Optimization of the Temperature Effect on Ethanol Production through use of Simulation

Abdul Sattar Jatoi[1], [2]Shaheen Aziz[2], Imran Nazir Unar[2], Suhail Ahmed Soomro[2], Mohammad Siddique[3]

[1]Department of Chemical Engineering, Dawood University of Engineering and Technology Karachi Pakistan,
[2]Department of Chemical Engineering, Mehran University of Engineering and Technology Jamshoro Pakistan,
[3]Departments of Chemical Engineering , Balochistan University of Information Technology, Engineering and Management Science, Quetta Pakistan

Abstract

Ethanol production from molasses using microorganism is well-known regarding conversion of sugar content in molasses into useful product. Different process parameter had handsome effect on ethanol production, regarding to this study focused on to investigate the temperature effect on performance of Kluyeromyces Marxian's using molasses as a substrate through numerical simulation. And also optimize the range for maximizing the ethanol production from 35-50^{o}C with step size 5^{o}C temperature effects were investigated by utilizing Monod kinetic model to distinguish the experimental and model results gave. Experimental and model results gave approximately same up to 90%. Experimental and model results gave ethanol concentration up to at 55^{o}C about 77g/l and 81% respectively. These results suggest that Monod kinetic model can be utilized for modifying process of fermentation by considering the temperature effects.

Key words: Thermotolerant Klyueromyces Marxians, Ethanol, Temperature, Numerical Simulation, Rk Order4

Corresponding author: engr.abdulsattar@yahoo.com

INTRODUCTION

Pakistan is on 7th position for cultivation of sugarcane among the world. On the bases of this sugarcane production in the form of sugar while doing that molasses also drawn off. This molasses can be useful for various purposes. Pakistan has 82 operational distilleries for producing ethanol from molasses. For increasing concern of ethanol production from molasses design and simulation plays an important role. Regarding to this different researchers produce different mathematical model for microbial growth. Growth could be inhibited by various operational parameters; Such as temperature, aeration rate, pH and agitation intensity. During the process of fermentation exothermic reactions occurs that reactions emit handsome amount of heat. Temperature effects on ethanol production were investigated through the use of mathematical model, fermentation process done by different microorganisms but mostly used microorganisms are nothing but the saccharomyces servisae. Molasses had potential effect with the utilization of Saccharomyces cerevisiae as biocatalyst to carry out fermentation (Phisalaphong et al., 2006). Sanchez et al. discussed the temperature dependency that effect production of ethanol and xylitol kinetic parameter (Sánchez et al., 2004). For explaining denaturation of ribosomes and enzymes explained through linear model was developed (McMeekin et al., 2002), an empirical linear model was developed for describing the temperature and nutritional effect on ethanol production through fermentation (Dragone et al., 2004). Microorganism activity effected through the environmental conditions. On behalf of that temperature effect could increase or decrease the activity of microorganism. Apart from this fermentation process is also victim of theses environmental condition that changes the phenomena of process. During Fermentation environmental conditions which coupled with mass transfer and metabolic behavior of microorganisms that utilize to convert substrate into product. To gain insight into the morphology associated time-variant process dynamics, various kinetic models associated with key parameters for ethanol fermentation have been proposed (Aiba et al., 2000; Birol et al., 1998; de Andres-Toro et al., 1998; Ghaly and El-Taweel, 1997; Nishiwaki and Dunn, 1999; Oliveira et al., 1999; Sainz et al., 2003; Sree et al., 2000; Tyagi and Ghose, 1980). Mathematical models

were developed and applied for kinetics of kluyeromyces marxianus for ethanol production from molasses. The developed model predicate the effect of temperature, agitation intensity, pH, aeration rate and other process parameters (Jatoi et al., 2016). This work is related with the effect of temperature on ethanol production using numerical techniques.

METERIALS AND METHODS

Experimental data was collected from laboratory experiment to carry out the work related with different temperature ranges. The data comes in the form of cell mass, substrate concentration and ethanol concentration for investigating the temperature effect. Fig. 1 represents the methodology employed for carryout the numerical simulation of ethanol production from model to simulation results.

