Environmentally Sustainable Soy Supplemented IPA

Clay Bowes, Tony Hoch, Ryan Wollensak (BS Biological Engineering)

Problem Definition and Background

Objectives:

1. Utilize a waste product from industrial process
2. Reduce waste by 20% via recycling spent grain and CO_2
3. Generate >25% ROI

Across the globe, tofu production on average accounts for 2,610 kg of soy whey wastewater is created for every 80 kg of tofu produced[2]. Currently, this wastewater has no industrial applications, even though it is high in proteins (40-60%), carbohydrates (25-50%). The United States has seen a 24% increase in plant-based protein consumption since 2015[3]. Utilization of viable biological process wastes will increase environmental sustainability in the next 25-50 years. First to market in the soy-supplemented beverage space will solidify our breweries stance and market share in the space. With an expected profit margin of 59%, our brewery will set a precedent in the alternative-supplemented beer market and spur future economic activity in the craft beer market.

Variables Of Impact

Global: Soy Waste
Social: ABV, Safety Marketing
Cultural: US Beer Consumption
Economic: ROI, Manufacturing Cost
Environmental: CO_2 Output, Waste Utilization

Marketing

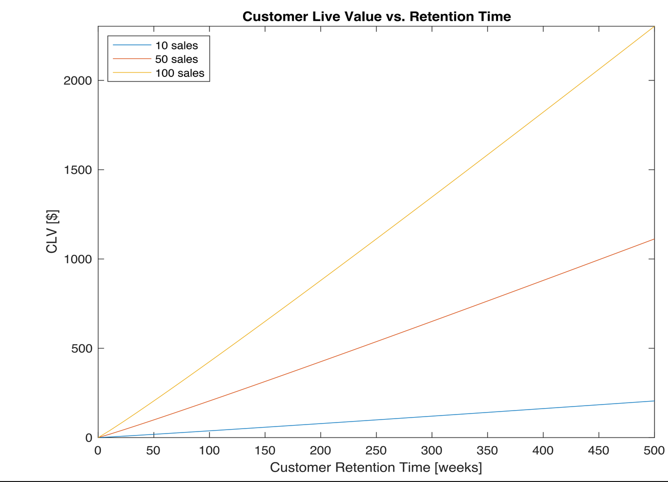
Target Audience: Upper-middle class ages 25-50 Health Conscious Consumers

Target Location: US Coasts

Economic Analysis

- Total capital investment of $2.55 million fits appropriately in expected range for microbrewery.
- Total product cost of $2.2 million reduces to $0.39/12 oz bottle.
- Annual Net Profit of $3.3 million and ROI of 83% indicates profitability if sales are met.
- Customer life value calculated based on the quality and taste of beer sold. A customer with 50 purchases over 10 years is worth $2,300 to the brewery.

Investment	
Equipment Cost (after tax)	$546,949.368
Fixed Capital Investment	$2,171,288.99
Total Capital Investment	$2,554,253.55



Annual Operating Cost	
Manufacturing Cost	$1,661,220
Direct Product Cost	$1,121,129
Fixed Charges	$108,502
Plant Overhead	$431,589
General Expenses	$523,202
Total Product Cost	$2,184,425
Total Product Cost Per Beer	$0.39
Selling Price	$0.90
Profit Margin	59%

Design Process & SuperPro

Plant output was back calculated from the average annual output of a microbrewery: 15,000 – 20,000 BBL/year[5].

