

Numerical Simulation of Ethanol Production for Different Carbon Sources Using Thermotolerant *Kluyveromyces Marxianus*

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Abstract

*During process of fermentation a variety of parameters effect on ethanol production, current work focusses to investigate the effect of different carbon sources on ethanol production using numerical simulation. The fermentation process was carried out using microprocessor-controlled fermenter in which different types of carbon sources were studied like glucose, sucrose and molasses from 10 % to 15% of range. The model proposed by Monod was found to be more appropriate for describing the batch growth and ethanol production using *kluyveromyces marxianus*. The maximum yield of ethanol production took place using 15 % molasses as carbon source. The maximum ethanol production (76 g/l) was observed at 15% molasses, as for sucrose and glucose are concerned it gives lower value of ethanol production up to 73g/l by keeping other operational parameter under optimized condition such are 35°C, 300rpm, 0.2vvm/l and pH5.5. Approximately same results were achieved by using experimental data and model execution.*

Keywords: Carbon Source; Ethanol; *Kluyveromyces Marxianus*; Fermenter; Glucose; Molasses; Sucrose

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INTRODUCTION

World researchers are focusing their cumulative attention on renewable and clean fuel cell like Bio-ethanol, because of its environmental benefits. Bio-ethanol is produced by using different renewable feedstock like e.g. cassava (1st generation), corn, cellulose biomass (2nd generation) sugarcane, algae biomass (3rd generation) and wheat (Baeyens, 2015). By product of sugar industry say molasses, is easily convertible into bio fuel by fermentation. It is mostly used because of easy availability and low cost. Variation up to 50-55% fermentable sugar for converting it into ethanol (Zayed, 1997). Ethanol production using microbial organisms is deliberated as renewable fuel for reduction of environmental impacts (Shenoy, 2011; Singhanian, 2008). The raw materials which are rich in sugar can easily be converted into ethanol by kinetics of alcoholic fermentation using most useful microorganism *saccharomyces cerevisiae* (Najaf, 2004). The most convenient carbon source for metabolism is molasses which is an agro-industrial by-product frequently used in alcohol distilleries owing to the presence of fermentative sugars (Cazetta, 2007). Owing to gorgeous presence of sucrose it has been remained on the top of research interest to convert this sugar cane refining process, which presents a substrate not requiring pre-treatment prior to the fermentation. Productivity and substrate concentration remained major portion of inhibition of growth during traditional batch fermentation for distilled ethanol production using *S. cerevisiae*. Its limitation are 2.3 and 1.8 g/l.hr (Baptista, 2006). Molasses are a potential feedstock for ethanol production (Bouallagui, 2013). Ethanol has received worldwide attention as an alternative energy source mainly for transportation fuels production (Cardona, 2007; Walter, 2008). Mathematical modeling plays an important role to understand the fundamental relationship between different variables and give an economic way to optimize various parameters (Jatoui, 2016). Numerical simulation of ethanol production also discusses in our work with the utilization of Monod Model (Maher, 2017; Jatoui, 2016). But current work describes the utilization of numerical technique for optimization of carbon source for maximum ethanol production.

MATERIALS AND METHODS

Programming C++ was used to carry out numerical simulation by using Range Kutta (RK) order 4 as a numerical method to solve Monod model on the basis of experimental data.

Data was collected from previous work; Monod model was used to study the effects of different carbon sources on ethanol production. Initial conditions that were taken for numerical simulation are described here as $t=0$, $X_0=0g/l$, $s_0=150g/l$ and $P=0g/l$. C++ program was developed for solving Monod model using RK 4th order method.



