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Design of a Modular Facility for the Extraction of a Chitosan-Based Biostimulant from Crab Shell Waste

Background Information

- Acadian Seaplants Limited produces a crop biostimulant from seaweed. They are currently investigating modular production of a biostimulant from an alternative raw material.
- A biostimulant is a material that contains substances and/or microorganisms whose function is to enhance and benefit crop quality, nutrient uptake, growth efficiency and environmental stress resistance.[1]
- In 2013, it was predicted that that the global market for biostimulants would reach 2.2 billion dollars by 2018.[2,3] It is expected that the demand for biostimulants will continue to rise.[3]
- An estimated 6 to 8 million kg of crustacean waste is produced annually; much of this waste pollutes our oceans. [4]
- Crustacean shell waste was determined to be a viable raw material for biostimulant production, with chitin/chitosan identified as the primary biostimulant derived from their shells. Chitin/chitosan supports plant pathogenic stress tolerance.[5]
- Crabs were chosen as the raw material for processing because a large percentage of Atlantic Canadian shell waste is crab.

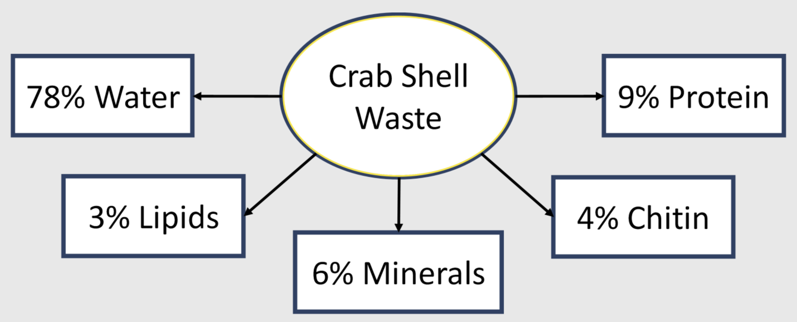

Figure 1 Composition of Crab Shell Waste[6]

Design Objectives

- Design an economically viable modular process to manufacture a chitosan-based biostimulant from crab waste that supports plant pathogenic stress tolerance.
- Design must be marketable, sustainable and safe.
- Process equipment must be constrained to the size of standard shipping containers.
- Facility must process 300 metric tonnes of crab waste annually.

Modular Design Aspects

- Designed facility processes 300 metric tonnes of crab waste annually. This was chosen based on the annual crab shell waste production of the Arichat Fisheries plant located in Nova Scotia.
- Designed facility produces 13 600 kg of biostimulant annually.
- Equipment is housed in eight standard size containers called modules. All modules are 2.45 m wide and 2.89 m tall. Modules #1 and #5 are 6.06 m long, while all other modules are 12.2 m long.
- Reactor and filtration units within each module will be placed on their side and secured for shipping. All other pieces will remain upright.
- Modules will be set-up inside a warehouse according to the modular facility layout. All container walls will be removed once inside.
- Warehouse site will provide water, steam and other utility hookups, as well as wastewater treatment.

Process Overview

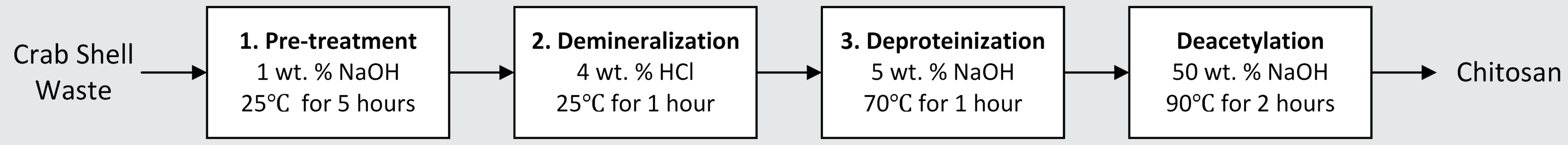

Figure 2 Chitosan Extraction Process Overview

1. Pre-treatment

- The raw crab shell waste is grinded to 600 μm.
- Waste is agitated in a dilute NaOH solution to remove excess lipids.
- Solids are washed with water and filtered to remove waste chemicals.

2. Demineralization

- Solids are agitated in a dilute HCl solution to solubilize calcium carbonate minerals into salts and carbon dioxide.
- Solids are washed with water and filtered to remove waste chemicals.

3. Deproteinization

- Solids are heated and agitated in a dilute NaOH solution to remove proteins; chitin remains.
- Chitin solids are washed with water and filtered to remove waste chemicals.
- Solids are dried to ensure solvent purity in step 4.

