

Simulation of Ethanol Production by Fermentation of Molasses

¹Ruhul Amin M., ²Saqib Hossain M., ³Sarker M.

¹Assistant Professor, Chemical Engineering Department, BUET, Dhaka, Bangladesh

²Chemical Engineering Department, BUET, Dhaka, Bangladesh

³Research Assistant, Chemical Engineering Department, BUET, Dhaka, Bangladesh

Email: amin@che.buet.ac.bd

Abstract – Ethanol is a renewable resource of energy and is potentially cleaner alternative to fossil fuels. Production of ethanol is growing day by day at a great extent for its versatile application and demand. During recent years, production of ethanol by fermentation on a large scale has been of considerable interest to meet to increased demand. Fermentation is a biological process in which sugars such as glucose, fructose, and sucrose are converted into cellular energy and thereby produce ethanol and carbon dioxide as metabolic waste products. It has long been recognized that molasses from sugar-cane or sugar provide suitable substrates for ethanol production. Production of ethanol by fermentation of molasses is simulated by Simulation software Aspen Hysys 7.1 to investigate the effect of few important parameters like fermentation temperature, pressure that effect the production of ethanol and to optimize those parameters. The present investigation has demonstrated the trend of changing production by changing of those parameters.

Keywords – Ethanol, Fermentation, Simulation, Molasses, Renewable energy

1. Introduction

Ethanol is mostly used as fuel and has become an alternative of renewable energy source now-a-days. Ethanol is an eco-friendly alternative to petroleum-based fuel as it has fewer greenhouse gas emissions. The production of ethanol is growing day by day at a great extent for its versatile application and demand. As the supply and price of oil and gas worldwide has become a major problem, ethanol is taking place as an alternative. Worldwide ethanol production as fuel reached 32.35 billion gallons in 2012. ^[1] Ethanol is obtained by the fermentation process where the sugar content in juices and honey of crops are transformed into alcohol using yeast. ^[2] Though ethanol can be produced by different process fermentation is mostly feasible for countries Brazil where sugar cane is produced at a large extent. ^[3] Ethanol production can largely be increased if fermentation process is updated. Simulation of this process can be performed form which new ideas for increasing production and minimizing cost can be achieved as computer based simulation has been very popular now-a-days for different chemical engineering purposes. In this work a detailed study becomes of the process by means of simulation in Aspen Hysys v7.1. This simulation was performed by assuming and simplifying several things. Though simulation does not give the real world performance or the real life production environment but if the basic process is known

and related data are available, it surely is the best way by which an individual can get ideas of an industrial process without conducting any experiment.

2. Methodology

The process of producing Ethanol from molasses is simulated in Simulation software Aspen Hyssy 7.1. Aspen HYSYS process simulator is a core element of AspenTech's aspenONE® Engineering applications. ^[4] It has already been proved as an efficient simulator with reasonable accuracy. It offers a comprehensive thermodynamics foundation for accurate determination of physical properties, transport properties, and phase behavior. Aspen HYSYS can be used to determine outlet process conditions if the inlet conditions like temperature, pressure, and composition are specified. The NRTL model fits best to equilibrium because the components involved in the process have characteristics of polarity and electrolytes, besides operating conditions in the process is less than 10 bar pressure. ^[5] The process assumes a pressure drop, which implements pump units only.

2.1 Process Description

Depending on the extraction process of molasses from different sources, compositions can be varied. The raw

material composition used for this simulation is shown in the Table 01.

Table 1. Compositions of Dissolve Sugar from Molasses

Component	Mole fraction (%)
Water	83.2783
Sucrose	6.4406
Glucose	4.9554
Fructose	5.3256

The whole process of producing ethanol from molasses is shown in a block diagram in figure 01.

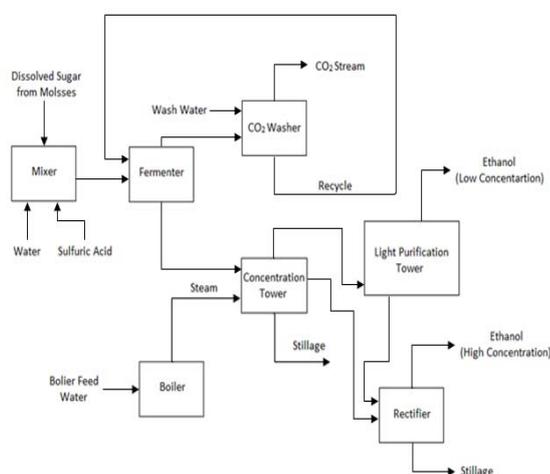
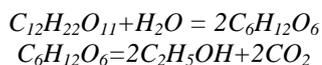


Figure 1. Process Block Diagram of Ethanol production from molasses

2.1.1 Reaction involved

Two reactions involve with this process, one is for fermentation and another is for conversion of fructose to ethanol.



