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Process Intensification & Simulation for Hydrolysis of Sucrose

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ABSTRACT: -
In food process industry, Fruit juice is processed by converting fruit into canned juice with a long shelf life without losing the original taste of fruit. Also, they have a limited life span and are perishable in nature. So it is impossible to make fresh fruits available throughout a large area in a limited period of time. In this project, the Major objective is to study the possibility of increasing the concentration of liquid solution process from the reactor by using the Air stripping method. Fruit juice mainly contain of natural sugar(sucrose), so we used "hydrolysis of sucrose" reaction to perform our experiment.

$C_{12}H_{22}O_{11}+H_2O \rightarrow C_6H_{12}O_6+C_6H_{12}O_6$
(sucrose) (glucose) (fructose)

In this lab based experiment method, we performed this experiment with the help of blending tank and packed bed column reactor and simulation of theprocess using DWSIM software.

Keywords: hydrolysis, blending, simulation, packed bed column reactor, DWSIM software

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I. Introduction: -

A crucial segment of the total processed fruit industry is represented by Juice and juice products. Most of the fruits grow in a particular season and a specific climatic zone. Also, they have a limited life span and are perishable in nature. So it is impossible to make fresh fruits available throughout a large area in a limited period of time. It is easier to make it available over the entire year in the form of juice products. Concentration means a reduction of the water content of a solution. The concentration of raw juice has many benefits including increased shelf life, easy transportation and packing, reduction in volume and weight of the product, increase in stability and an overall reduction in cost.

A large amount of solutions are concentrated in different process industries such as food processing industries, organic and inorganic chemical industries, oil industries, petrochemical industries etc. for optimal utilization of storage volume. Concentration is mainly done industrially by Thermal evaporation under vacuum using various types of evaporators.

Fruit juice are mainly contains of natural sugar (sucrose) , so we used "Hydrolysis of Sucrose" reaction to perform our experiment on lab-based scale . One of the main benefits of using concentrated fruit juice in food processing is that it can reduce transportation costs. By removing the water from the juice, the product is lighter and takes up less space, which can lead to significant savings in shipping and handling. Also it can enhance the flavor and aromaof food products. The removal of water intensifies the natural sweetness of the fruit, making it a popular choice for use in desserts and baked goods. Overall, the reduction of water from fruit juice has numerous benefits in the food processing industry, including cost savings, improved flavor, and reduced waste.

Experimental methods

1. INDUSTRIAL METHOD

Thin film and wiped film evaporator are commonly used for fruit juice as the products are heatsensitive. The liquid flows vertically down the evaporator wall by gravity. It forms a thin film on the wall aided by mechanical wipers that cover the evaporating surface. Heat is supplied to the other side of the surface. Non-uniform distribution of the heat and formation of local hotspots are major disadvantages of the equipment. The low heat transfer coefficient values, and decrease in the magnitude at high feed rate result in large sizes of evaporators and also highoperating costs.

2. ALTERNATE LAB BASED METHOD

An alternative to using thermal energy for the concentration of the solution could be stripped of water from the solution using gas/air. Air stripping involves the transfer of the water from the solutions in the form of vapour from the liquid into the unsaturated air stream. The operating cost is expected to also be lower as the process that relied completely on thermal energy in evaporators for a reduction in water content of the solution is partly replaced by mass transfer.Some of the conventional equipment for directly contacting air-liquid mass transfer are packed bed, spray column, staged column, etc. The major concern with air stripping process is that removal of water by mass transfer in these equipment would be low as gas-liquid mass transfer coefficients are small. Therefore, the volume of conventional mass transfer equipment for thismethod such as fixed bed would be large.

