PRODUCTION OF STARCH-BASED BIOPLASTICS

Dalhousie University — Inspiring Minds

Gabryelle Beland, Claire Stienburg, Matthew Marshall, Nicholas Pichurski

Department of Process Engineering & Applied Science

Introduction

Motivation

- Petroleum-based plastic bags can take 400 years to biodegrade
- Only 9% of plastic waste is recycled and 87% ends up in the ocean/landfills, creating a major environmental issue

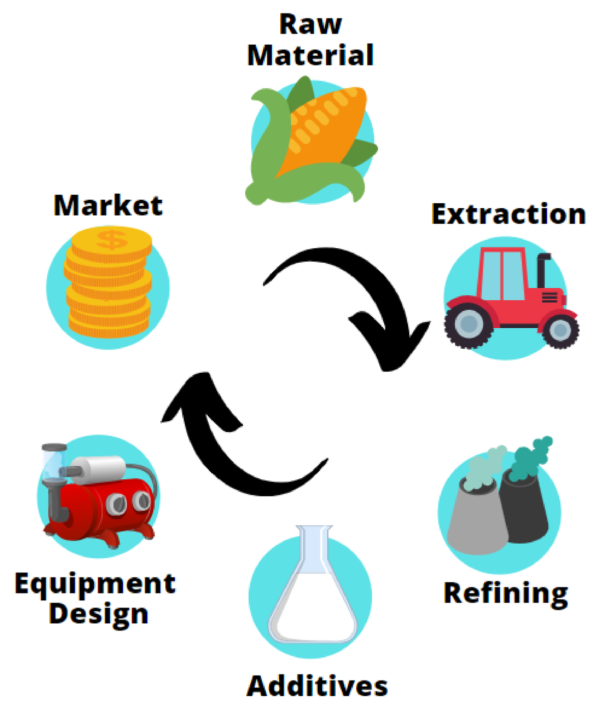
Objectives

- Design production plant for starch-based bioplastics
- Use local feedstock from Nova Scotia
- Product should have similar properties, functionality and price of regular plastics

Scope

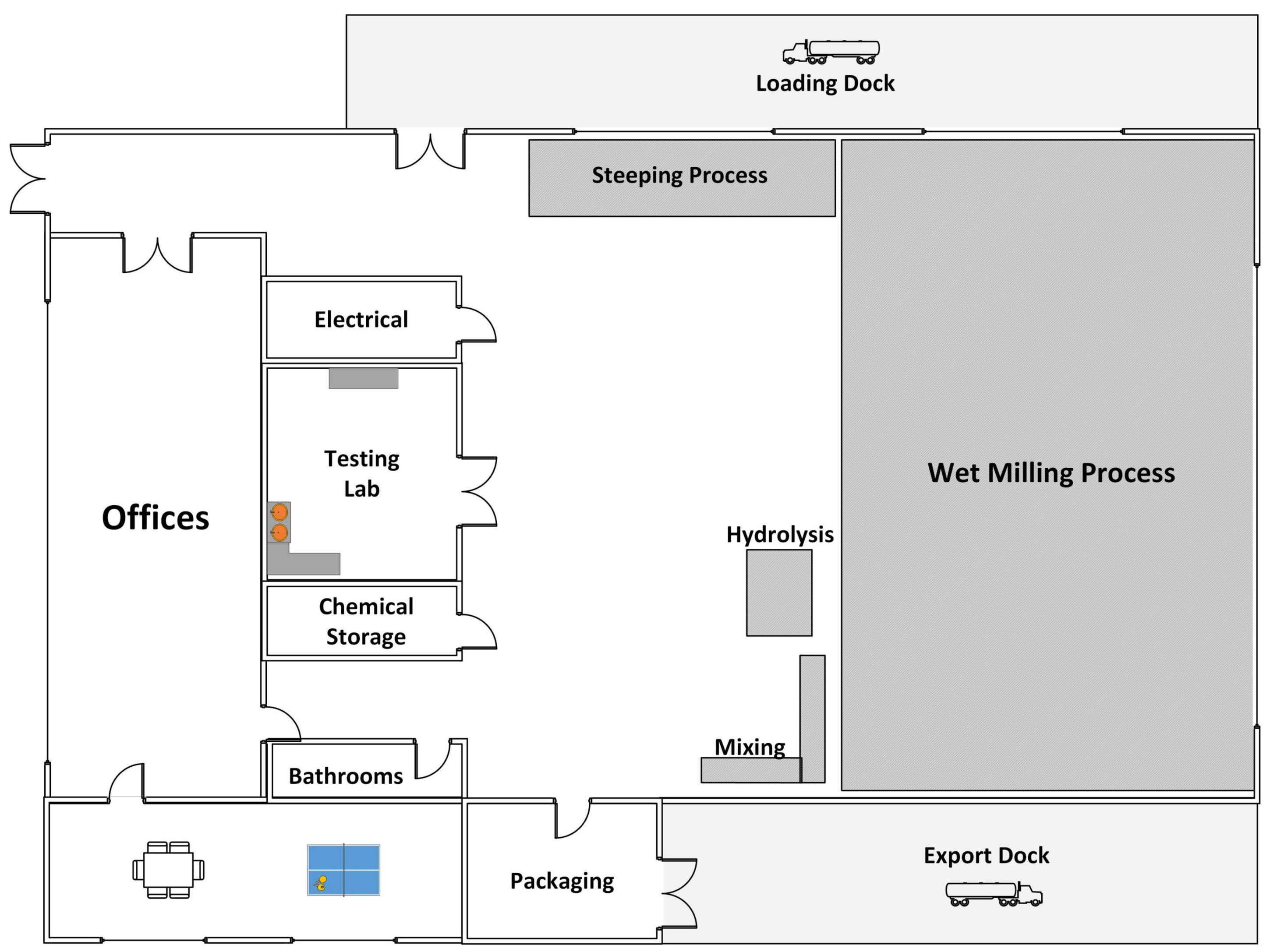
- Processing from feedstock delivery to production of pellets
- Detailed design of steeping, milling, hydrolysis and blending units
- Economic and hazard analyses
- Options for producing value-added by-product