In first step, initial condition was chosen on the basis of collected date and for model fixation that results. On second step these initial conditions were utilized with model couple with numerical method Rk order 4. Numerical simulation was done through the utilization of C++ program for developing that algorithm.

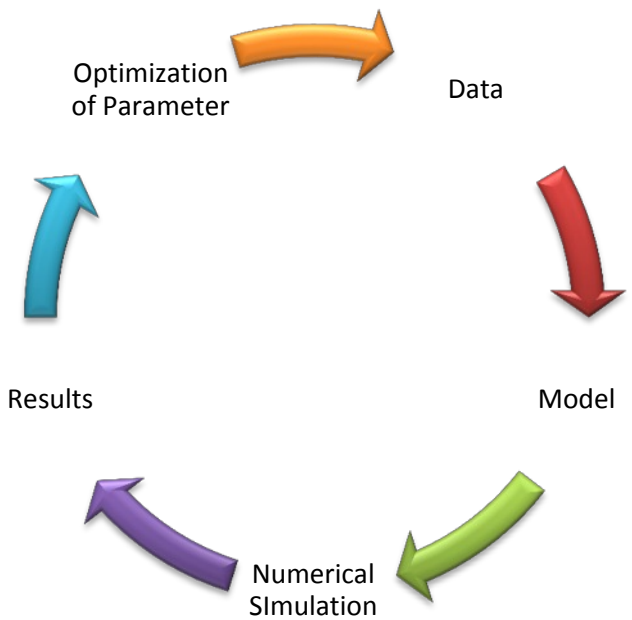

Figure 1: Flow Chart for Numerical Simulation of Ethanol Production

Model

Monod kinetic model were used to investigate the temperature effect on ethanol production. Monod Model gave a fundamental kinetic relationship between the production rates versus time (Jatoi et al., 2016). For cell growth, substrate utilization and ethanol production.

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

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

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

Where μ_{max}=maximum cell growth,X=cell growth,S=substrate utilization,kxx =half saturation , q_{max}=maximum specific growth,Yx/s=yeild coefficient cell.

RESULTS AND DISCUSSION

Ethanol production has importance over current situation of fossil fuel depletion. Experimental and model results were compared with different temperature ranges, rates of cell mass, substrate and ethanol production with respect to time. Temperature had important effect with respect to the activity of microorganisms, because of tolerable limit of microorganisms is up to 40°C. Current study focused on thermos-tolerant kluyeromy cesmarxians that bear up to 55°C. On the bases of this experimental and model, results were compared to investigate the potential of model with respect to experimental results. Temperature ranges from 35-50°C under study to observe effect on cell mass (g/l), substrate (g/l) and production of ethanol (g/l). Monod kinetic model were utilized to investigate the temperature effect on ethanol production.

Cell growth and substrate utilization with respect to ethanol production at 35°C

Cell mass related with substrate utilization Figure 2 represents the parametric effect of temperature on cell mass, substrate and ethanol production. Comparison between experimental and simulation results shows the cell growth, substrate and ethanol production at 35°C. The maximum ethanol production about 75g/l while numerical results shows typical 75.8g/l. The lower down the trend of substrate is due to the microorganisms utilizes that particular percentage of sugar for converting into ethanol. This could lead to simultaneously removal of sugar concentration from molasses converted into ethanol.

