CHAPTER V
KINETICS AND MODELING

5.1 Models for growth kinetics

5.1.1 Logistic model

Under optimal growth conditions and when the inhibitory effects of substrates and product play no role, the rate of cell growth kinetics is given by

\[
\frac{dX}{dt} = \mu_0 X \tag{5.1}
\]

Where \( \mu_0 \) is a constant defined as the initial specific growth rate equation implies that \( X \) increases with time regard less of substrate availability. In reality the growth of cell was governed by a hyperbolic relationship and the logistic equation is given by

\[
\frac{dX}{dt} = \mu_0 t \left[ 1 - \frac{X}{X_{\text{max}}} \right] X \tag{5.2}
\]

The logistic equation was utilized to describe the kinetics of several polysaccharides fermentation systems. Integrating the equation (5.2) with the initial condition, \( X = X_0 \) at \( t = 0 \) gives a sigmoidal variation of \( X(t) \) that may empirically represent both an exponential and a stationary phase

\[
X(t) = \frac{X_0 e^{\mu_0 t}}{1 - \left( \frac{X_0}{X_{\text{max}}} \right) (1 - e^{\mu_0 t})} \tag{5.3}
\]

The kinetic parameter, \( \mu_0 \) was determined by rearranging equation (5.3) as

\[
\ln \frac{X_{\text{max}}}{X_0} = \mu_0 t - \ln \left[ \frac{\bar{X}}{1 - \bar{X}} \right] \tag{5.4}
\]

Where \( \bar{X} = \frac{X}{X_{\text{max}}} \) if the logistic equation describes the data suitably, then plot of \( \ln \left[ \frac{X}{X_{\text{max}}} \right] \) Vs time should give a straight line of slope ‘ \( \mu_0 \)’ and intercept \( -\ln \frac{X_{\text{max}}}{X_0} \).

5.2 Model for product formation kinetics

5.2.1 Leudeking-Piret model

The kinetics of cellulase protein production was described by Leudeking-Piret model which states that the product formation rate varies linearly with both the instantaneous cell mass concentration (\( x \)) and growth rate (\( \frac{dX}{dt} \)) as:
\[
\frac{dp}{dt} = \alpha \frac{dx}{dt} + \beta X \quad \cdots (5.5)
\]

Where \(\alpha\) and \(\beta\) are empirical constants that may vary with fermentation conditions, \(P\) is product concentration (g/l); \(X\) is substrate concentration (g/l). The parameters \(\alpha\) and \(\beta\) were determined.

5.2.2 Model evaluation of growth kinetics

Logistic model was tried for the evaluation of growth kinetics. This model representing the experimental data obtained with all the three microorganism namely \(C.fimi\), \(C.flavigena\) and \(C.biazotea\). The model parameter values presented in table 5.1 was used to simulate data cell mass concentration during the entire course of fermentation.

The simulation results of the Logistic model is in good agreement with the experimental data obtained from rice straw, wheat straw, tapioca stem and the minimum average error was shown in table 5.1.

Logistic model fits well with the experimental data and predicts more accurately the cell mass concentration. The minimum average% error was found to be 3.77 for biomass concentration of \(C.flavigena\) using wheat straw as substrates. This indicate Logistic model is more suitable for predicting cell mass concentration of \(C.fimi\), \(C.flavigena\) and \(C.biazotea\) using rice straw, wheat straw, tapioca stem.

Fig.5.1.1, 5.1.2 and 5.1.3 shows the \(R^2\) values for cellulase and xylanase production from various substrates using Logistic model. Since the value is very high for the Logistic model and was found to predict cell mass concentration more accurately during the entire course of fermentation.
Fig. 5.1.1 Statistical evaluation of Logistic model for growth kinetics of *C. fim* using (a) rice straw (b) wheat straw (c) tapioca stem

Fig. 5.1.2 Statistical evaluation of Logistic model for growth kinetics of *C. flavigera* using (a) rice straw (b) wheat straw (c) tapioca stem
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Fig. 5.1.3 Statistical evaluation of Logistic model for growth kinetics of *C. biozatea* using (a) rice straw (b) wheat straw (c) tapioca stem