Design Process

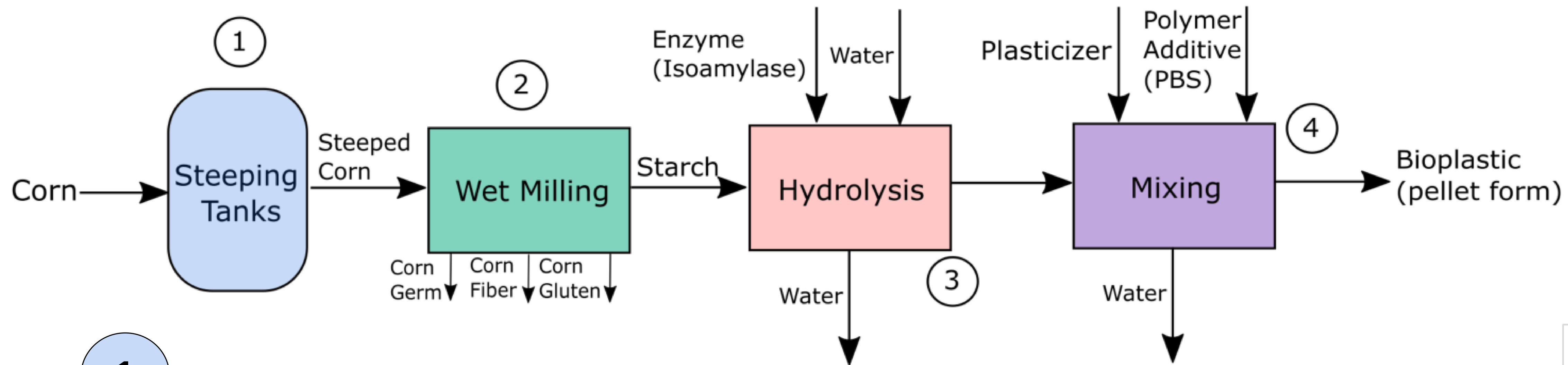


- Starch based corn crop was chosen due to local abundancy, economics, and polymer quality
- Starch extraction and polymer processing methods were studied to determine required processes
- Enzyme, plasticizer and other additives were chosen based on maximizing quality of product and process efficiency
- Equipment sizing and design were established through calculated flowrates
- The cost of material, equipment, and operation was evaluated along with bioplastic pellet revenue.

