Homework 3

CSTBRs

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Finding Model Parameters

From the raw data, the $Y_{X/S,app}$ was found for each dilution rate by plotting the cell concentration versus the initial substrate concentration and finding the slope of the linear regression lines (Figures 1-4).

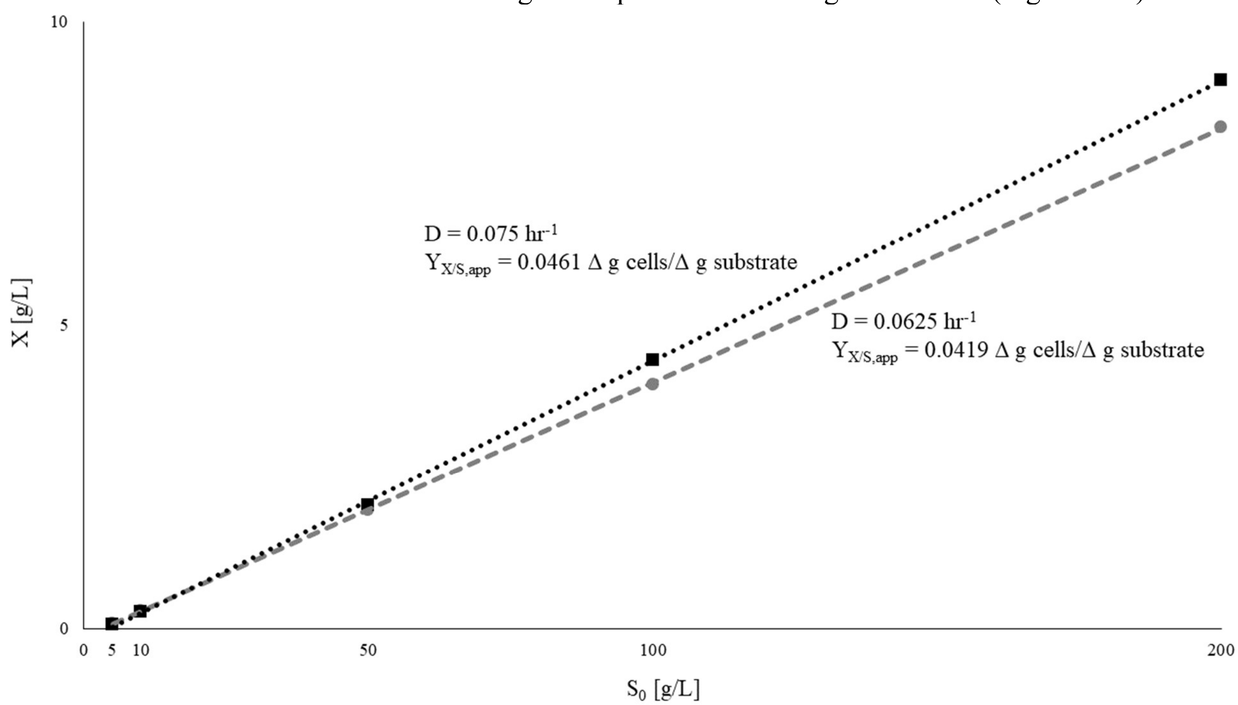

Figure 1: cell concentration vs. initial substrate concentration for dilution rates of 0.0625 hr^{-1} and 0.075 hr^{-1}.