4. Deacetylation

- Chitin is heated and agitated in a concentrated NaOH solution for its conversion to chitosan.
- Solids are washed with water and filtered to remove waste chemicals.
- The product is dried for distribution.

Modular Facility Layout

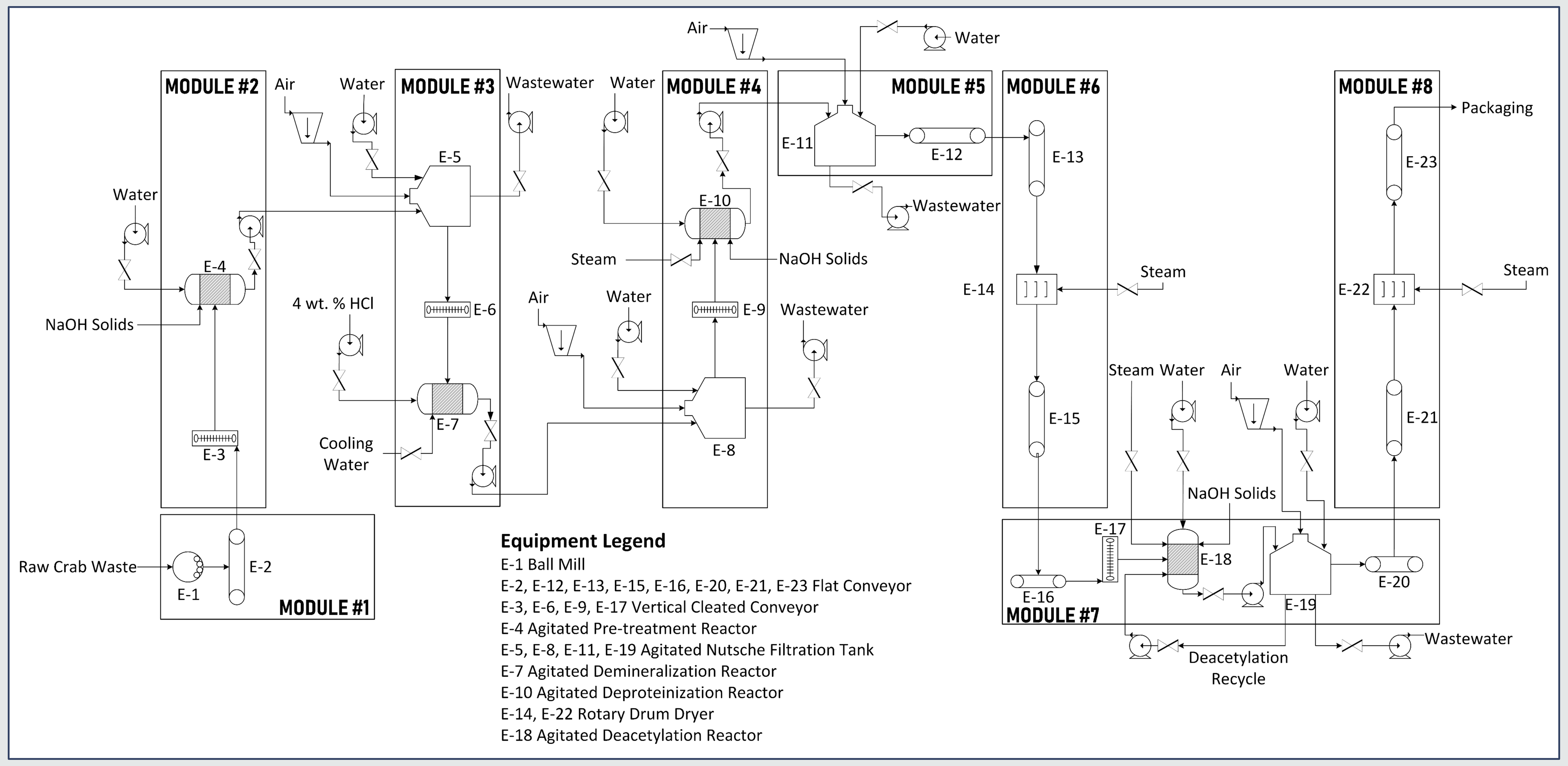

Figure 3 Process Flow Diagram of the Modular Extraction Facility

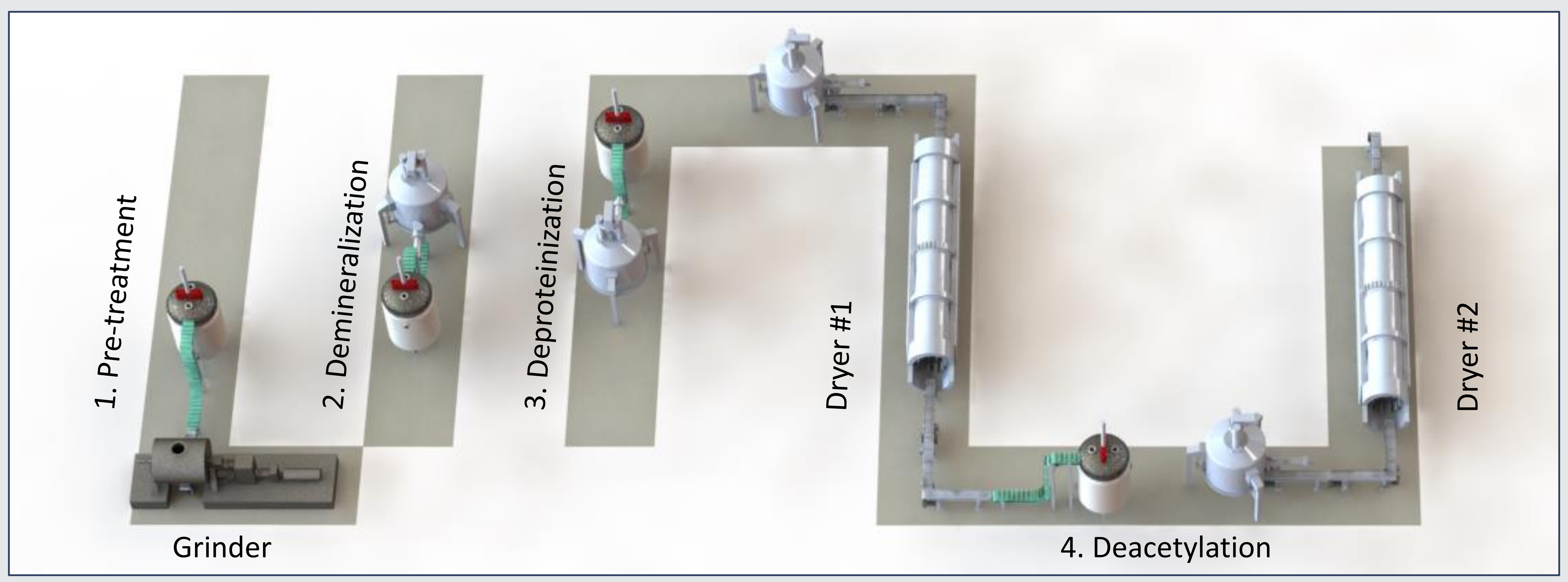

Figure 4 A 3-D Rendering of the Modular Extraction Facility

Safety Considerations

- Additions to the warehouse site building safety include travel distances and access