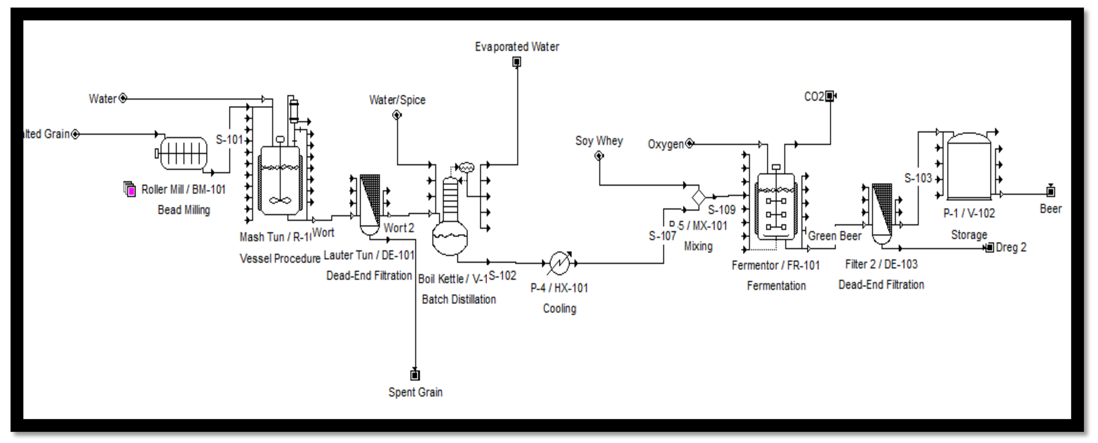
- Batch Production: 33,800 L
- Batch Cycle Production: 5,633.3 L/day

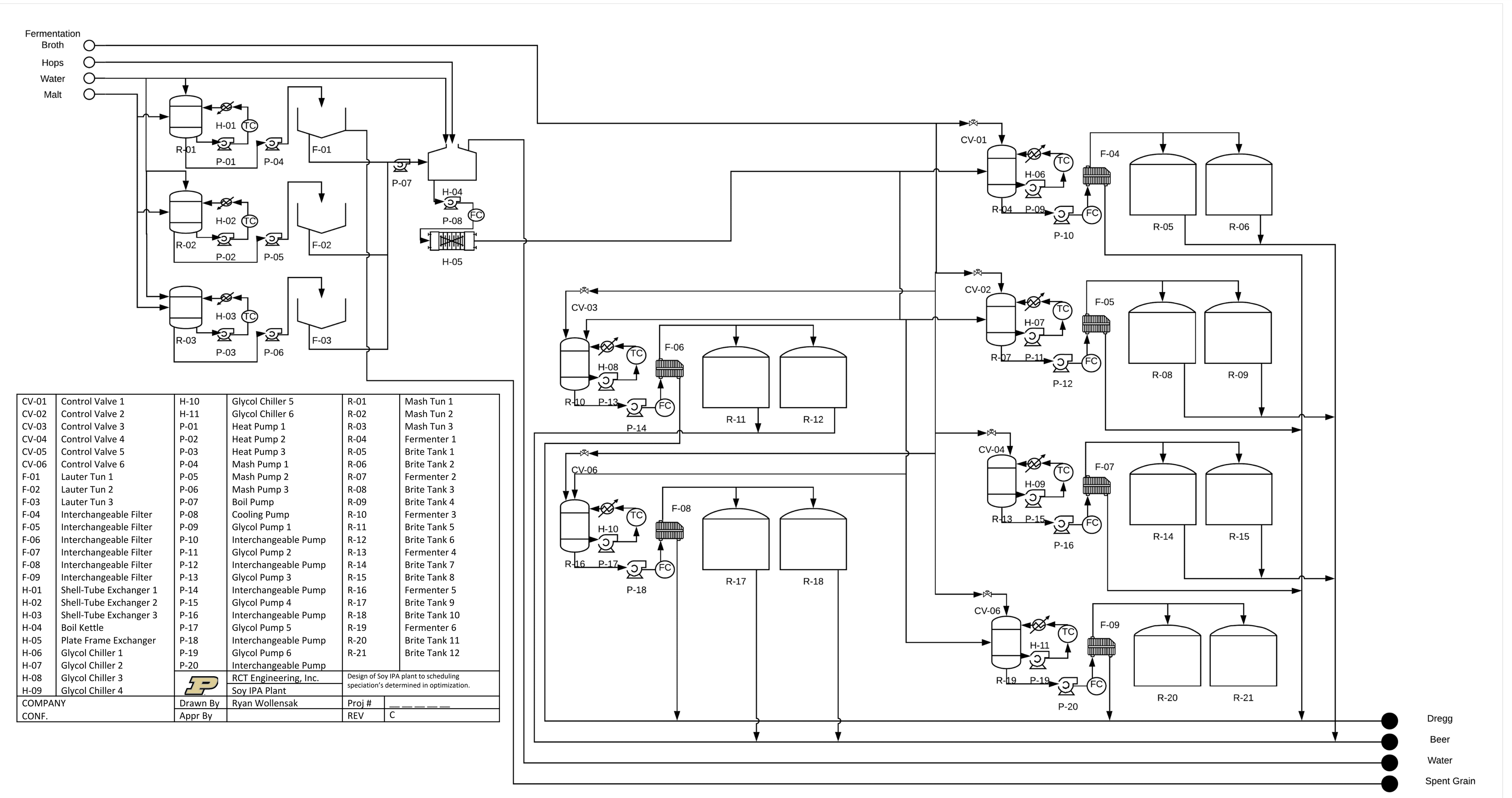
Modelling system based on clone recipe shown below:

