Affordable Monitoring for Bioreactors

Aaliyan Kapadia, Adrian Foell and Irfan Khan

UNIVERSITY OF WATERLOO
FACULTY OF ENGINEERING
Department of Chemical Engineering

Introduction | Problem Statement

Cell cultivation is a rapidly growing industry [1]

Focuses on the production of biological products and cells such as yeast, algae [2]

Often requires specialized equipment such as bioreactors [2]

Cell cultivators are priced out of automatic monitoring systems [3]

The current alternative is to manually measure batch conditions infrequently [3]

There is a need for an accurate way to continually monitor cell growth in a bioreactor [3]

Constraints | Criteria

1. Costs of the solution must not exceed $1000 CAN
2. The system must be applicable to cell cultivation
3. The system must be able to determine the amount of biomass and sugar within a bioreactor at any time

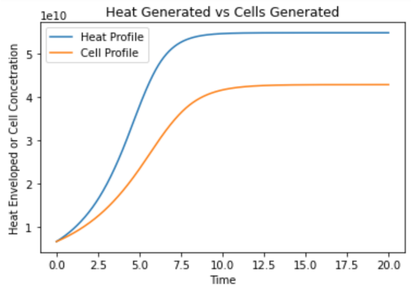
1. Ability to detect deviations from typical conversion rates
2. Non-invasive to the reactor to reduce the chance of contamination
3. The ability to ensure users can interpret complex data pertaining to process conditions

Decision Matrix

Parameters	Weight	Optical Density Sensor [4]	Off-gas analysis [5]	Calorimetry [6]
Bioprocess Applicability	1	+1	0	+1
Cost	1	-1	+1	+1
Accuracy	1	+1	0	+1
Non-Invasive	0.5	-1	+1	+1
Deviation Detection	0.5	-1	+1	+1
Interface	0.5	0	+1	+1

References

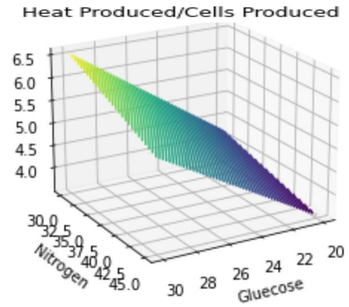
Experimental Results: Calorimetry



Heat shows high correlation to cell density throughout the run.
Machine learning algorithm used to determine the heat produced through the batch and its extension to biomass

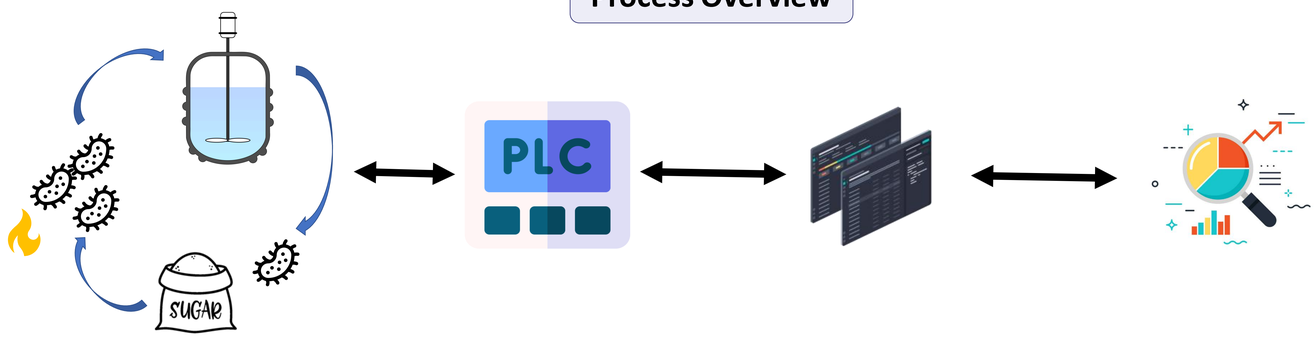
Materials and Methods

- *Saccharomyces cerevisiae* was grown in a 2L bioreactor.
- Optical density measurements were taken every hour.
- Heating requirements were measured consistently.
- A DOE was conducted to analyze the effects of different media compositions.
- The amount of heat generated per cell was determined.



The efficiency of metabolism can be determined over a range of media compositions.
Extended to optimize media over a set of operating conditions

Process Overview



The bioreactor is used to maintain process conditions. As cells metabolize sugars, heat is released into media

Sensors and controllers attached to the bioreactor are connected to a PLC. Becoming a client, data is sent to a server for data to be utilized

A server continuously interacts with the PLC to take analog values and data mine the important information for the user

Batch progression and cell density data is visualized for the user on the web application. The user can interact with the parameters and data

Unit Operation Analysis

Cells are inoculated in a bioreactor. Optimal conditions for cell growth are maintained based on set parameters

Sensor values are measured and recorded while relays send information to the bioreactor and Node-RED

Sensors values are stored in a database that can be accessed by a server and scripts to interact with the batch data

Python scripts interact with batch data to determine cell density through the heat generated and store it back in the database

A NodeJS server accesses the database values and sends all relevant data to the frontend

A frontend React app connects to the server to access data. Users view data visualizations and interact with them via buttons

Results

- Cell density determined with a confidence interval of 90% over a range of media compositions
- Cost of a fully furnished unit is $400 CAD resulting in a 92% cost reduction
- Non-invasive final product that reduces costs and labor needs for cell cultivators
- User friendly interface that reduces knowledge burden

Impacts

- Increases access to bioproducts by reducing the cost to accurately monitor a bioprocess
- Reduces the raw materials needed by optimizing production and reducing risk of contamination
- Enables the ability to create a cyclical city in which waste products are used as raw materials through the optimization of media

Interface

https://aaliyank.github.io/react-capstone/#/

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