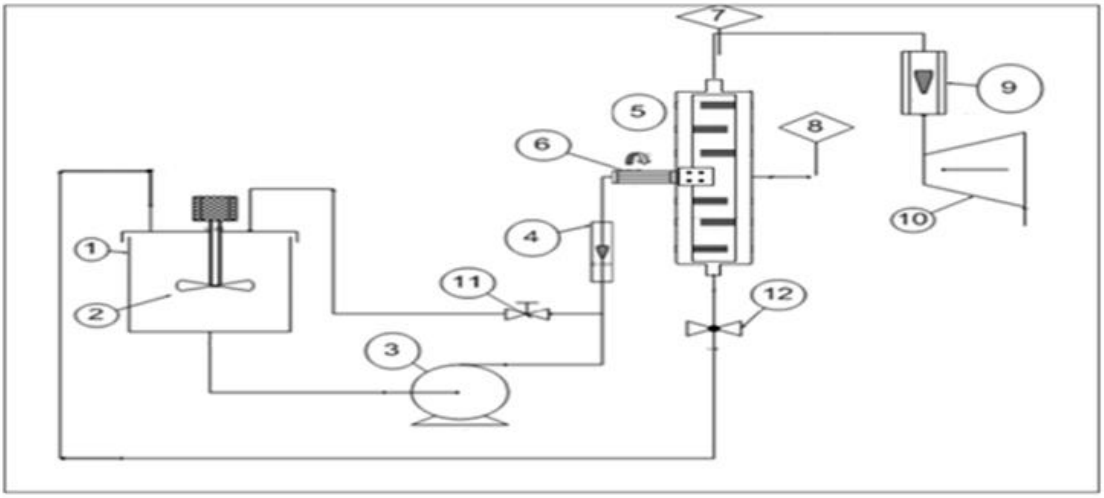

Fig 1. Lab based method setup

1) Solution Tank 3) Feed pump 5) RZB 7) Air inlet 9) Air Rotameter
11) Bypass valve 2) Tank stirrer 4) Liquid Rotameter 6) Rotor 8) Air outlet
10) Air compressor 12) Liquid outlet valve

For experimental work we have taken sucrose ($C_{12}H_{22}O_{11}$) of M.W. 342.30 as a representationof fruit juice [As juice compose of natural sugar i.e., sucrose]

3.1 Experimental procedure for hydrolysis of sucrose

Reaction: $C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$

(sucrose) (glucose) (fructose)

Chemicals: Sucrose = 83 gm

H_2O = 500 ml

H_2SO_4 / HCL (Catalyst) .

Requirements : Beaker (500 ml) , Magnetic stirrer , Pack bed column .

Procedure :

A] For Stirrer Tank (Batch)

1. Take 83 gm of sucrose in 500 ml beaker which serves as a batch reactor .
2. To this 1-2 drop of concentrated HCL is added and reaction it allowed to proceed .
3. Place the beaker on a Magnetic stirrer at speed of approx. 200 rpm .
4. At regular interval of time (5 min) , 20 ml of reaction mixture is taken from reactor for testing .
5. In each case , 20 ml of reaction mixture is immediately transferred in conical flask containing ice cubes for reducing rate of reaction .

B] For Packed bed Reactor

1. Prepare the liquid and gas phases: The liquid phase may be prepared by dissolving aknown quantity of solute in a solvent, while the gas phase may be a pure gas or a mixture of gases. Both phases should be carefully prepared to ensure their composition is accurately known.

2. Set the experimental parameters: The flow rates of both the liquid and gas phases, as well as their respective temperatures and pressures, should be set to the desired values. The flow rates are typically controlled using pumps or flow controllers, while temperature and pressure can be measured using appropriate sensors.

3. Begin the experiment: Start the flow of both the liquid and gas phases into the packed bed column. Allow the system to equilibrate for a sufficient amount of time, typically until steady-state conditions are achieved.

4. Measure the mass transfer rate: The mass transfer rate between the liquid and gas phases can be measured by analysing the concentration of the solute in the liquid phase as it exits the column. This can be done using various analytical techniques such as spectrophotometry or chromatography.

5. Record data: Record the data obtained during the experiment, including flow rates, temperatures, pressures, and mass transfer rates. These data can be used to analyse the performance of the packed bed column and to compare it to theoretical predictions.

6. Analyse data: Use appropriate data analysis techniques to analyse the experimental results, including mass transfer coefficients, overall mass transfer rates, and any other relevant parameters. Compare the results to theoretical predictions and identify any sources of error or deviation from expected behaviour.