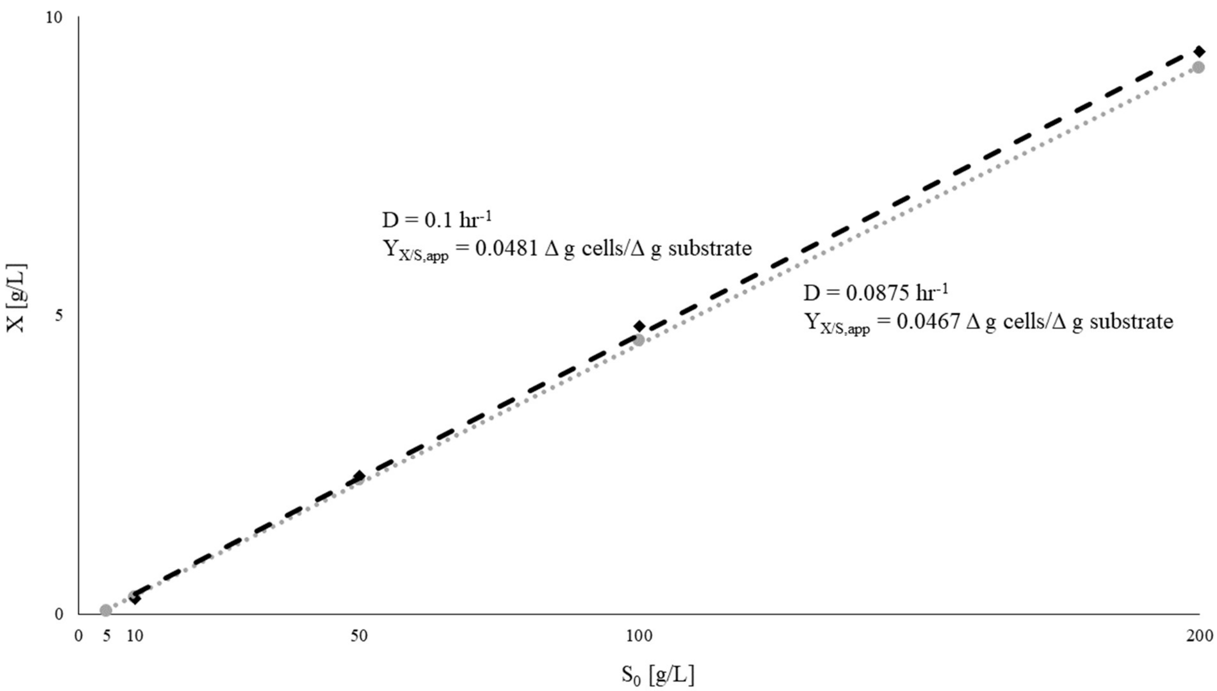

Figure 2: cell concentration vs. initial substrate concentration for dilution rates of 0.0875 hr^{-1} and 0.1 hr^{-1}. The data point for an initial substrate concentration of 5 g/L for the dilution rate of 0.1 hr^{-1} was removed as it is beyond the critical point and results in a washout of the CSTBR.

