SENIOR CAPSTONE/ SENIOR DESIGN EXPERIENCE 2024

Crustacean Bioplastics

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Objective

Crustacean Bioplastics is looking to divert ***17.6 million tons*** of raw chitin (shell) waste and turn it into a renewable, green plastic alternative. Chitin is fire resistant, has strong tensile strength, and low cost of production. It has several environmental benefits, including biodegradability and a lower environmental cost of production, such as reduced carbon emissions.

Problem

Plastic is the largest contributor to pollution worldwide but is essential to today's world.

- 400 million tons per year in 2024
- ***1.1 billion tons*** per year by 2050

Public focus on plastic waste has spurred a wave of investment in renewable bioplastics.

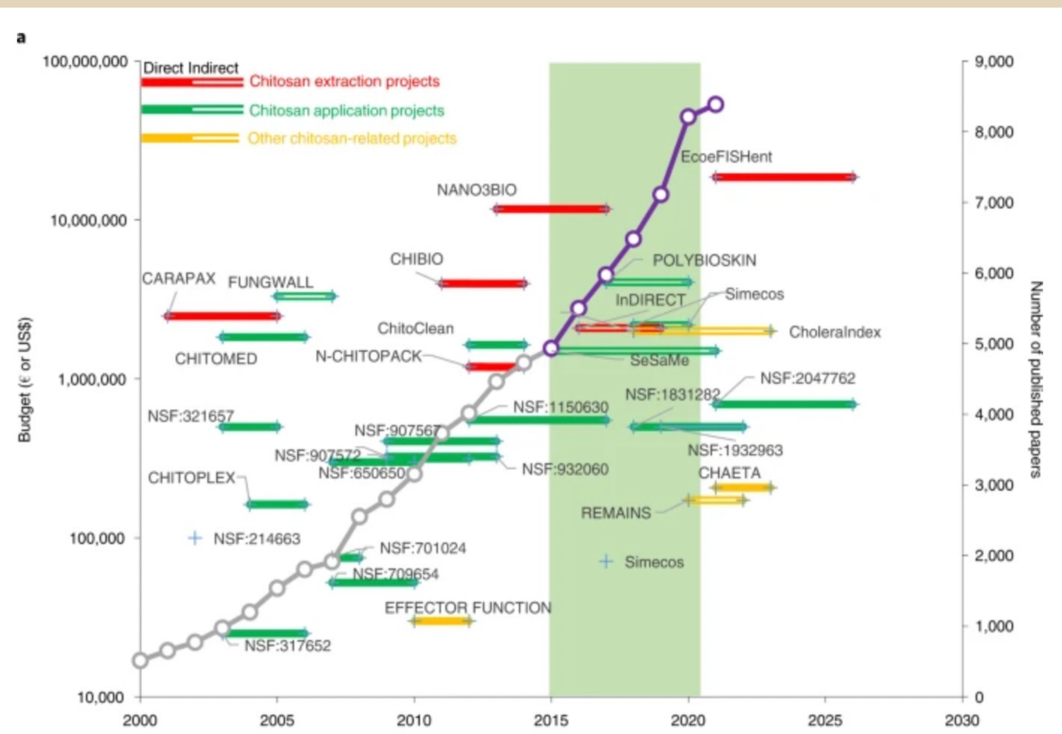


Figure 1: Increase in chitin, chitosan based plastic budgets, patents over time (Amiri, 2022)

Evaluation of Alternatives

The single largest barrier to bioplastics emergence in the single use plastic market is their increased cost. Plastic bags cost about $2/kg. Our bioplastics, while more expensive than that at $13.17/kg, become a much more economic option when you consider that the cost of waste management for plastic bags brings the true cost up to $36/kg.