Figure 1: Block diagram showing steps from inception to end process

RESULTS AND DISCUSSION

Effect of temperature on ethanol production using different carbon source

Monod model was used to study the effects of temperature on ethanol production using different carbon sources such as sucrose, glucose and molasses. In this work the study was done at the temperatures of 40°C and 45°C. A high temperature led to a decrease in the ethanol and cell yields but an increase in the inhibition effect of ethanol and sugar on cell growth and ethanol production (Phisalaphong, 2006). The maximum ethanol production was achieved at 40°C. During process of fermentation microbial growth affected by different carbon sources, because microbes that were used have need of nutrients like carbon, sucrose, glucose and molasses. Numerical simulation was practiced by using Monod kinetic equation for cell growth, substrate utilization and ethanol production. In numerical simulation C++ program was developed by utilizing RK order 4th (Numerical method) to solve Monod model. The maximum ethanol production was observed at 40°C using 15% molasses. In figure 02 the maximum ethanol production was obtained at 40°C at 10% glucose. In figure 03 for sucrose the maximum ethanol production occurred at 15% at 40°C for comparison between these three carbon sources the maximum ethanol production was achieved by using molasses setting its concentration up to 15%.

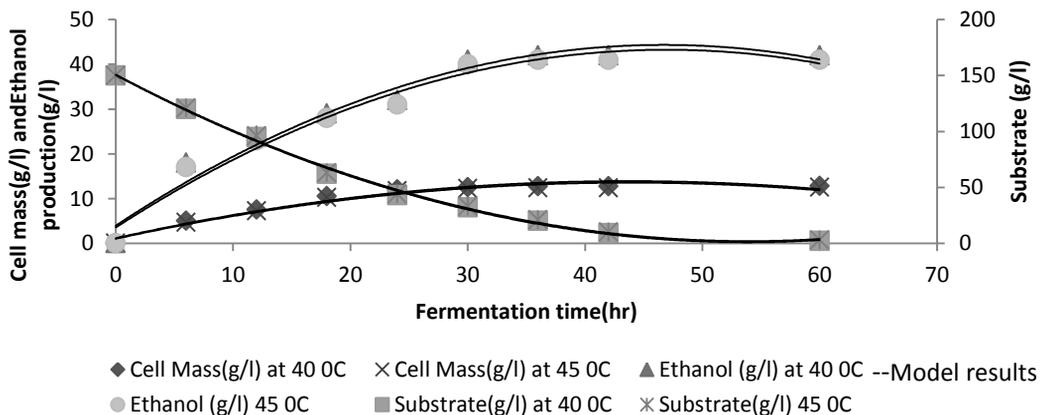


Figure 2: Ethanol production using glucose as carbon source at 40°C and 45°C

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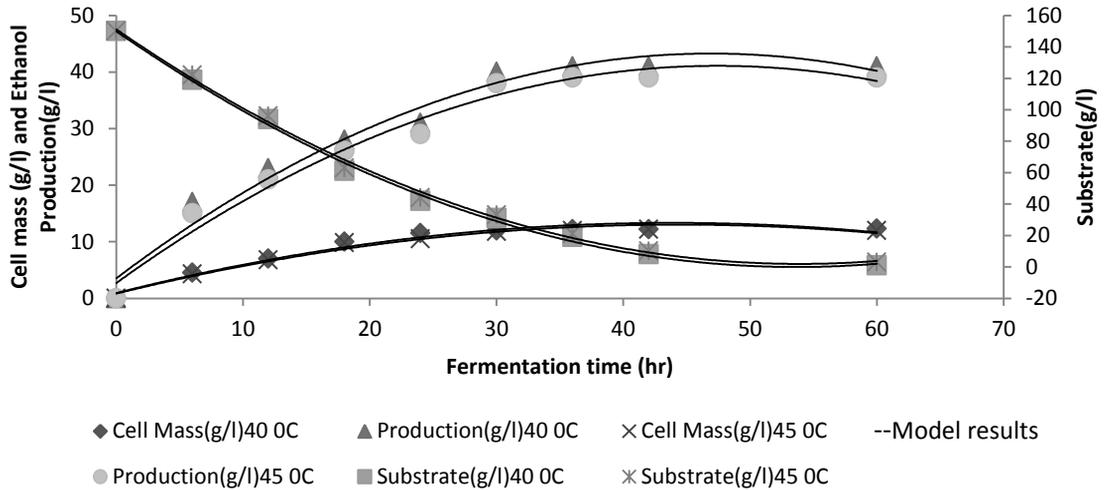