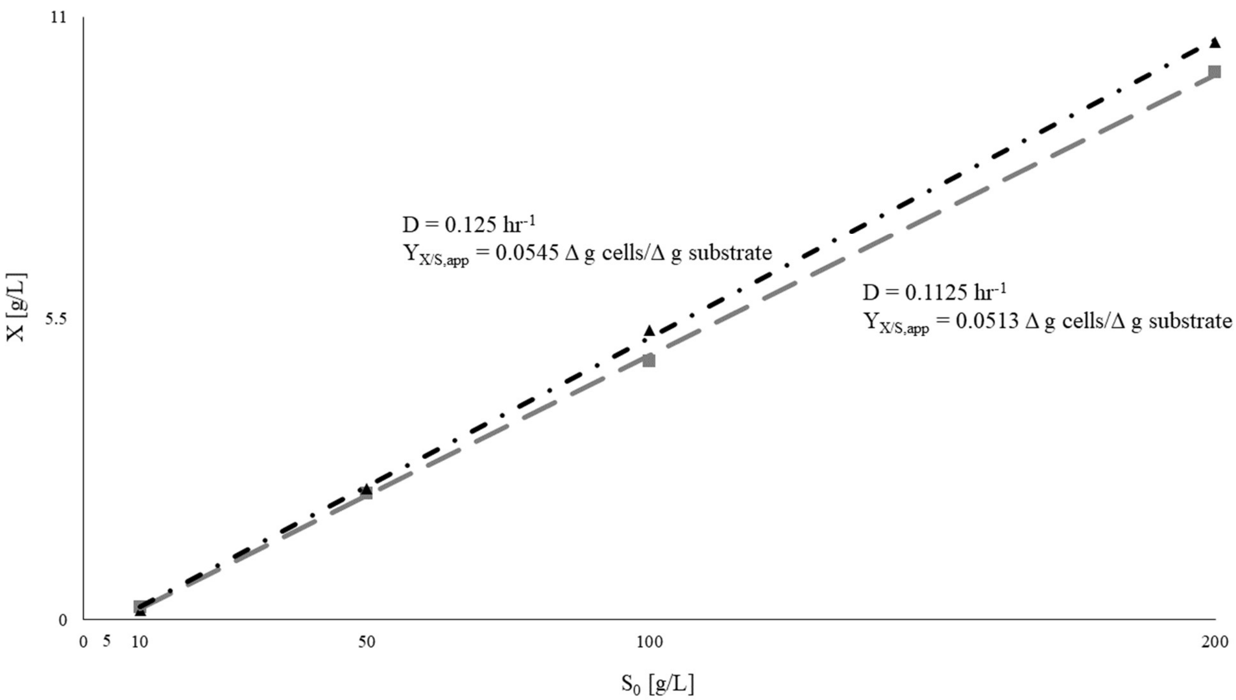

Figure 3: cell concentration vs. initial substrate concentration for dilution rates of 0.1125 hr^{-1} and 0.125 hr^{-1}. Both data points for an initial substrate concentration of 5 g/L were removed as they are beyond the critical point and results in a washout of the CSTBR.

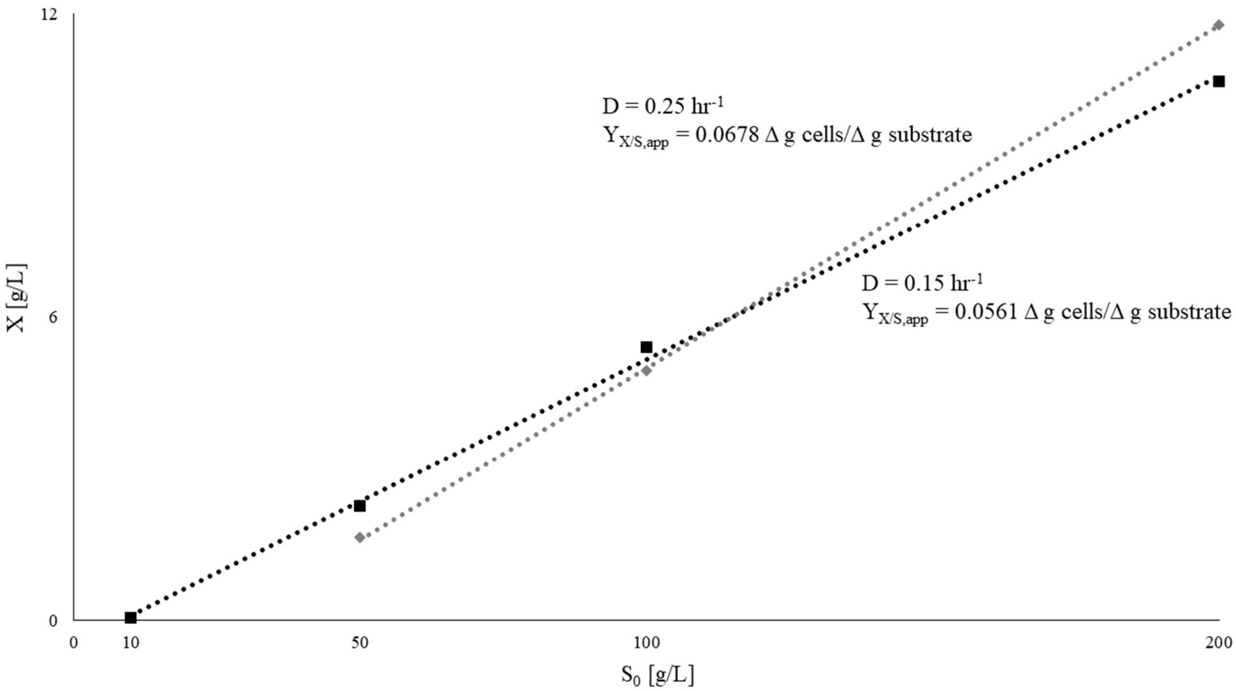

Figure 4: cell concentration vs. initial substrate concentration for dilution rates of 0.15 hr^{-1} and 0.25 hr^{-1}. Both data points for an initial substrate concentration of 5 g/L as well as the data point for an initial substrate concentration of 10 g/L for the dilution rate of 0.25 hr^{-1} were removed as they are beyond the critical point and results in a washout of the CSTBR.

The inverse of $Y_{X/S,app}$ values were then plotted against the inverse of the dilution rates. The slope of the linear regression gave the m_e value and the y-intercept gave the $Y_{X/S}$ (Figure 5).