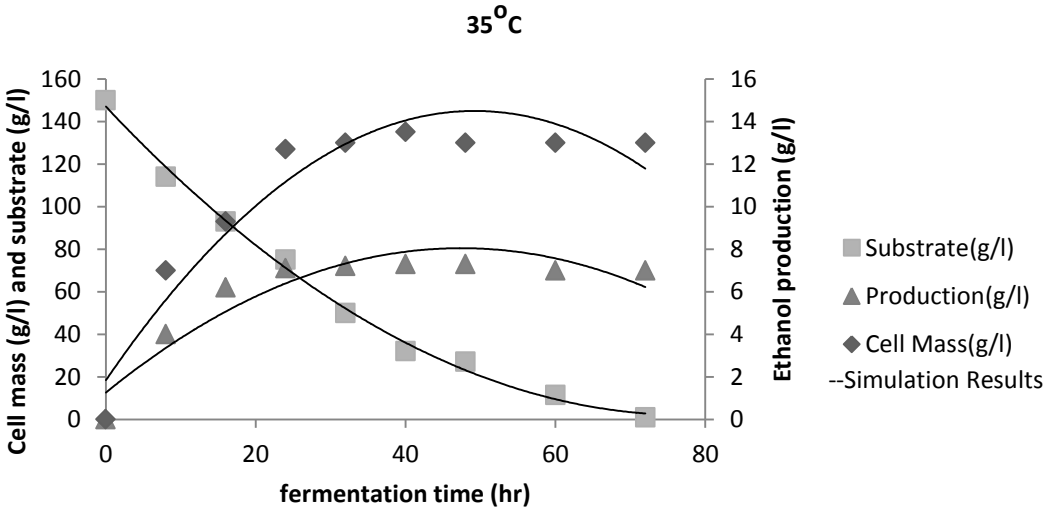

Figure 2: cell mass, substrate utilization and ethanol production at 35°C

Cell growth and substrate utilization with respect to ethanol production at 40°C

Cell mass rate could be increase or decrease with respect to temperature. Temperature is an important factor which decrease or increase microbial activity of microorganisms. Different temperature ranges were studied to discuss the important factors effects on ethanol production. During microbial growth in fermentation process affected by varying temperature because microorganism did not survive with unsatisfactory environment. Substrate utilization depends on the microorganism activity for handling this problem temperature effect must be considered as important factor. Figure 3 represents the effect of temperature at

40°C coupled with substrate utilization, cell growth with respect to ethanol production. The maximum ethanol production observed about 76 g/l for experimental and as for simulation results concerned about 76.8g/l.

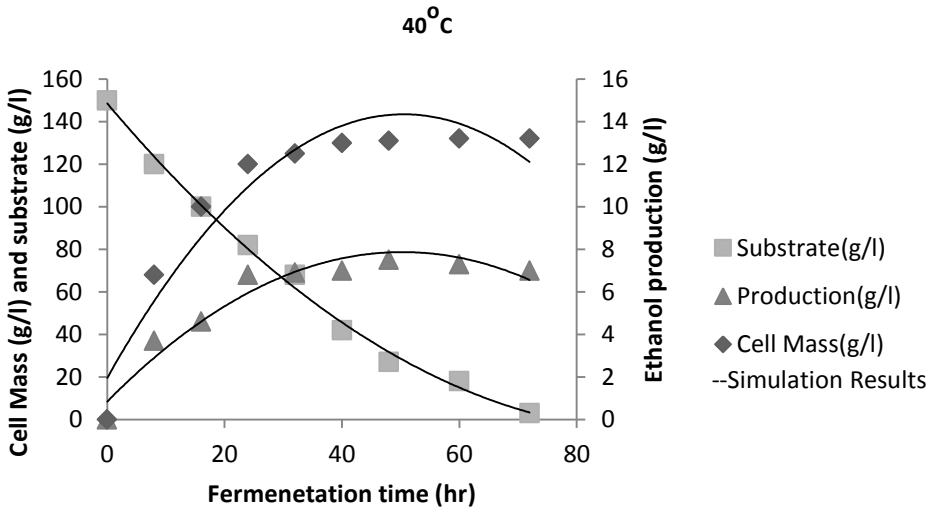

Figure 3: Cell mass, substrate utilization and ethanol production at 40°C

Cell growth and substrate utilization with respect to ethanol production at 45°C

Numerical simulation was done using Monod-model at different temperature ranges to investigate the maximum utilization of substrate for alcohol production. Figure 4 represents cell growth, substrate and ethanol production at 45°C. The ethanol production with respect to substrate utilization depends on temperature effect. The trend of substrate utilization represents the variation in cell mass and ethanol production is due to decrease in percentage of substrate. Because microorganisms are totally depends on temperature that's why alteration in ethanol concentration caused by microbial activity.