Figure 3: Ethanol production using molasses as carbon source at 40°C and 45°C

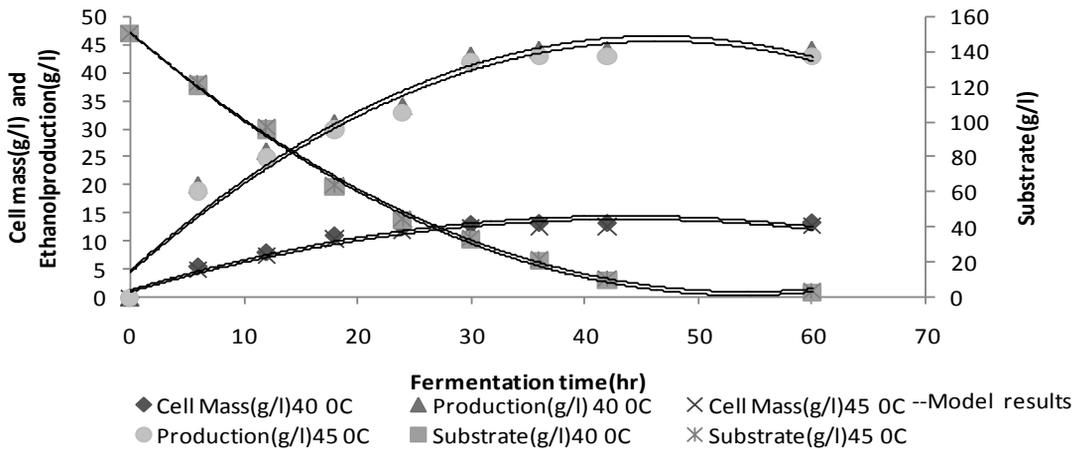


Figure 4: Ethanol production using sucrose as carbon source at 40°C and 45°C

Effect of oxygen flow rate on ethanol production using different carbon source

During process of fermentation nutrients are used for cell growth of microorganism which will enhance the production of ethanol, by this process molasses is converted into ethanol at different operating parameters. Apart from this oxygen flowrate also plays main role in fermentation process, because of it optimization of oxygen flow rate was also done along with the carbon sources using numerical simulation RK 4th order to solve Monod model. In figure 04 Sucrose is used as carbon source for using 0.1vvm/l and 0.2vvm/l but the maximum production was observed at 0.1vvm/l using 15% sucrose. The maximum ethanol production occurs at 10% glucose at 0.1vvm.

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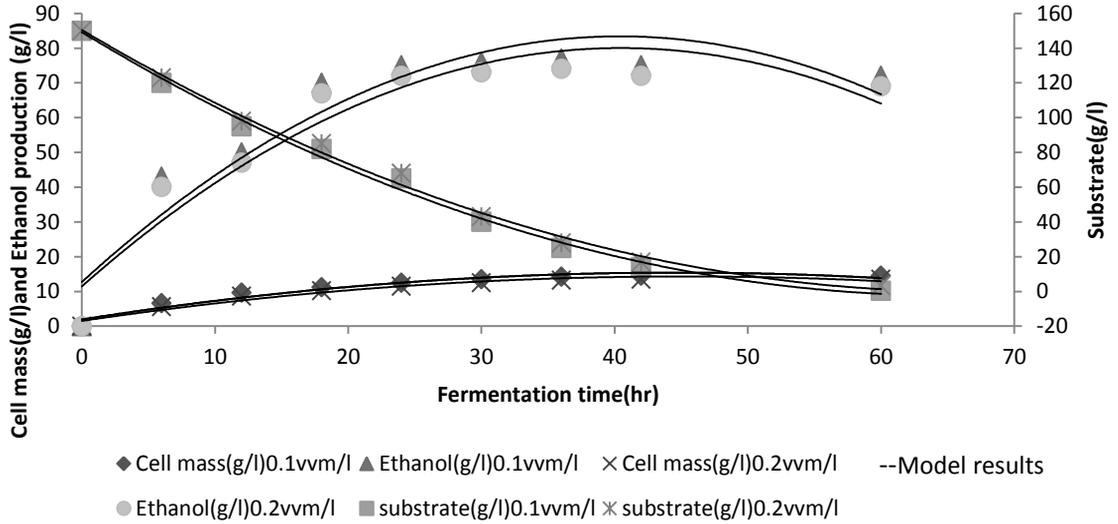


