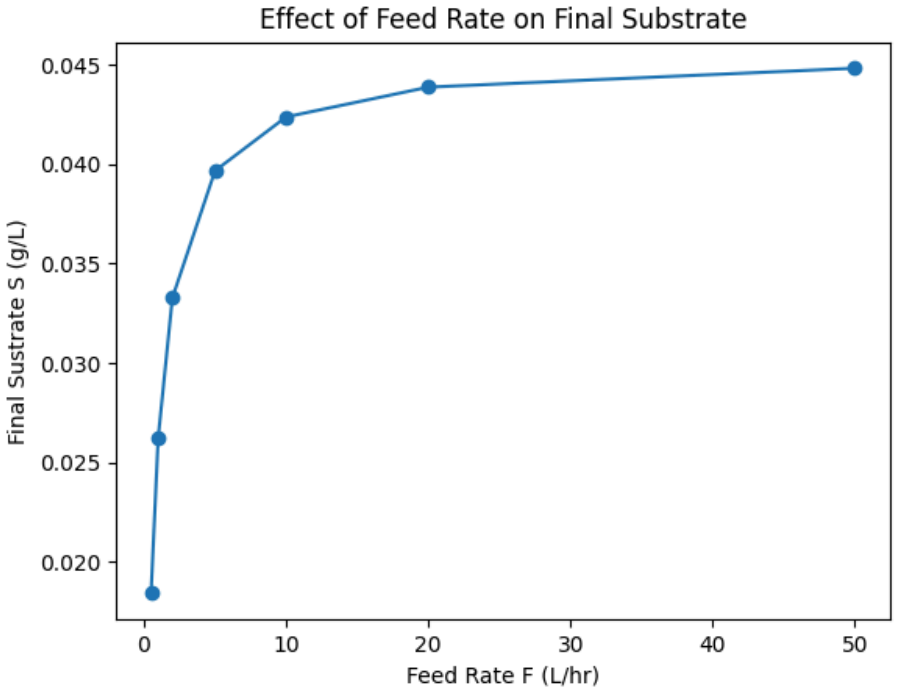
The objective of this project was to develop a mechanistic computational model of fed-batch bioreactor processes governed by Monod Kinematics to investigate the effect of feed rate on biomass growth, substrate utilization, and final product yield.

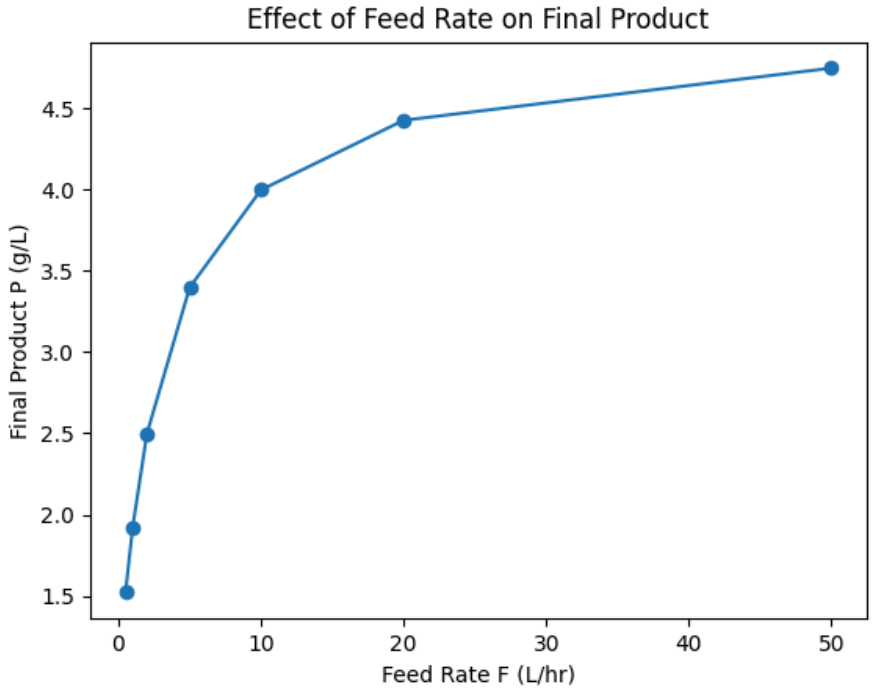
A system of ordinary differential equations was derived from bioreactor mass balances for biomass (X), substrate (S), and product (P), and reactor volume (V). Microbial growth was modeled using Monod Kinematics. The model was implemented in python using scipy.integrate.odeint. A parametric study was performed in which feed rate was varied while all kinetic parameters and feed substrate concentration were held constant.

