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PARAMETRIC EFFECT ON ETHANOL PRODUCTION THROUGH USE OF MONOD MODEL

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Abstract

Numerical simulation had many advantages over use of mathematical model through numerical techniques. The objective of this study is to investigate the effect of various parameter such as RPM, temperature, pH and aeration rate on ethanol production using Monod model (M-Model). Monod model utilized well known mathematical technique of Range Kutta (RK) for simplification of differential equation. In the current study RPM varied from 250-450 with step size 50 RPM, pH changed from 4-6.5 with step size 0.5, temperature raised from 30-45°C with step size 5, and aeration rate increased from 0.1vvm/l to 0.3vvm/l with step size 0.1vvm/l. The results revealed that maximum yield (77 g/l) of ethanol achieved at 300RPM, pH 4.5, 35°Cand aeration rate 0.2vvm/l. Moreover, theoretical investigations were also verified by fitting the data in M-Model and found in quite good agreement with the model.

Keywords: Monod, Ethanol, Parametric effect, Numerical Simulation, and Mathematical Model

1. Introduction

On behalf of partial global supply of fossil fuels, ethanol has one of rematerialized as an alternative to petroleum-based liquid fuels. More importantly, it is useful in the reduction of gas emission and greenhouse effect with simultaneous and substation supply of future energy [1]. Apart from renewable energy sources bio-ethanol has also advantages over environmental pollution [2, 3]. Another route for ethanol production during last decade was from biomass material (cellulose or starch) transformed to glucose. Fermentation could be improved with the understanding of kinetic characteristics of ethanol production and cell growth. One of the most useful technique of ethanol fermentation is fed batch system to avoid phenomena such as product or substrate inhibition and to attain high yield/productivity [4–7]. Substrate levels can be varied transiently in a fed-batch operation to achieve favorable exchange between product formation and cellular growth. Mathematical model could be beneficial where reaction network is complex to analysis [8–10]. During fermentation of process different key parameter that would cause product inhibition may be explained by proposed model with yeast saccharomyces cerevisiae [11–16]. Diauxic growth and lag-phase is simply described by Cybernetic models [17].

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S. cerevisiae has complex system which was successfully extended and related work on micro-organism was also done by klebsiella oxytoca in a previous work [18–20]. Cybernetic model was recently developed for S. cerevisiae to study the cell growth and its complete complex kinetic characteristics [21], higher concentration of glucose were used to fit the experimental data for a fermentation process. Baker's yeast production has been tested industrially [23, 24] by using hypothesis of so-called "bottleneck" models [22].

2. Materials and Methods

2.1. Model

Mathematical model regarding analysis to predict the behavior during ethanol production. The detail knowledge required for assessment of kinetic model to explain growth behavior of saccharomyces servisae [23]. Kompala el al. introduced a general modeling framework by involving viewpoint of cyber net. Before that complicated dynamics were very difficult to predict them using unstructured models [17]. Monod kinetic model were utilized in this study to investigate the parametric effect on ethanol production using fermentation process. The equation to explain the growth, substrate and production rate are given below.

$$\frac{dx}{dt} = \mu_{max}\left(\frac{S}{k_{xx} + S}\right)x \qquad \text{(I)}$$

$$\frac{dP}{dt} = q_{max}\left(\frac{S}{k_{sp}+S}\right)x \qquad \text{(II)}$$

$$\frac{dS}{dt} = -\left(\frac{1}{Y_{\frac{x}{s}}}\frac{dx}{dt}\right) - \left(\frac{1}{Y_{\frac{p}{s}}}\frac{dP}{dt}\right) \qquad \text{(III)}$$

Where μ_{max} =maximum cell growth,X=cell growth,S=substrate utilization, k_{xx}=half saturation constant, q_{max}=maximum specific growth,$Y_{x/s}$=yeild coefficient