Figure 5: Ethanol production using glucose as carbon source at 0.1vvm/l and 0.2vvm/l

It is seen that the higher production of ethanol can be achieved by using molasses as compare to glucose.

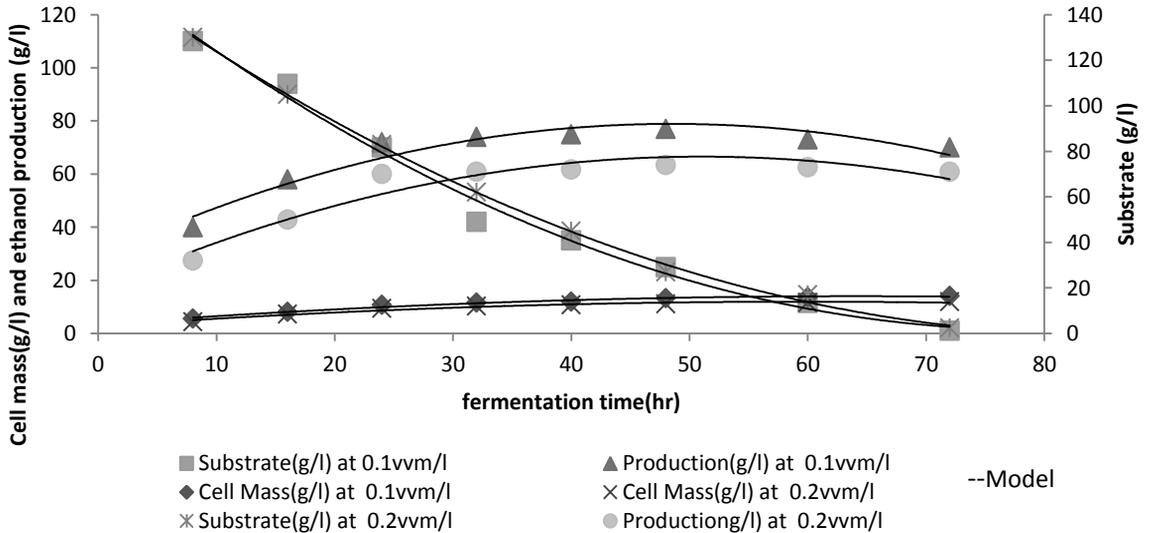


Figure 6: Ethanol production using molasses as carbon source at 0.1vvm/l and 0.2vvm/l

Effect of pH on ethanol production using different carbon source

Rate of fermentation is very much influenced by pH while producing ethanol from bio materials Like, molasses, sugar, starch etc. Because of that pH is critically adjusted to achieve better production in different biological and chemical processes.