Plant Layout

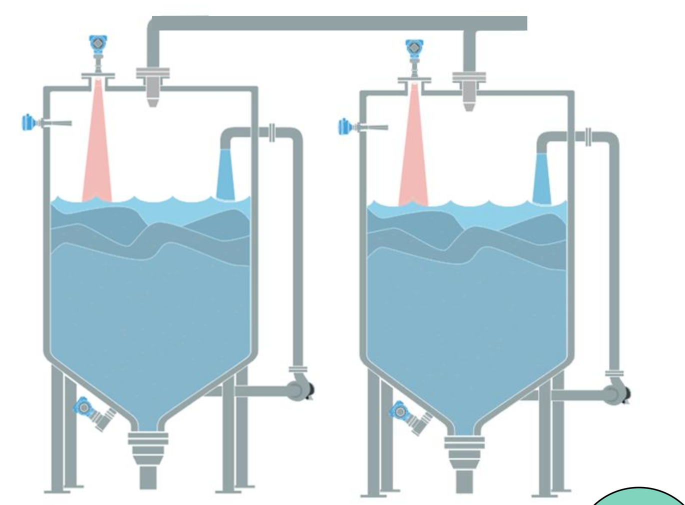


Design Details

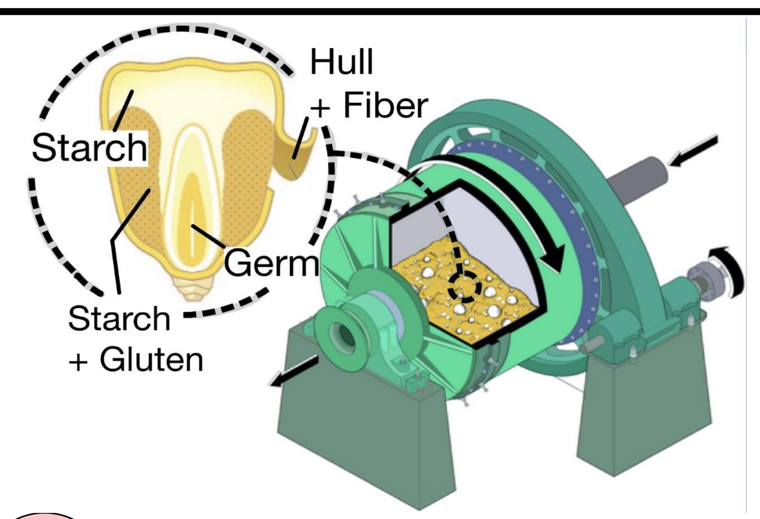


1 Steeping

- Steeping softens kernel wall to increase starch extraction
- Steep solution is composed of 0.2% sulfur dioxide, 0.5% lactic acid, and water
- Corn undergoes three 12-hour steeping stages
- To minimize chance of process disruption the system contains 4 tanks in total
- Water is recycled through the tank, no mixing required
- Corn remains stationary, exposure to three stages occurs by moving varied concentrations of water between tanks