Catalyst of fermentation reaction is invertase enzyme from yeast and Catalyst of ethanol conversion reaction is zymase.

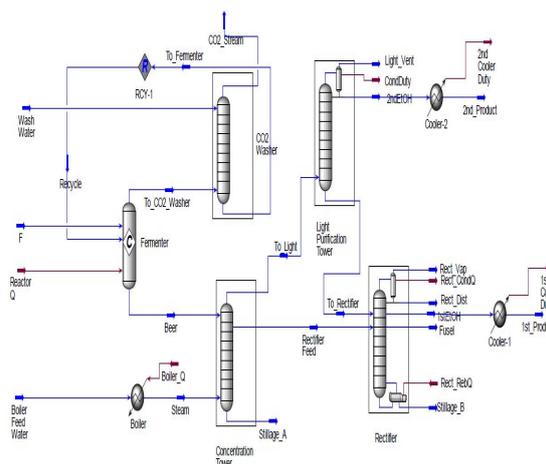


Figure 2. Process Flow Diagram of Ethanol Production from Molasses by Fermentation

2.1.2 Fermentation

Dissolved sugar from ground up molasses is diluted by mixing water with it. Sulfuric acid is added with diluted sugar to prevent bacterial contamination. Yeast is added with this before feeding to fermenter. Yeast provides invertase and zymase enzymes. Only sucrose of this diluted sugar is degraded by invertase enzyme, this process is referred to as hydrolysis. Glucose and fructose are obtained by hydrolysis of sucrose. The conversion of sucrose in the fermenter was defined in 90 %.Glucose and Fructose is converted into ethanol and carbon-dioxide, where conversion rate is defined as 95%. Catalyst of this reaction is zymase.CO₂ gas leaving the fermenter carries away some ethanol with it.

2.1.3 CO₂ washing

This gaseous stream is sent to CO₂Washer which is an absorption column. Here ethanol is absorbed by wash water. The gaseous stream leaving the absorber contains negligible amount of ethanol and this stream is vented in atmosphere. The liquid stream is recycled to the fermenter.

2.1.4 Ethanol Distillation

The liquid stream leaving the fermenter is a very dilute ethanol solution which also contains some sucrose, glucose, fructose and sulfuric acid. This stream is sent to the Concentration Tower which is a stripping column. Superheated steam at atmospheric pressure is used as the stripping gas. The Liquid Stream from the bottom of this tower contains water with trace of sucrose, glucose fructose and sulfuric acid. A side stream is drawn from the 6ththeoretical stage of this tower, which is sent to Rectifier. The gaseous stream emerging from top of the tower is sent to Light Purification Tower.

Light Purification Tower used in this simulation is modeled as refluxed absorber in Hysys. Partial condenser is used in this tower. Ethanol content of the gas stream leaving the condenser of this tower is low and its flow rate is also kept very low. By this stream rest of the CO₂

gas is vented to atmosphere, which was not removed by the CO₂ Washer. The liquid stream leaving the bottom of this tower is a dilute ethanol solution with no other component. This is also fed to the Rectifier. The condensate collected from this unit is the light ethanol (74.23%) which is cooled to 25°C.

Rectifier used in this simulation is a distillation column which has to feed, one is from Concentration Tower and other one is from Light Purification Tower into 22nd and 19th theoretical stage respectively. Concentrated ethanol (88.14%) is drawn out from the 2nd theoretical stage of this tower which is also cooled to 25°C.

3. Results and Discussions

Simulation work is done to optimize different parameter of process to obtain maximum products. Those are fermenter condition like temperature and boiler feed water flow rate.

3.1 Effect of Fermenter Temperature Ethanol Product Flow Rate

Fermentation condition is an important parameter of fermentation process. Controlled condition can ensure maximum product from fermentation. In this current study Ethanol production is maximized by controlling fermentation temperature by simulation. As per simulation there are two product streams. Simulation is done for both product lines separately.

3.1.1 Effect of Fermenter Temperature on 1st Ethanol Product Flow Rate

For the first ethanol product line the data obtained from simulation are shown in Tabular form in Table 02.