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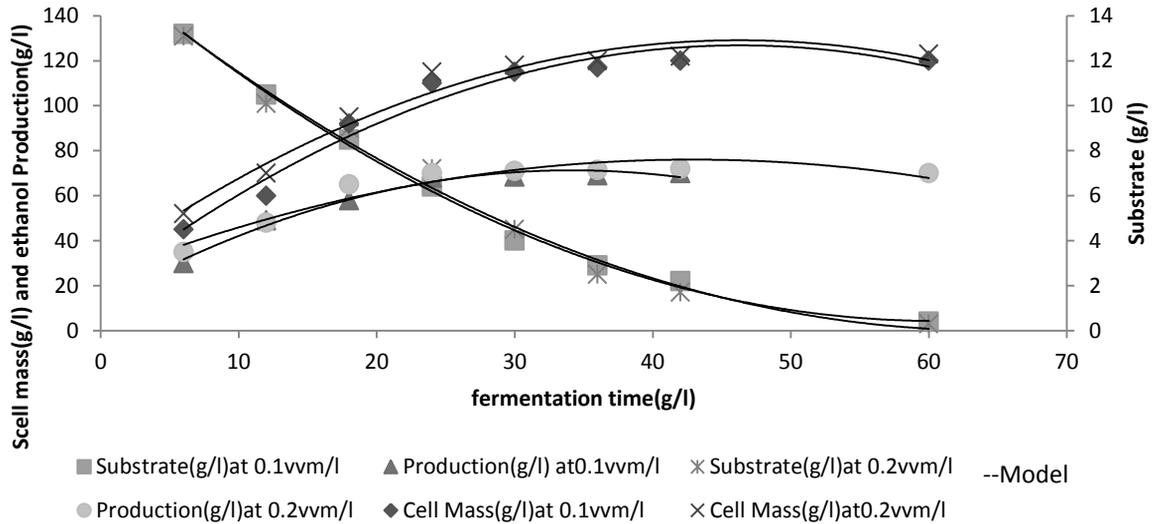


Figure 7: Ethanol production using sucrose as carbon source at 0.1vvm/l and 0.2vvm/l