Ingredient	Amount
Water	5,6333 L
Malt Blend	3279 kg
Hop Blend	63.33 kg
Supplemented Soy Protein	256.6 kg

SuperPro beer yield differed 26% from MATLAB models. Hand calculation/excel modelling determined potential to recycle 68% of carbon dioxide.

Stream Name	Malted Grain	Water	Soy Whey	Beer
Source	INPUT	INPUT	INPUT	P-1
Destination	Roller Mill	Mash Tun	P-5	OUTPUT
Stream Properties				
Activity (U/ml)	0.00	0.00	0.00	0.00
Temperature (°C)	25.00	25.00	25.00	21.00
Pressure (bar)	1.01	1.01	1.01	10.00
Density (g/L)	1,260.18	994.70	1,169.95	999.59
Total Enthalpy (kW-h)	41.59	162.51	7.62	161.44
Specific Enthalpy (kcal/kg)	10.91	24.96	11.60	18.24
Heat Capacity (kcal/kg-°C)	0.44	1.00	0.46	0.87
Component Flowrates (kg/batch)				0.00
Ash	442.34	0.00	0.00	687.90
Carbohydrates	272.16	0.00	548.05	1,345.06
Glucose	2,295.30	0.00	16.95	0.00
Water	269.21	5,603.17	0.00	5,582.53
TOTAL (kg/batch)	3,279.00	5,603.17	565.00	7,615.49
TOTAL (L/batch)	2,602.02	5,633.00	482.93	7,618.60





Process Control Optimization

Optimization and process control reduce cost and ensure process reproducibility. Below are Process control tables for (A) mashing, (B) fermenting, and (C) filtration:

(A)

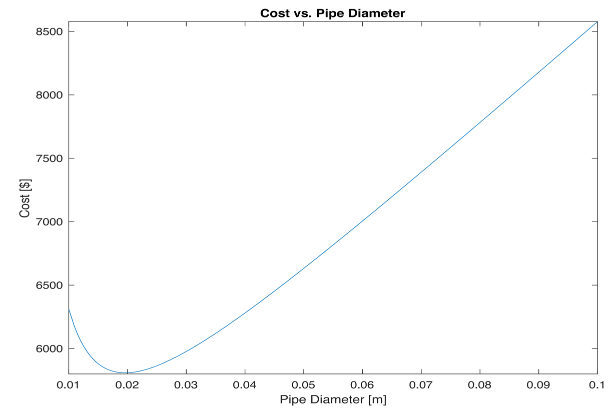
Type of Control System	Single-loop feedback
Manipulated Variables	Steam flow rate
Output Variables	Internal mash temperature
Sensor Type	Type: Thermometer
Actuator	Stepper motor linear actuator

(B)

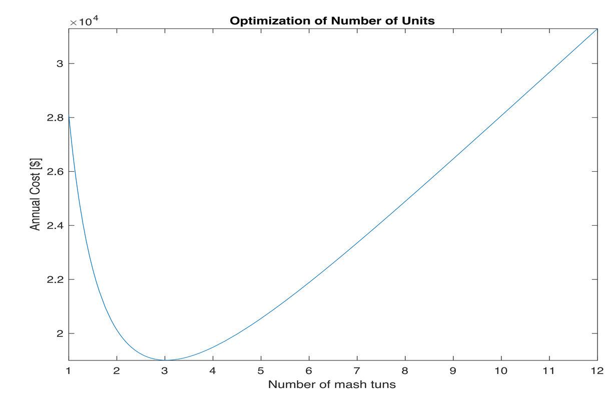
Type of Control System	Single-loop feedback
Manipulated Variables	Glycol flow rate pH
Output Variables	Internal vessel temperature Wort pH
Sensor Type	Temperature probe pH probe
Actuator	Stepper motor linear actuator