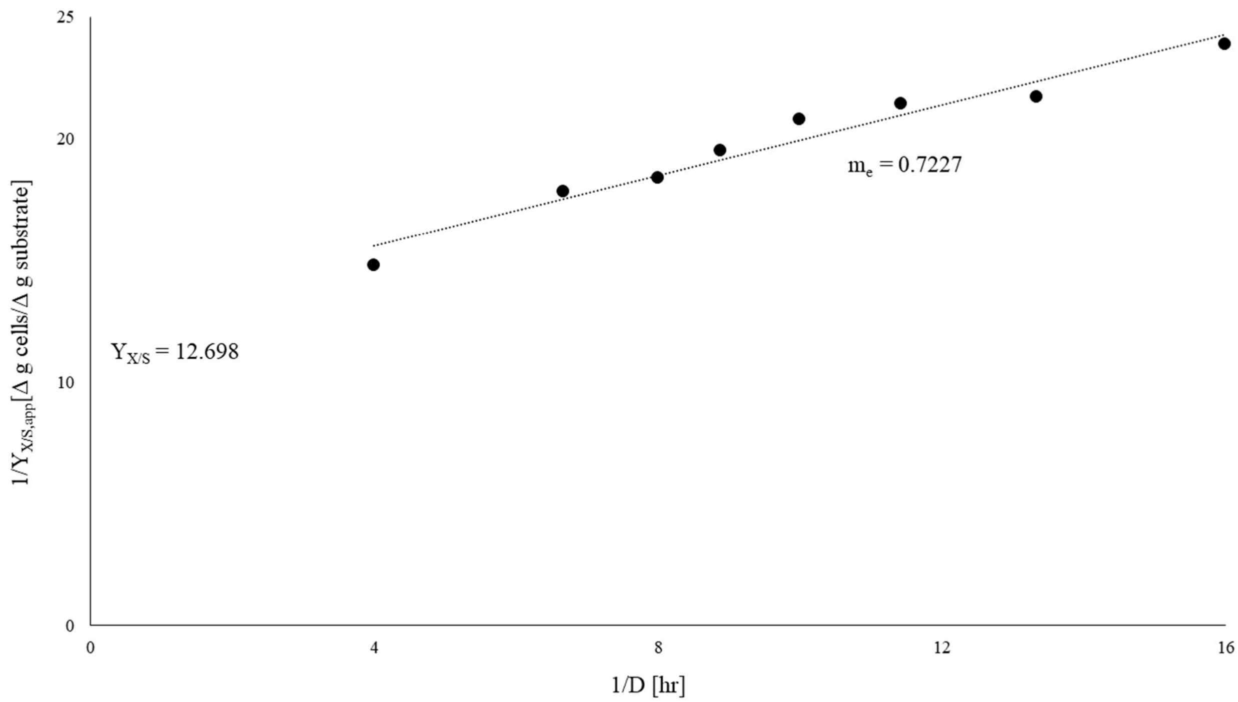

Figure 5: inverse plot of the apparent cell growth to substrate consumption ratio vs. dilution rate. The linear regression gave the values for parameters m_e and $Y_{X/S}$.

Knowing the $Y_{X/S}$ and the D values, the K_S and μ_{max} values were calculated with Excel's Solver function from the experimental S values given for each of the dilution rates when the initial substrate concentration was 50 g/L. This initial substrate concentration was chosen because it is that of the CSTBR to be modeled. The average K_S and μ_{max} values of the eight trials were taken to be the values of the parameters for the model. K_S was found to be 0.719 g/L and μ_{max} was found to be 0.134 hr^{-1}.

Modeling the Transitory Behavior of the CSTBR

Figure 6 shows the plot of the transitory behavior of the CSTBR as modeled by the code found in Figure 7.