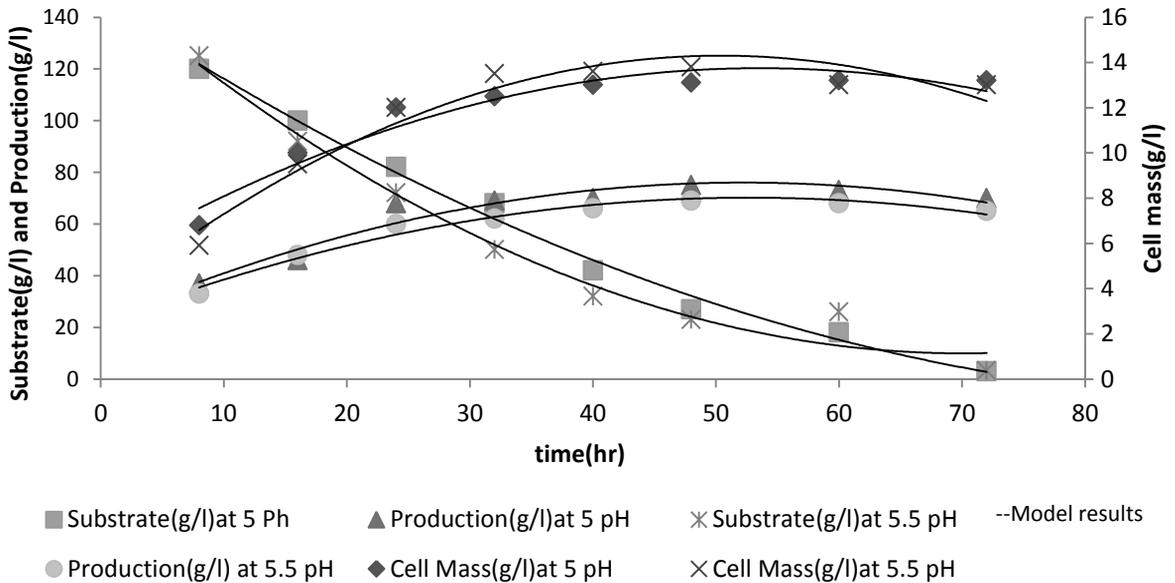


Figure 8: Ethanol production using glucose as carbon source at pH 5 and 5.5

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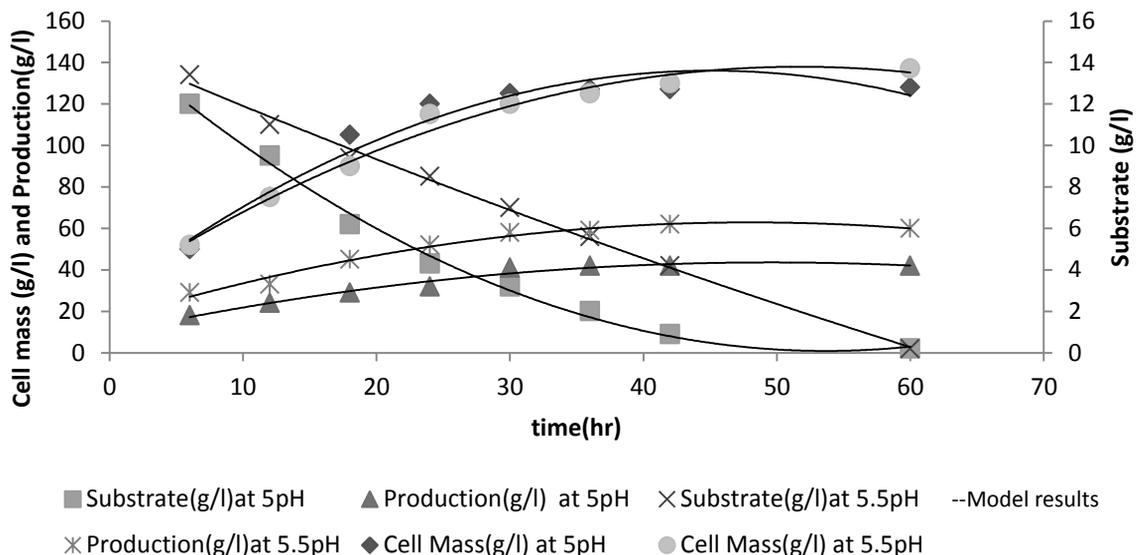


Figure 9: Ethanol production using molasses as carbon source at pH 5 and 5.5

Numerical simulation was carried out to study the effects of different pH ranges on ethanol production. In figure 9, 10% glucose & 15% glucose was used at pH 5 and 5.5, but the maximum ethanol production achieved at 10% glucose pH 5.5 in figure 9.

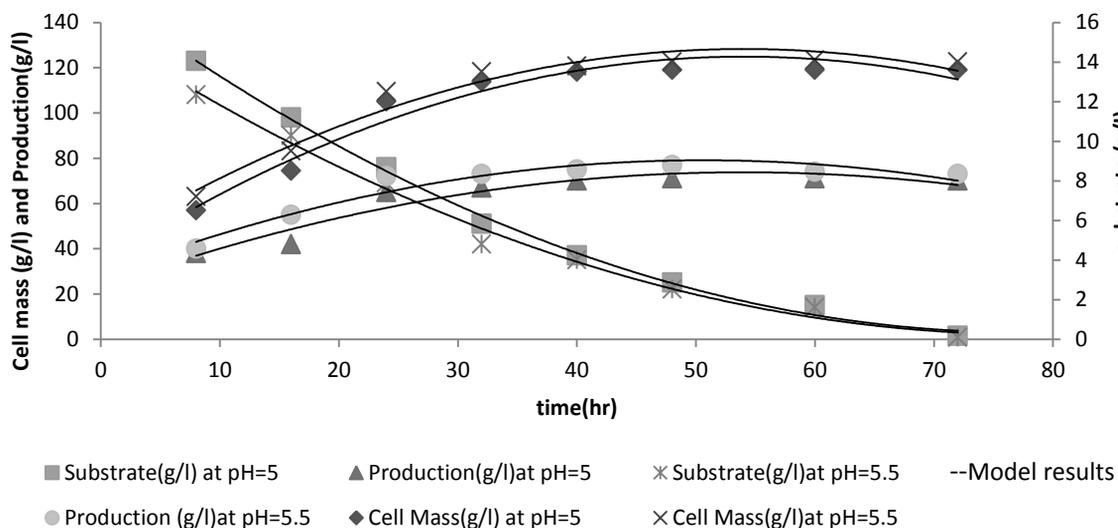


Figure 10: Ethanol production using sucrose as carbon source at pH 5 and 5.5

Effect of Agitation intensity on ethanol production using different carbon source