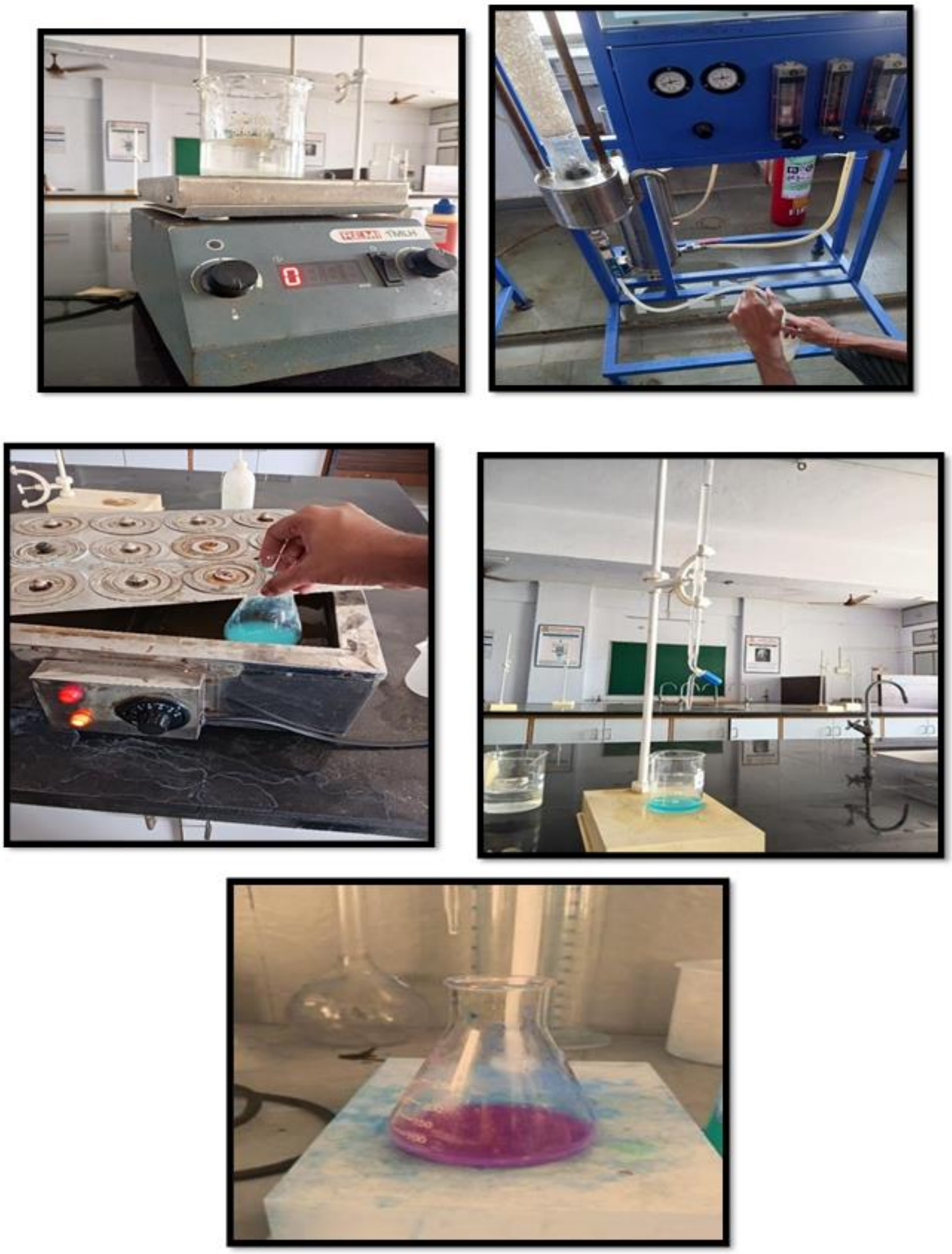

Fig 2: EXPERIMENTAL SETUP

Observation table

Time [min]	Blending tank Concentration	PBR Concentration
5	4	7
10	7	11
15	9	16
20	8.9	15.7

Table no .1 Observation Table

II. SIMULATION: -

Chemical process simulation aims to represent a process of chemical or physical transformation through a mathematic model that involves the calculation of mass and energy balances coupled with phase equilibrium and with transport and chemical kinetics equations.