3. Methodology

Experimental data was used to produce ethanol by varying temperature ranges as done by *Aziz (*2009) applying numerical method. Monod model was used to investigate the parametric effect on ethanol production. Successive steps for development procedure are displayed in Figure 1 to carryout numerical simulation. C++ programming and RK Order4 are the best tools for numerical simulation which were used in this model. Results were compared and analyzed by doing comparison between simulation with experimental results

Figure 1. Methodology for use of Monod Model

4. Results and Discussion

4.1. Effect of temperature on ethanol production

As from the previous study the thermo tolerant *kluyeromyces marxianus* were used to carry out the fermentation process, while ethanol, substrate and biomass were three state variables used to describe the phenomenon of fermentation. The kinetic parameters of the model were determined by using the least-square method during process of fermentation where temperature plays an important role during growth period of microbes for that concern at different ranges. The effects of different temperature ranges were observed on ethanol production as various microorganism were used to carry out the fermentation process.

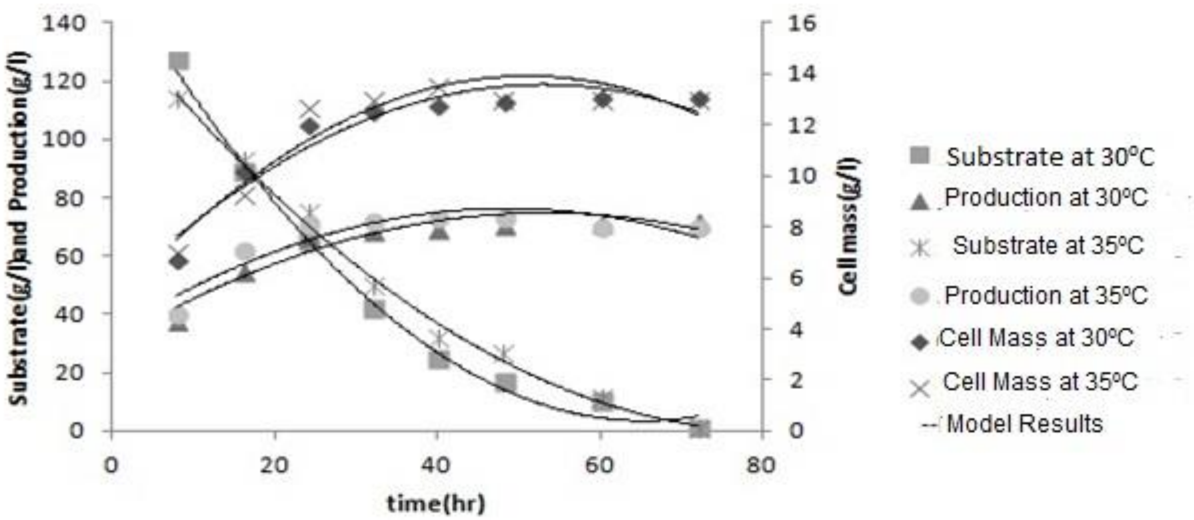

Figure 2. Effect of temperaure on ethanol production

There is a need to find that at what temperature maximum ethanol production occurs. The temperature ranges that were under study is from 30-65 □C. From the above graph, ethanol production can be optimized at the temperature of 35 □C

4.2. Effect of agitational intensity on ethanol production

Different RPM were under study for ethanol production. RPM has also significant effect on ethanol production using different species: as previous study shows that RPM has effect on