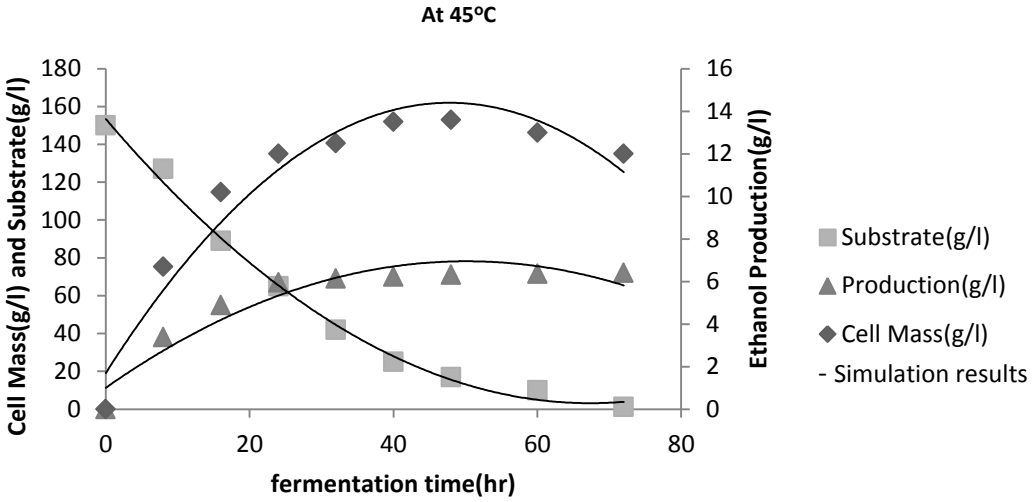

Figure 4: cell mass, substrate utilization and ethanol production at 45°C

Cell growth and substrate utilization with respect to ethanol production at 50°C

Study was made on effect of different temperature on ethanol production with change in range of temperature. Figure 5 represents ranges to investigate the temp at which maximum alcohol production occur, Monod model were used in this study using C++ programming for ethanol production from different temperature. The maximum ethanol production was occurring at 33°C at this temperature numerical simulation gave ethanol production about 76g/l and for experimental results also gave 76g/l the minimum ethanol production occurs at 20-25°C for numerical results.

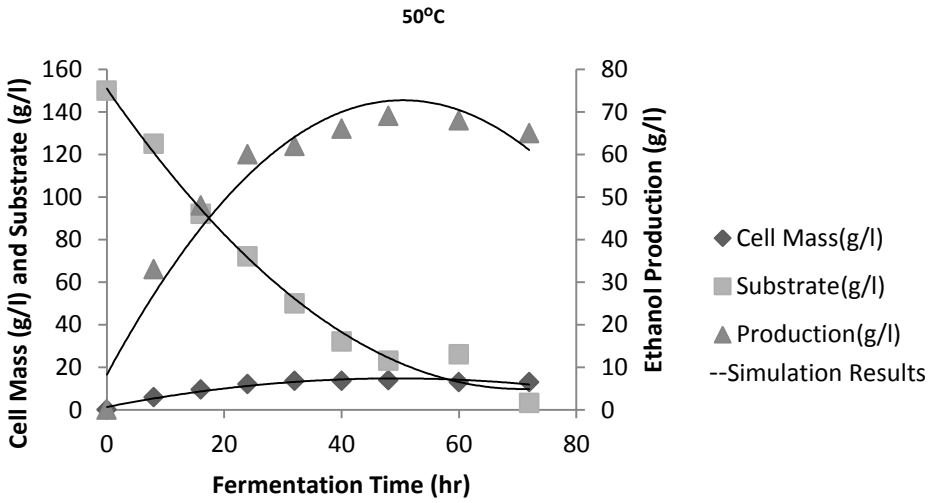

Figure 5: cell mass, substrate utilization and ethanol production at 50°C

CONCLUSION

Study was made for carryout temperature effect on ethanol production from molasses, it was found through experimental and numerical study that temperature had effect on ethanol production due to microbe use to carryout fermentation process. Cell growth, substrate utilization and ethanol production were made to study the effect of temp on it. It was found that by utilizing temperature 35-5^{0}C give maximum cell growth 10g/l, maximum substrate utilize and maximum ethanol production about 76g/l for experimental and model results.

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