DWSIM is based on the Aspen Plus simulator and can perform steady-state and dynamic simulations of various unit operations such as distillation, absorption, extraction, reaction, and more. The software uses a combination of thermodynamic models such as Peng-Robinson, Soave-Redlich-Kwong, and UNIFAC to predict the behaviour of chemical compounds under different conditions.

The software has a modular structure, allowing users to add custom unit operations or thermodynamic models. It also features an extensive library of pre-built components, including pumps, valves, reactors, and more. DWSIM supports several output formats, including CSV, Excel, and HTML, making it easy to analyse and visualize simulation results.

DWSIM is compatible with Windows, Linux, and macOS and can be used in multiple languages. It is continually updated, and new features are added frequently, ensuring that it remains a powerful and versatile tool for process simulation.

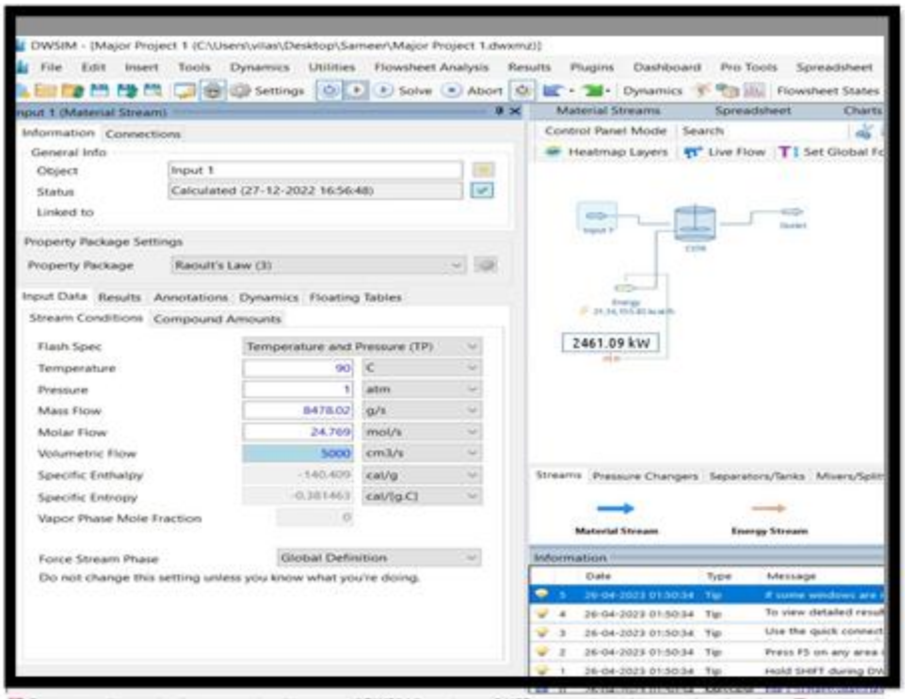

Fig 3: Material Stream (DWSIM)