Regarding ethanol production, in fermentation process agitator were used to provide homogeneous mixing between nutrient and microorganism for the growth. Regarding this agitation intensity had much significance to measure the value change in growth by changing rpm. Numerical simulation was carried out to measure the changes with respect to change in rpm, different rpm was used from 250-450rpm and different carbon sources like sucrose, glucose and molasses for numerical simulation. The maximum ethanol production for sucrose as carbon source at 300 rpm is about 15% sucrose shown in figure 12. For glucose, the maximum ethanol production was observed at 15% glucose at 300 rpm shown in figure 13. In figure 14 molasses is used as a carbon source by utilizing about 10% and 15%, but the maximum ethanol production was observed at 15% molasses at 300 rpm using numerical simulation.

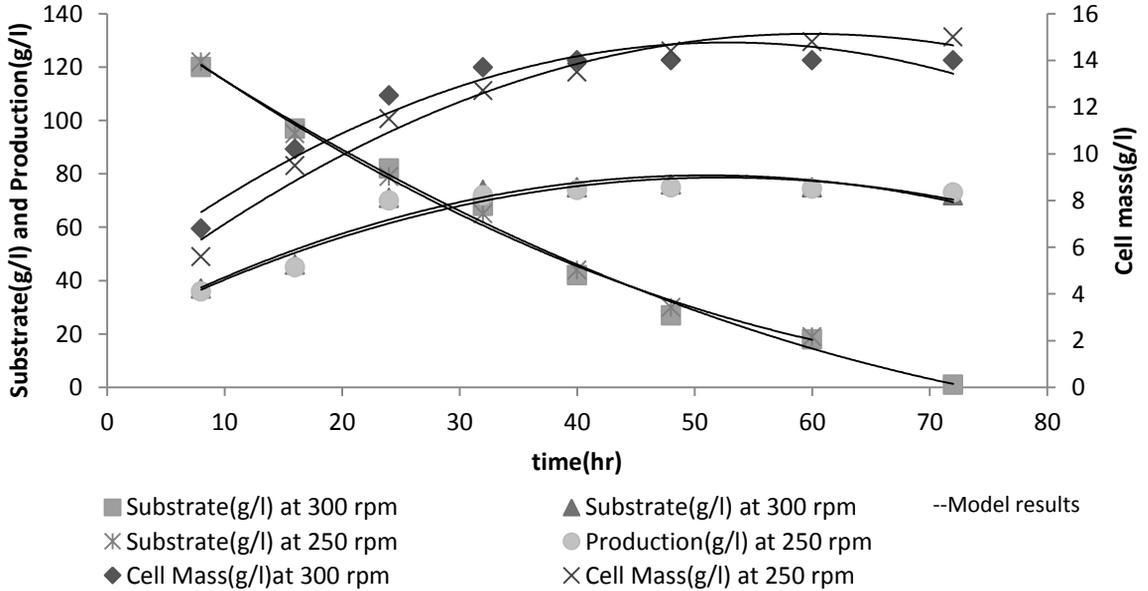


Figure 11: Ethanol production using glucose as carbon source at 250rpm and 300rpm