(C)

Type of Control System	Single-loop feedback
Manipulated Variable	Fermented wort flow rate
Output Variables	Internal vessel temperature Wort pH
Sensor Type	Orifice Meter
Actuator	Stepper motor linear actuator



- Optimizing the pipe ID to 19 mm saved ~ $70 annually



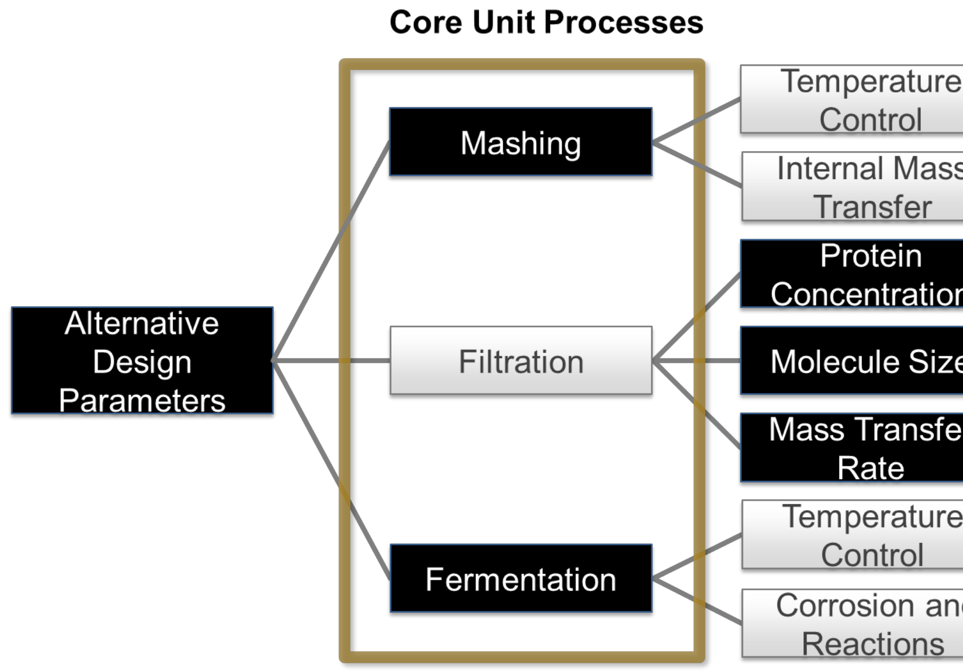
- Optimizing the # of mash tuns to 3 saved ~ $9,000 annually

Product and Process Experimentation

- New recipe was necessary after initial taste tests: Dogfish Head IPA Clone
- Changes based on experimentation: single mash infusion, removal of filtration step, and addition of secondary fermentation
- Main Variables: temperature and time (mashing), filtrate flow rate (filtration), temperature, time, and sugar concentration (fermentation), and temperature, time, weight of dry hopping, and clarification material (secondary fermentation)

Alternative Solutions and Decision Making

- Continuous reaction vessels are common alternatives in mashing and fermentation.
- Given the scale of our brewery output, 17,000 BBL/year, batch processing is more suited to our plant design.
- Mashing and Fermentation: Stainless steel jacketed vessels
- Filtration: Forgoing cold crashing, secondary microfiltration to preserve protein concentration of beer.



Final Solution Feasibility and Quality

- With a total capital investment of $2.55 million, a total cost per unit (12 oz.) of $0.39, and a profit margin of 59% at a selling price of $0.90/unit, the brewery is financially feasible and suitable for startup.
- A projected ROI of 83% was established.
- Initial product is to be improved through process refinement and recipe analysis.
- Global soy waste is to be tracked and marketed.
- An environmentally sustainable brewing process was created through waste product utilization, internal resource renewal, and biodegradable packaging.
- Optimization, process control design, and engineering principles were implemented to create a sustainable business with grounds for further improvement after startup.
- Finally, successful marketing campaigns and sales will spur the creation of a new sustainable brewing market.

References:

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[5]Craft Beer Industry Market Segments. (n.d.). Retrieved November 20, 2018, from https://www.brewersassociation.org/statistics/market-segments/

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