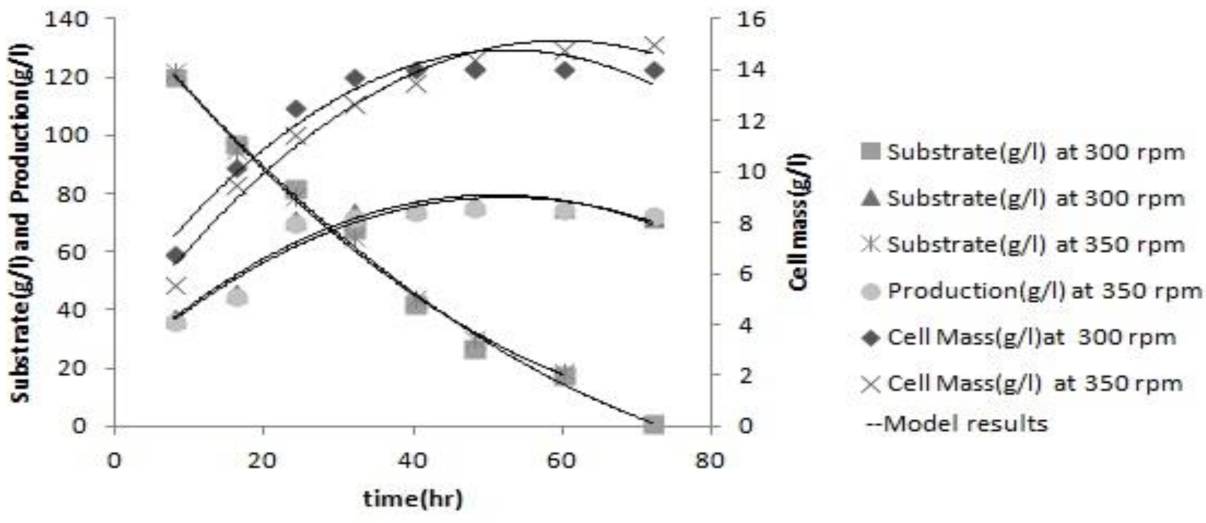

Figure 3. Effect of agitational intensity on ethanol production

ethanol production. Different RPM were used to study the effects on ethanol production. The maximum ethanol production occurs at 300 RPM because RPM provide homogenous substrate for microbes involved during process of fermentation. In figure 3. Numerical simulation of effect of agitation intensity on ethanol production under optimized condition is shown. The maximum ethanol production of about 74 g/l occurs for experimental and model results. During process of fermentation microbial growth was effected by varying the percentage of nitrogen and carbon source. The ethanol production will increase by selecting an appropriate percentage of carbon and nitrogen sources.

4.3. Effect of aeration rate on ethanol production

Different oxygen flow rates were studied using experimental and model results. It was observed that oxygen flow rate had significant effect on ethanol production during process of fermentation. During process of fermentation oxygen involve for microbial growth. As an aerobic fermentation was concerned there were significant effects of oxygen flow rate, because the organism that were used to carried out the fermentation need percentage of oxygen. Experimental and model results were compared to see the effects of different ranges of oxygen flow rate on ethanol production. The maximum production was seen at 0.1vvm/l from figure 4 below, the maximum ethanol production of about 74 g/l was observed at 0.1vvm/l.