Table 2. Effect of Fermenter Temperature on 1st Ethanol Product Flow Rate

Temperature of Fermenter (°C)	Flow Rate of 1 st Ethanol Product (kgmole/hr)
30	67.9
40	67.83
50	67.4
60	65.74
70	61.61
80	52.99
85	45.21
90	33.21

Data from simulation are represented in a graphical format in figure 03 in which product flow rate of first product line is plotted as a function of Fermenter temperature

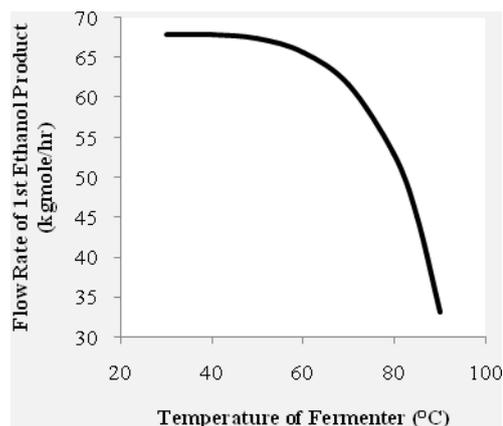


Figure 3. Effect of Fermenter Temperature on 1st Ethanol Product Flow Rate

From figure 03, it can be clearly seen that at low fermenter temperature production rate is higher. Then as the fermenter temperature increases production rate falls down. Rate of falling down of production rate is lower in low temperature but higher in high temperature. To optimize production fermenter temperature should maintain at lower. Thus fermenter media should be cooled.

3.1.2 Effect of Fermenter Temperature on 2nd Ethanol Product Flow Rate

For the second ethanol product line the data obtained from simulation are shown in Tabular form in Table 03.

Table 3. Effect of Fermenter Temperature on 2nd Ethanol Product Flow Rate

Temperature of Fermenter (°C)	Flow Rate of 2 nd Ethanol Product (kg mole/hr)
30	2.781
40	2.53
50	2.34
60	2.129
70	1.823
80	1.288
85	0.8331
90	0.1591

Data from simulation are represented in a graphical format in figure 04 in which product flow rate of second product line is plotted as a function of Fermenter temperature

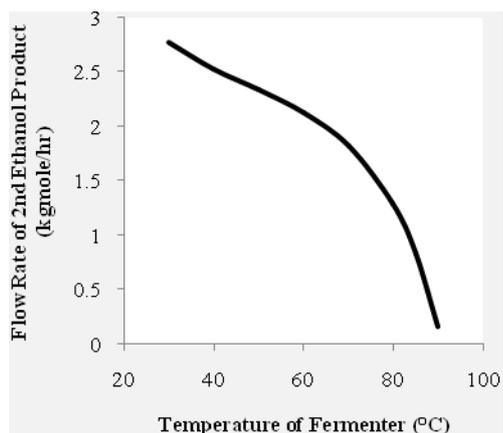


Figure 4. Effect of Fermenter Temperature on 2nd Ethanol Product Flow Rate

From **Figure 4**, it can be clearly seen that at low fermenter temperature production rate is higher. Then as the fermenter temperature increases production rate falls down. Rate of falling down of production rate is quite similar at low and high temperature. To optimize production fermenter temperature should maintain at lower. Thus fermenter media should be cooled before operation.

3.1.3 Effect of Boiler Feed Water Flow Rate on Light Stream Composition

Simulation is done to optimize the boiler feed water flow rate to maximize the production. Simulation data are presented in tabular form showing effect of boiler feed water flow rate on light stream composition in Table 04

Table 4. Effect of Boiler Feed Water Flow Rate on Light Stream Composition

<i>Flow Rate of Boiler Feed Water (kgmole/hr)</i>	<i>Mole fraction of Ethanol in To_Light Stream</i>
100	0.315776
110	0.316297
120	0.31636
130	0.316351
140	0.316334
150	0.316322
160	0.316305
170	0.316295

Data from simulation are also represented in a graphical format in figure 05 in which composition of light stream line is plotted as a function of Boiler feed water.

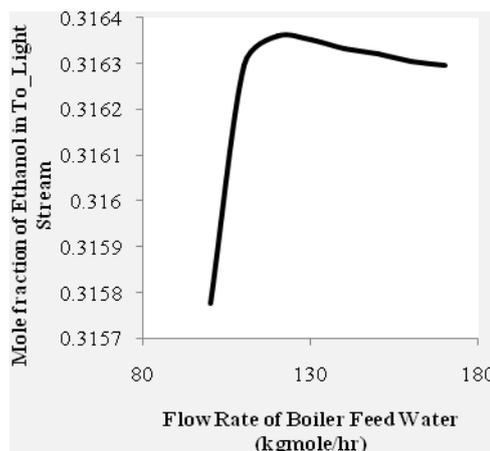


Figure 5. Table 04: Effect of Boiler Feed Water Flow Rate on Light Stream Composition

From **Figure 5**, it is seen that ethanol content in Light stream increases with the increment of Boiler Feed Water flow rate. But when Boiler Feed Water flow rate reaches at a certain value, ethanol content in Light stream reaches its peak value. For more increment in Boiler Feed Water flow rate, ethanol content in To_Light stream decreases. For this reason Boiler Feed Water flow rate should maintained at optimized value in simulation.