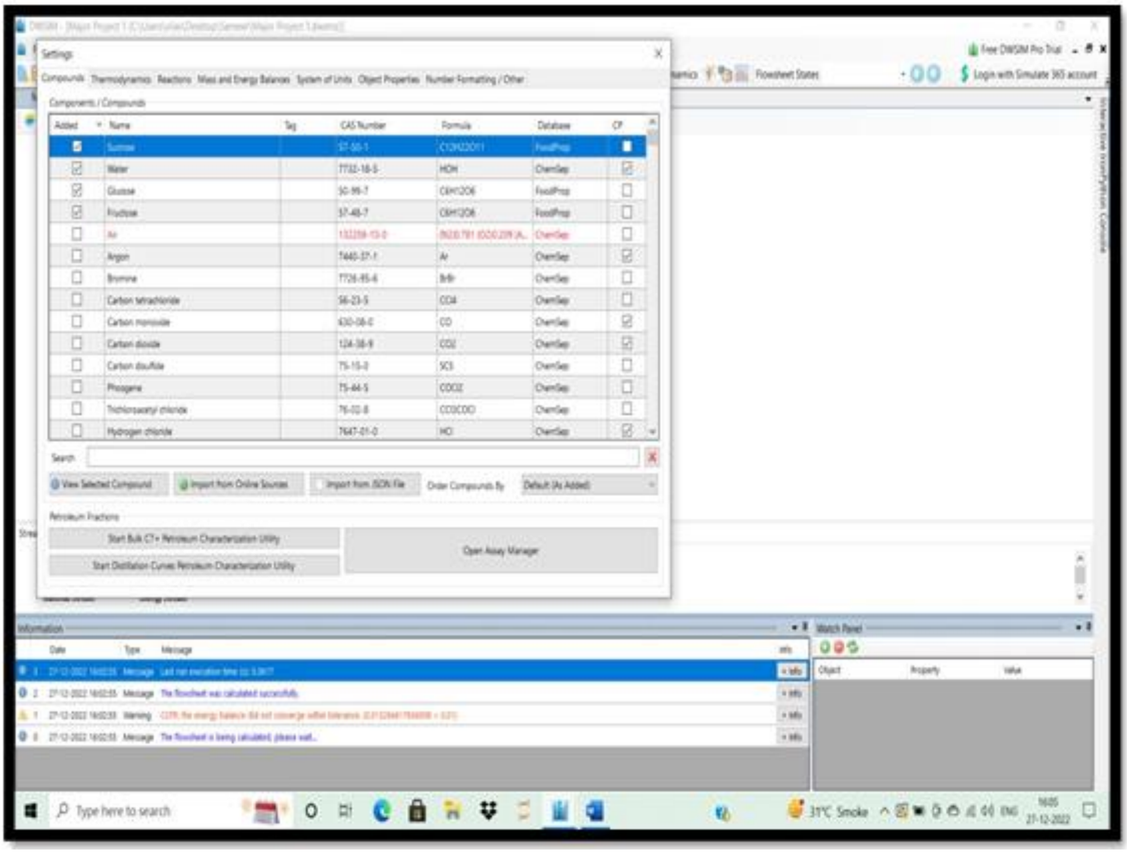

Fig 4: Kinetic Reaction (DWSIM)

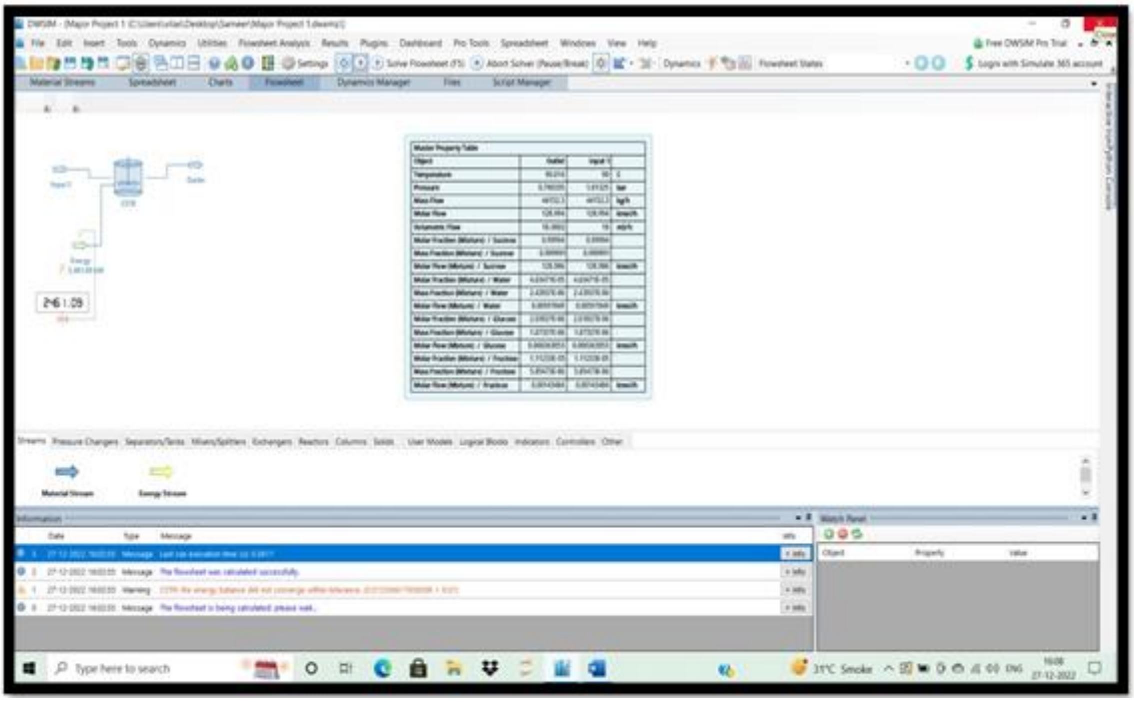

Fig 5: Simulation of CSTR (DWSIM)