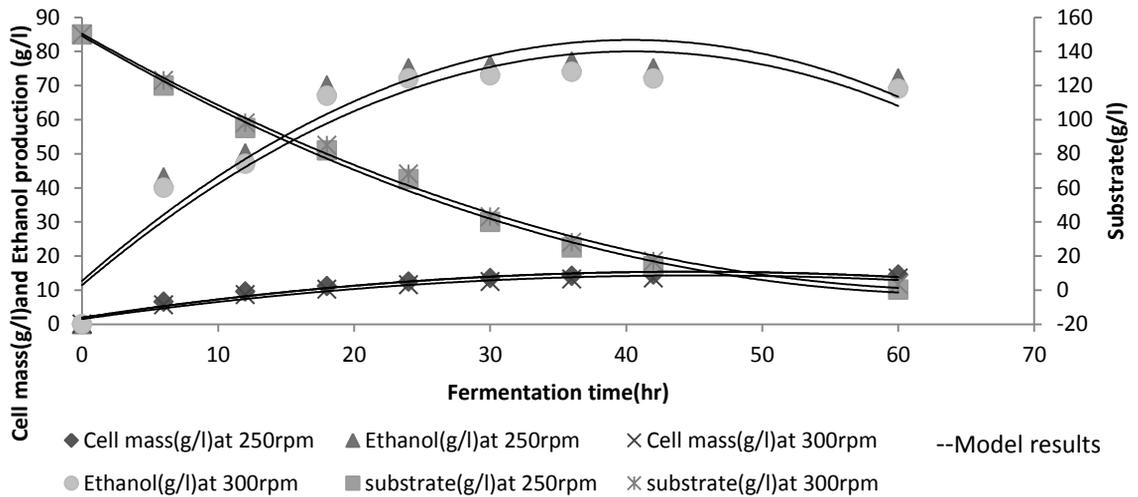


Figure 12: Ethanol production using molasses as carbon source at 250rpm and 300rpm

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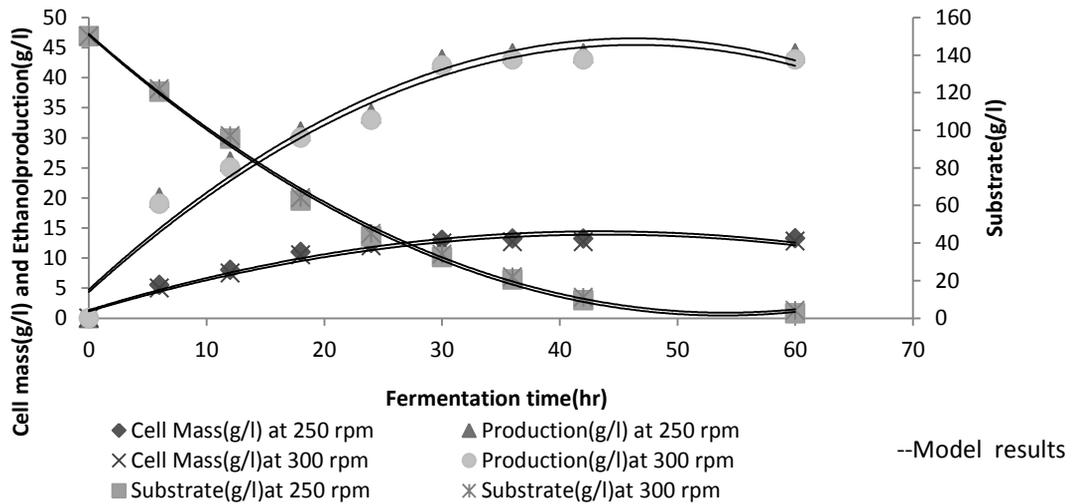


Figure 13: Ethanol production using molasses as carbon source at 250rpm and 300rpm

CONCLUSION

Numerical simulation could solve various differential equation in short period of time by utilizing appropriate numerical method. RK order 4 gave the best possible results regarding ethanol production from molasses by utilizing different carbon sources. During process of fermentation different carbon sources can be utilized, through this work. Experimental data and Monod model declared best possible results comparatively same. The maximum ethanol production (76 g/l) was observed at 15% molasses, as for sucrose and glucose are concerned it gives lower value of ethanol production up to 73g/l by keeping other operational parameter under optimized condition such are 35°C, 300rpm, 0.2vvm/l and pH5.5.

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