Mole fraction of ethanol in the concentrated product was 0.8814, where azeotropic mole fraction is 0.89. To increase concentration of ethanol in final product other separation process should be used. Packed column can be used which absorbs water and increases ethanol concentration. Dehydrating agents can be used.

8. Conclusions

Ethanol is a relatively low-cost alternative fuel. It is considered to be better for the environment than gasoline. Ethanol-fueled vehicles produce lower carbon monoxide and carbon dioxide emissions, and the same or lower levels of hydrocarbon and oxides of nitrogen emissions.^[6] It burns with a smokeless blue flame that is not always visible in normal light.^[7] As the raw material of ethanol is farm based its production supports farmers and creates domestic jobs. And because ethanol is produced domestically, from domestically grown crops, it reduces dependence on oil and increases the nation's energy independence. Worldwide fuel ethanol production is increasing day by day as per demand. For all these reasons; it is a great challenge for chemical engineers to produce ethanol in low cost. Simulation analysis has become very handy tool now a day to test a process to verify its feasibility at different operating parameters. The fermentation of molasses into ethanol is one of the earliest biotechnologies employed by humanity. In this present study fermentation process development to produce ethanol is main concern. And the job is done successfully by optimizing several operating conditions.

Acknowledgements

This section need not be numbered. It should be inserted after the Conclusions

References

- [1] Viewed 25 March 2013, <http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production>
- [2] J.P. Contreras, Chemical Engineer, Universidad de los Andes, Bogotá, Colombia
I.D. Gil, M.Sc. Chemical Engineer, Universidad Nacional de Colombia, Bogotá, Colombia *Simulation Of An Industrial Plant Of Anhydrous Ethanol Production From Sugar Cane Juice*
- [3] T. Austin, George: Shreve's Chemical Process Industries, 5th Edition McGraw-Hill Book Company
- [4] HYSYS. Aspen HYSYS user guide. Aspen Technology Inc. www.aspentech.com
- [5] Carlson, E.C.,(1996). *Don't Gamble With Physical Properties for Simulations*, Chemical Engineering Process, Octubre de 1996, pp. 35-46.
- [6] Viewed 25 March 2013 http://environment.about.com/od/ethanolfaq/f/ethanol_benefit.htm
- [7] USA (2012-03-06). "[Ethanol - PubChem](http://pubchem.ncbi.nlm.nih.gov)". Pubchem.ncbi.nlm.nih.gov. Retrieved 2012-04-23
- [8] Awatif Abid Al-Judaibi "Effect of Some Fermentation Parameters on Ethanol Production from Beet Molasses by *Saccharomyces cerevisiae* CAIM13" Department of Biology-Microbiology, King Abdulaziz University, Jeddah, Saudi Arabia
- [9] Cardona, C.A., Sánchez, O.J. (2006). *Energy consumption analysis of integrated flowsheets for production of fuel ethanol from lignocellulosic biomass*, Energy No 31, pp. 2447-2459.
- [10] Cardona, C.A., Sánchez, O.J., Montoya, M.I., Quintero, J.A., *Simulación de los Procesos de Obtención*

de Etanol a partir de Caña de Azúcar y Maíz, Scientia et Technica Año XI No 28 Octubre, pp. 187-192.

[11] Fogler, H.S., (2001). *Elementos de Ingeniería de las Reacciones Químicas*. Ed. Prentice-Hall, Capitulo 4, Capitulo 5.

Vitae



Dr. Ruhul Amin, was born in Bangladesh. He obtained a B.Sc degree in Chemical Engineering in 1994 from Department of Chemical Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

He obtained a M.Sc degree in Chemical Engineering in 1999 from Department of Chemical Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

He obtained a Ph.D degree in Chemical Engineering in 2010 from Department of Chemical Engineering of King Fahd University of Petroleum & Minerals, Saudi Arabia

He worked as an Assistant Professor in Chemical Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh. His research interest includes Polymer Science, Process Simulation and Optimization.