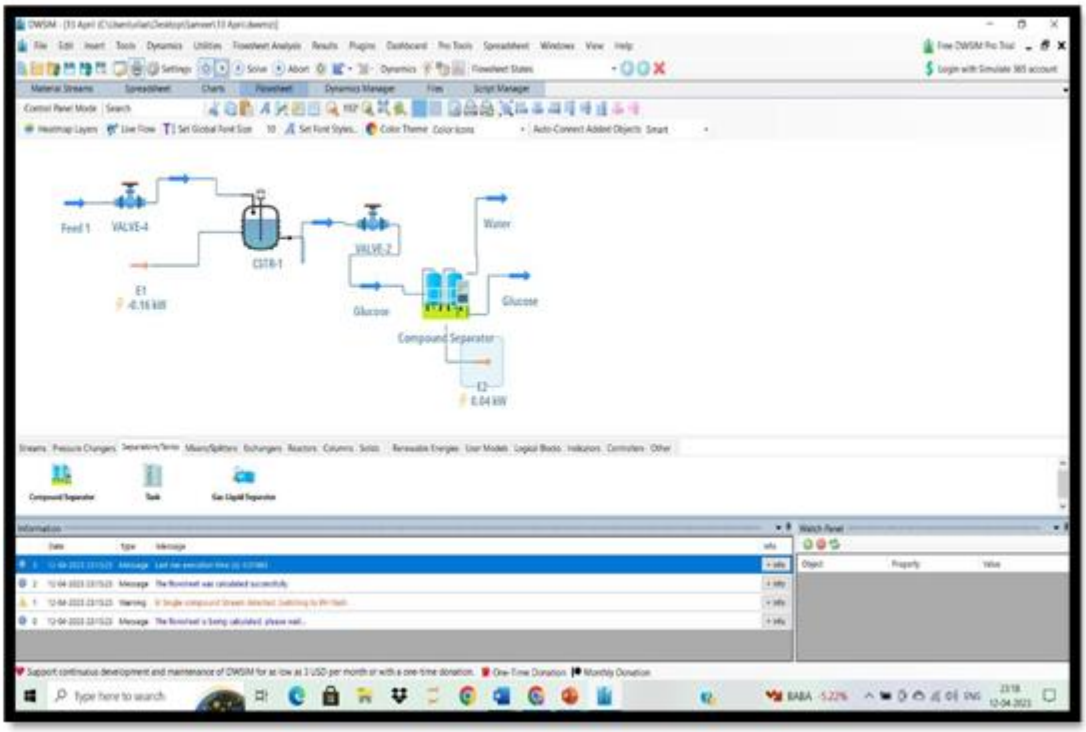

Fig 6: Simulation for Production of Glucose (DWSIM)