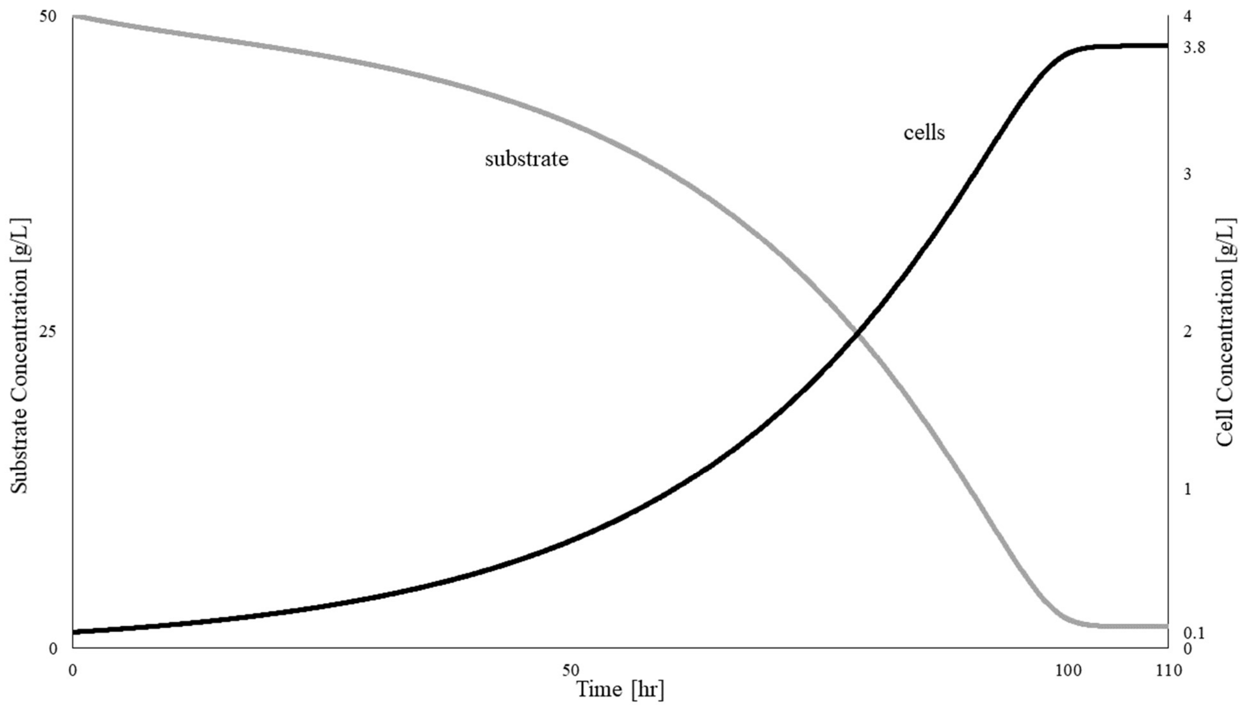

Figure 6: substrate and cell concentration vs. time for the transitory behavior of the CSTBR modeled.

```
Sub constants()
    'Enter the values for the step size and the number of equations here.
    stepSize = 0.05
    numEq = 2

    '********************************************
    ReDim I(numEq), O(numEq)        ' Just leave this line alone.  It dimensions the
                                    ' input and output arrays
    '********************************************

    ' Enter the initial conditions
    startTime = 0                'Time value at which the intial conditions are known
    O(1) = 0.1                     'Remark for Output 1
    O(2) = 50                     'Remark for Output 2

    'Enter the time at which you would like the simulation to end
    stopTime = 125

End Sub

Function inputs(eqnNumber As Integer, timeValue As Variant, outputs() As Variant)
    '********************************************
    Dim j As Integer                'Just leave this code alone.
                                    '
    For j = 1 To numEq              '
        O(j) = outputs(j)           '
    Next j                          '

    t = timeValue                   't is the time
    '********************************************

    'Enter the constants here
    Pi = 3.14
    F = 75
    S0 = 50
    X0 = 0
    Ks = 0.719
    mumax = 0.134
    V = 800
    D = F / V
    Ysx = 12.698

    'Constraints
    If O(1) <= 0 Then O(1) = 0
    If O(2) <= 0 Then O(2) = 0


    'Enter the input equations here
    I(1) = ((mumax * O(2) / (Ks + O(2))) - D) * O(1)
    I(2) = D * (S0 - O(2)) - ((mumax * O(2) / (Ks + O(2))) * O(1) * Ysx)

    '********************************************
    inputs = I(eqnNumber)

End Function
```

Figure 7: SIMBAS code to produce the model and plot seen in Figure 6.

Steady-State Conditions

At steady state, the cell concentration is 3.8 g/L and the substrate concentration is 1.67 g/L. The raw data was interpolated to find the analytical steady state solution of a system with an initial substrate concentration of 50 g/L and a flow rate of 75 mL/hr. With this method, the steady state solution was found to have a cell concentration of 3.56 g/L and a substrate concentration of 4.97 g/L. As such, the model predicted the cell concentration with an error margin of 6.74% and the substrate concentration with an error margin of 66.40%.

Length of Transitory Period

According to the model and Figure 6, takes about 100 hours to reach steady state.