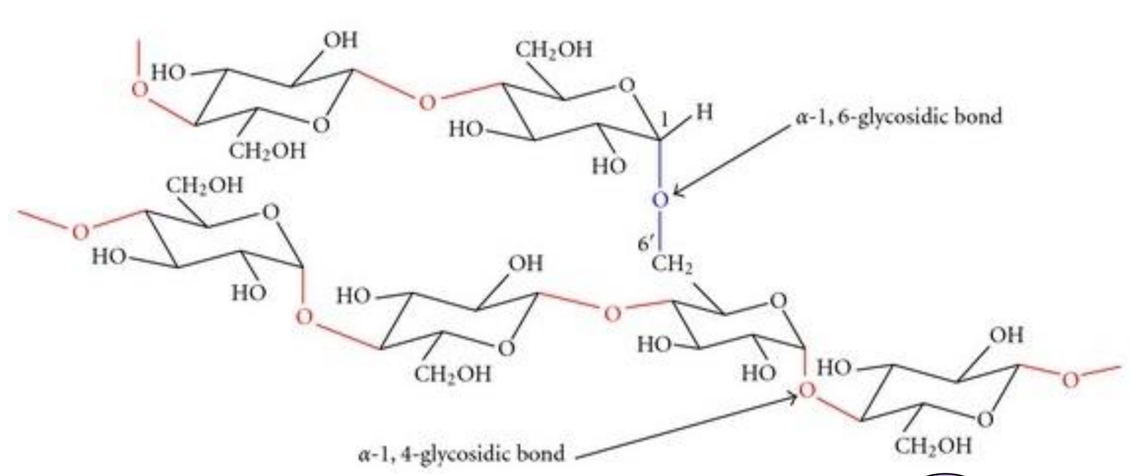
Wet Milling 2



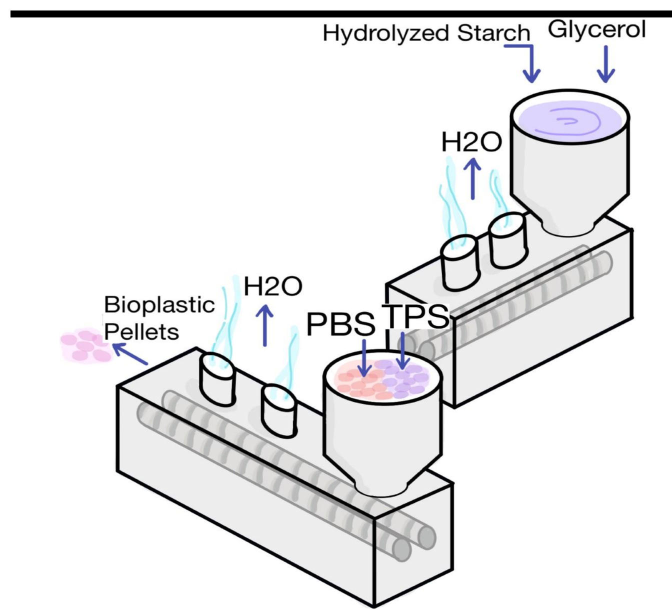
- Wet milling is essential for breaking apart the corn kernel into the germ, fiber, gluten, and starch
- Accomplished through a series of grinding, separating, washing, mixing, and drying equipment
- This results in 67% starch, 8.0% germ, 9.7% fiber, 6.0% protein/gluten, and 6.8% process water
- By-products can be sold as animal feed and corn oil for additional revenue
- Produces ~636,000 kg of starch

3 Hydrolysis

- 75% of corn starch sugars are crosslinked through α-1,4-glycosidic bonds
- An enzyme reactor is used to remove the α crosslink bonds between starch sugar chains
- Removing crosslinks is key for increasing crystallinity and mechanical strength of the final product
- Conversion of α-1,4-glycosidic bonds through hydrolysis is 99.8%