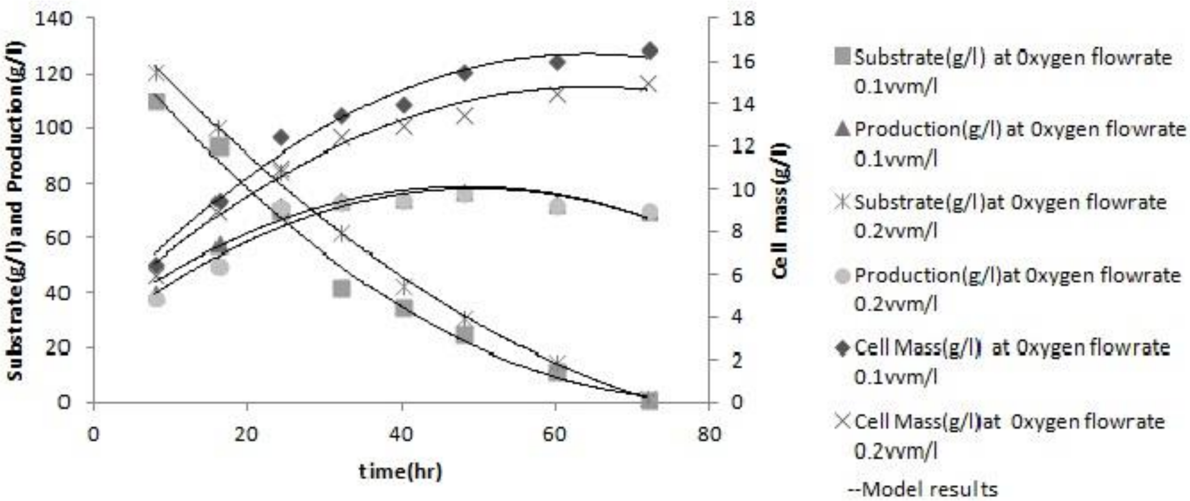

Figure 4. Effect of aeration rate on ethanol production

4.4. Effect of pH on ethanol production

Model and experimental results were compares to see the effects of different pH ranges to find what will be the optimum pH for both experimental and model results in figure 5. From previous study pH had significant effect on ethanol production. The ranges from 4-6.5 were under study to see the maximum production of ethanol. During process of fermentation, microbial strain need pH ranges from 4-5.5, because for ethanol production yeast involves for fermentation process utilize some limit of pH. The maximum ethanol production was observed at pH 5.5 at about 75 g/l.

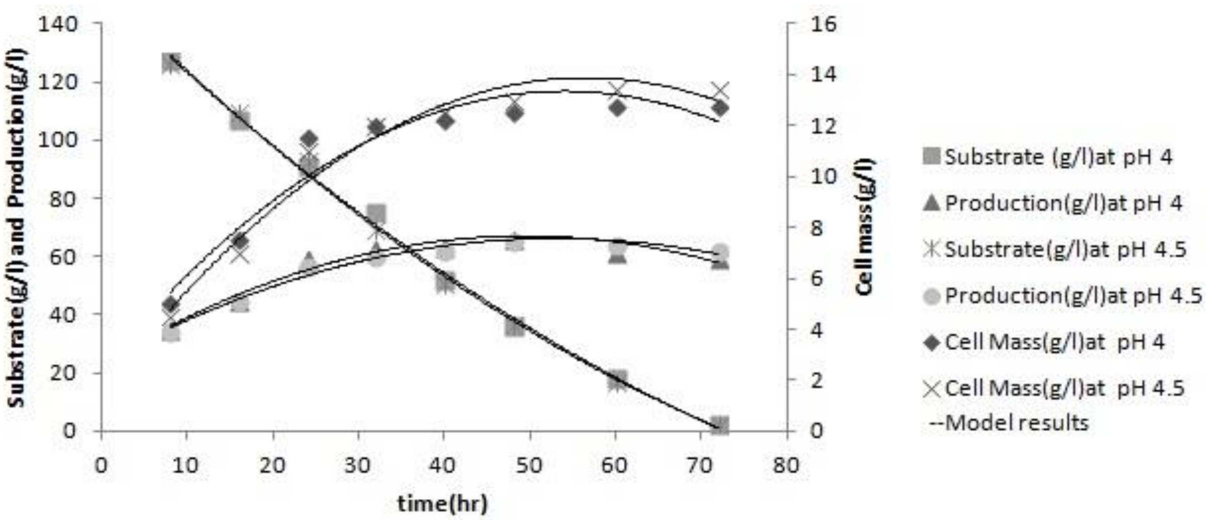

Figure 5.Effect of pH on ethanol production

5. Conclusion

Mathematical modeling plays an important role to optimize various parameters without using any experimental setup: parametric effects were investigated and analyzed to increase the productivity of ethanol without use of experimental apparatus and large set up. Different process parameter such as temperature, agitation intensity, pH and aeration rate of 300 RPM, temp 35ºC, pH 4.5 and 0.2vvm/l respectively gave maximum ethanol productivity of 77g/l.

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