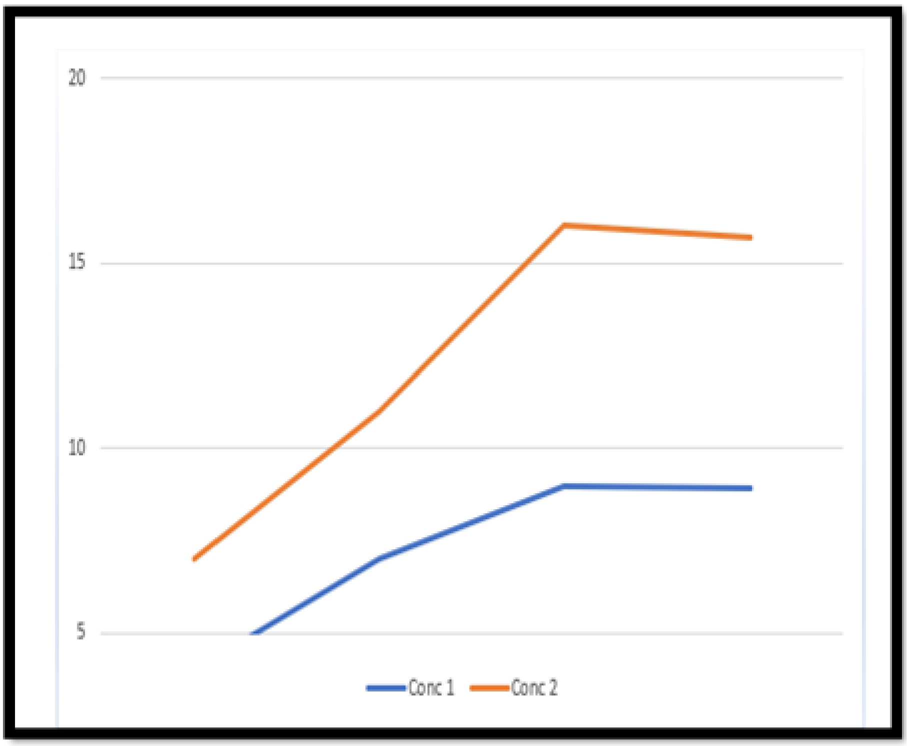

Fig 7: Sucrose conversion graph by Experimentation

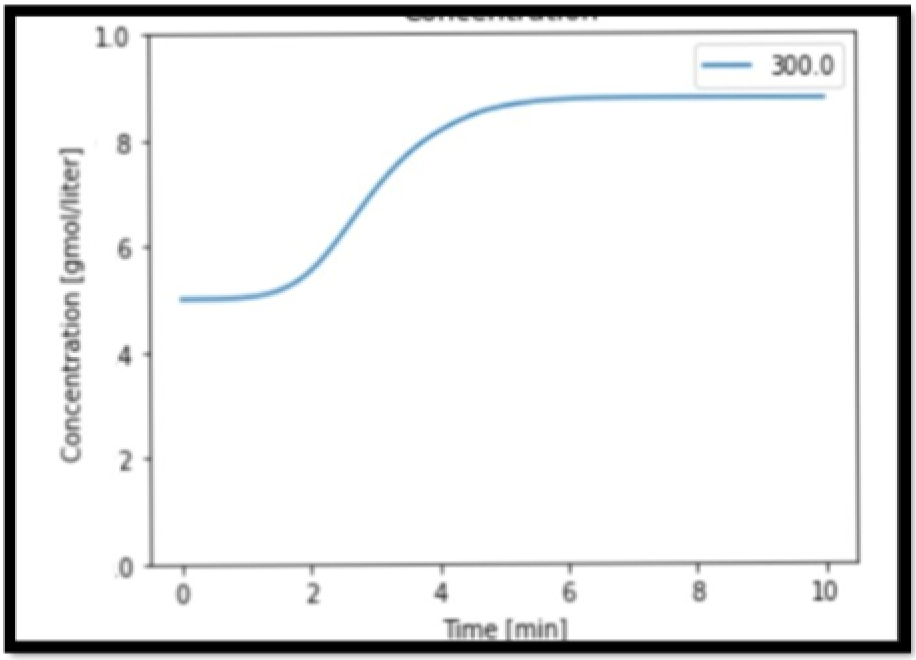

Fig 8: Simulated graph of Sucrose conversion (DWSIM)

Results & Discussion: - The conversion of sucrose from blending tank is **55 %.**
the conversion of sucrose from packed bed column reactor is **71.5 %.**

III. Conclusion: -

From the both the graphs we can conclude that, Concentration of solution was higher in packed bed column as compared to StirringTank. Volume of packed bed column is lower than tank, which increases the conversion rate is higher in Packed Bed Column then in CSTR. Energy Requirement is less in packed bed column. Air-Liquid mass transfer leads to better evaporation of water through counter contraction which make solution with lower water content and higher concentration. As volume used store the product is reduced will result in lower cost of product. The space required for the original process can be reduced with small size equipment's. Intensified process makes transportation of equipment's easy leading to small scaleindustry growth.

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