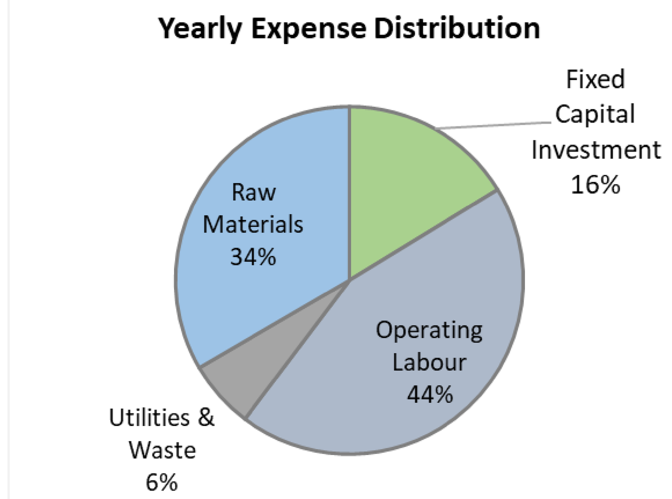
Mixing 4

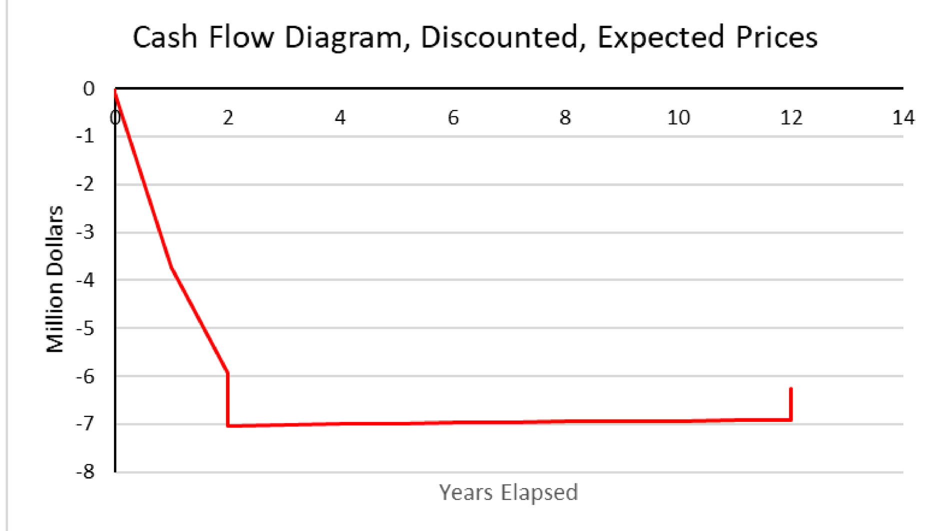


- Thermoplastic starch (TPS) is created by addition of plasticizer (glycerol) to increase ductility
- Another biopolymer (PBS) is blended with the TPS to increase strength
- The blending is done in 2 stages through reactive extrusion
- The resulting bioplastic pellets are sold externally to be blown-film extruded into bags

Economic Analysis & Feasibility Study

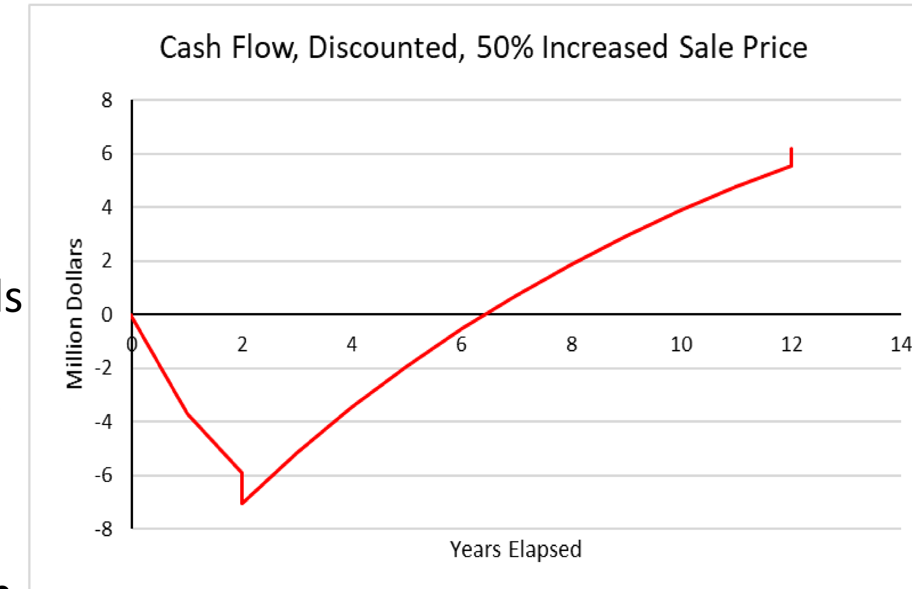
- Annual cost of manufacturing: $7,390,892.19
- Annual projected revenue: $7,165,826.88
- Fixed capital investment: $6,677,025.25
- Labour is largest expense, followed by raw materials





- Negative cash flow at expected price of $6.29/kg
- $23,000 yearly profit
- Fails to offset capital investment within projected lifespan

- Increasing price by $1/kg to $7.29/kg breaks even
- Increasing price by 50% to $9.44/kg yields a profit in 6.5 years
- Plastic is good quality and local
- Cumulative Cash Position = $6.2 million



Conclusion

- Project is only financially viable if the sale price of plastic is increased by $1/kg, or if capital investment is reduced by 50%
- Bags produced would be lower quality than conventional, non-biodegradable bags (approx. 70 % the tensile strength/elasticity) but are within an acceptable range of functionality, enhanced by the PBS additive
- Plant would produce 1,113,718 kg of pellets annually
- Solution is extremely eco-friendly with process water as the only waste source. Recycling the 126,720 kg of annual generated steam was not economical as the heat exchangers were too expensive

References

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