Process Design

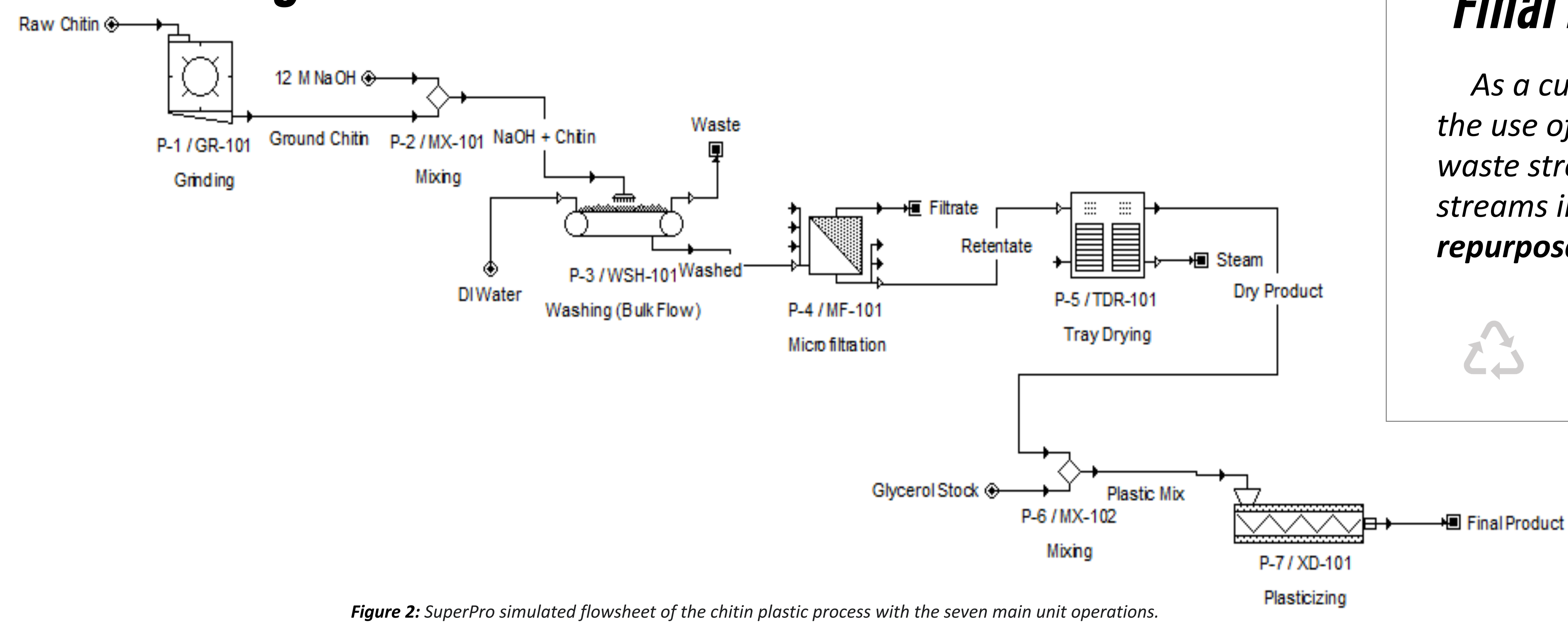


Figure 2: SuperPro simulated flowsheet of the chitin plastic process with the seven main unit operations.

Experimentation

Table 1: *Variables altered for designing the bioplastic. Where relevant, values are in reference to 5g of chitin.*

Unit Operation	Variables	Low	Center	High
Grinding	Water Added	2.5 mL	5.0 mL	7.5 mL
Deacetylation	Time	40 min	50 min	60 min
Deacetylation	Temperature	55°C	65 °C	75 °C
Filtration	Filter Pore Size	15 μm	-	45 μm
Plasticizing	Glycerin Concentration	15%	20%	25%
Plasticizing	Glycerin Volume	4.5 mL	5.0 mL	5.5 mL

Optimization

Table 2: *Effects of rotational speed optimization on grinding unit operation.*

RPM	Energy Use	Cost	Particle Reduction Time	Estimated Time Until Replacement
128	4.4226 kWh	$1,227	41 min	8.77 yrs
200	7.8617 kWh	$1,325	15 min	10.32 yrs
262	11.101 kWh	$1,406	9 min	11.71 yrs