![Graphs showing predicted biomass vs. experimental biomass for different substrates and plant parts.](image)

(a) (b) (c)

Fig. 5.1.4 Growth curves profiles for production of cellulase and xylanase by (a) *C. fimi* (b) *C. flavigena* (c) *C. biozatea*

![Graphs showing growth curves for cellulase and xylanase production.](image)

(a) (b) (c)
Table 5.1 Model parameter values for cellulase and xylanase production by *C. fimis*, *C. flavigena* and *C. biazotea* in submerged fermentation

<table>
<thead>
<tr>
<th></th>
<th>Model constants</th>
<th>Rice straw</th>
<th>Wheat straw</th>
<th>Tapioca stem</th>
<th>Rice straw</th>
<th>Wheat straw</th>
<th>Tapioca stem</th>
<th>Rice straw</th>
<th>Wheat straw</th>
<th>Tapioca stem</th>
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<td>% error</td>
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<td>6.58</td>
<td>3.74</td>
<td>3.77</td>
<td>4.48</td>
<td>9.26</td>
<td>5.96</td>
<td>7.44</td>
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<td>α</td>
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<td>α</td>
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Fig. 5.2.1 Statistical evaluation of Leudeking Piret model for product(cellulase) kinetics of *C. fim* using (a) rice straw (b) wheat straw (c) tapioca stem

Fig. 5.2.2 Statistical evaluation of Leudeking Piret model for product(cellulase) kinetics of *C. flavi*gena using (a) rice straw (b) wheat straw (c) tapioca stem

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Fig. 5.2.3 Statistical evaluation of Leudeking Piret model for product kinetics (cellulase) of *C. biazotea* using (a) rice straw (b) wheat straw (c) tapioca stem

Fig 5.2.4 Product curves profiles for production of cellulase by (a) *C. fimii* (b) *C. flavigena* (c) *C. biazotea*
Fig. 5.3.1 Statistical evaluation of Leudeking Piret model for product (xylanase) kinetics of \textit{C.\textit{fimi}} using (a) rice straw (b) wheat straw (c) tapioca stem

Fig. 5.3.2 Statistical evaluation of Leudeking Piret model for product (xylanase) kinetics of \textit{C.\textit{flavigena}} using (a) rice straw (b) wheat straw (c) tapioca stem
Fig. 5.3.3 Statistical evaluation of Leudeking Piret model for product kinetics (xylanase) of *C. biazotea* using (a) rice straw (b) wheat straw (c) tapioca stem

Fig 5.3.4 Product curves profiles for production of xylanase by (a) *C.fimi* (b) *C.flavigena* (c) *C.biazotea*
5.2.3 Model evaluation of product kinetics

Luedeking-Piret model was tried for the product formation kinetics. The model parameters of the Eq.5.7. The model parameter values presented in table 6.1 was used to simulate data of cellulase and xylanase production during the entire course of fermentation.

The simulation results of the Luedeking-Piret model is in good agreement with the experimental data obtained from rice straw, wheat straw, tapioca stem and the minimum average error was shown in table 5.1.

Luedeking-Piret model fits well with the experimental data and predicts more accurately the activity of cellulase and xylanase respectively. The minimum average% error was found to be 6.08 for cellulase production. The minimum average% was found to be 4.21% for xylanase production.

This indicate Luedeking-Piret model is more suitable for predicting the activity of cellulase and xylanase using rice straw, wheat straw, tapioca stem.

Fig.5.2.1, 5.2.2 and 5.2.3 shows the $R^2$ values for cellulase production from various substrates using Luedeking-Piret model. Since the value is very high for the Luedeking-Piret model and was found to predict the activity of cellulase more accurately during the entire course of fermentation. Fig.5.3.1, 5.3.2 and 5.3.3 shows the $R^2$ values for xylanase production from various substrates using Luedeking-Piret model. Since the value is very high for the Luedeking-Piret model and was found to predict the activity of xylanase more accurately during the entire course of fermentation.