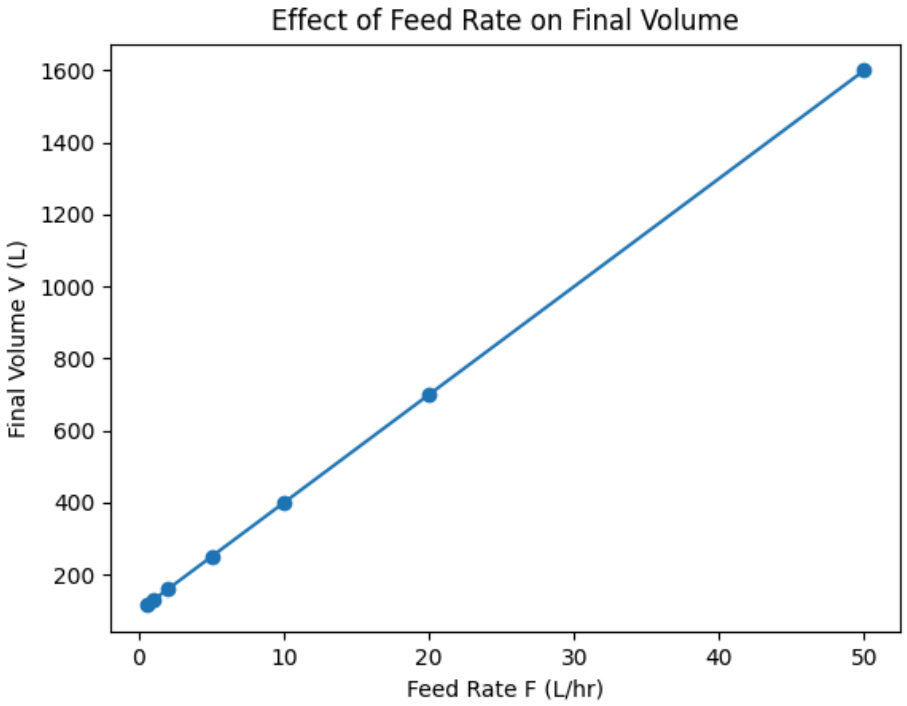
Feed rates ranging from high to low were simulated. Time profiles of biomass, substrate, product, and reactor volume were analyzed.

Graphs of each state variable analyzed are provided below.




Effect of Feed Rate on Final Substrate
Final Sustrate S (g/L)
0.045
0.040
0.035
0.030
0.025
0.020
0
10
20
30
40
50
Feed Rate F (L/hr)


Effect of Feed Rate on Final Product
Final Product P (g/L)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
0
10
20
30
40
50
Feed Rate F (L/hr)



The simulations indicated a strong, positive correlation between feed rate and final biomass, substrate, and product concentrations. The graphs below show that increasing the feed rate led to an increase in final biomass/substrate/product, though as feed rate increased the incremental gains in final biomass, substrate, and product concentrations became progressively smaller.

This project demonstrates how mechanistic modeling can be used to evaluate and optimize feed rate for a fed-batch bioreactor system. Future work could include implementing exponential feed strategies or fitting the model to specific experimental data.