Table 3: *Effects of rotational speed on deacetylation batch energy costs.*

Rotational Speed (RPM)	Cost ($/batch)
10	0.4143
600	0.0282
228.47	0.0032

Impact and Sustainability

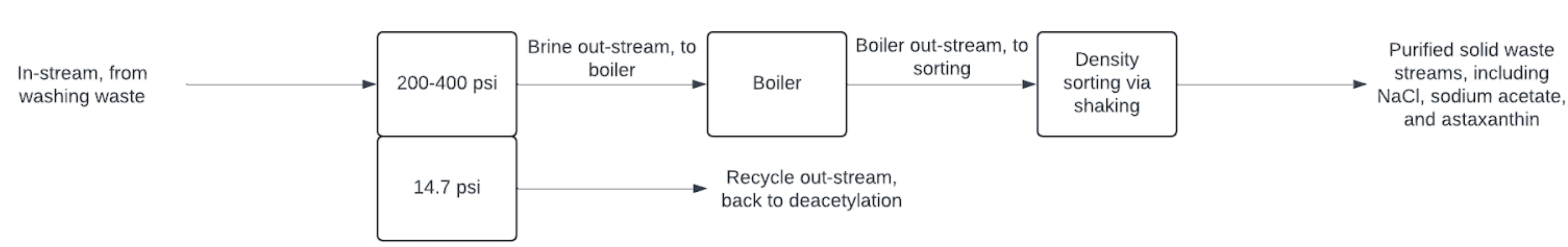


Figure 4: *Implementation of deacetylation recycling as a means of reusing reagents and saving cost*

Reverse osmosis allows for about 50% recovery of NaOH and water, this system will cut both the waste and production needs of the deacetylation process by 50%. Taking a simple savings of 35% of the NaOH purchased for the process gives an ***annual savings of $1,154,000***.

Final Product

*As a current byproduct of the industry, the use of chitin would functionalize the waste stream. Even further, waste streams in this process are **recyclable**, **repurposable**, and **profitable**.*

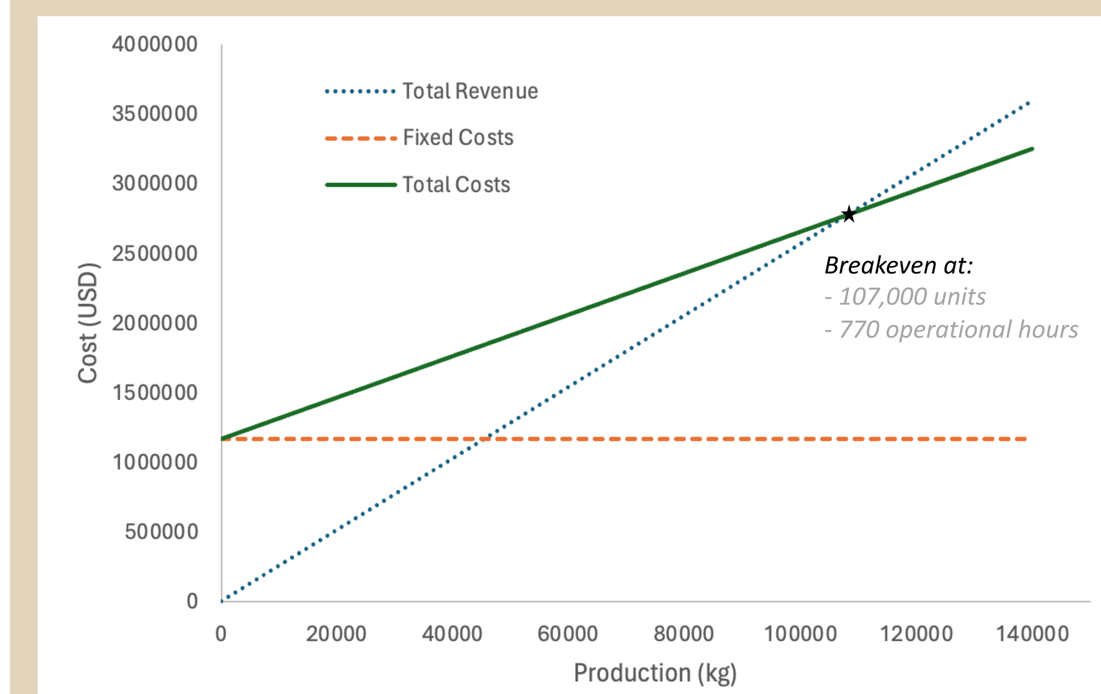
Figure 5: *Crustacean Bioplastic final product*

Economic Analysis

Total Capital Investment: $29.2 million/year

Total Product Cost: $28.5 million

ROI: 5% over 10 years



Future Work, Recommendations

- *Further improve upon product durability*
  - *Make more flexible to expand range of applications, uniformly smooth*
- *Evaluate extent to which Crustacean Bioplastics can be used for more plastic applications:*
  - *i.e.: water bottles, storage containers*
- *Quantify downstream effects of product degradation*
  - *Determine shelf-life, deduce microbial contamination risk with shelf-life*
- *Expand production to use other raw sources of chitin: insects*

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