to exits. The processing equipment shall not obstruct egress or increase travel distances to exits to a point where it exceeds the 2015 National Building Code of Canada.[7]
- Equipment and operator safety of the design follows the hierarchy of controls. This is investigated through the use of hazard identification techniques such as What-If and Failure Modes and Effects Analysis.
- Due to the modular design, all process equipment was chosen to minimize operator intervention.

Economic Summary

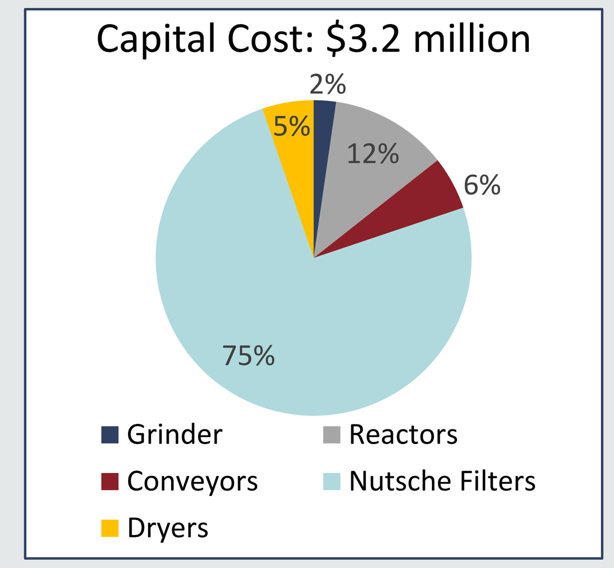

Figure 5 Capital Cost Comparison

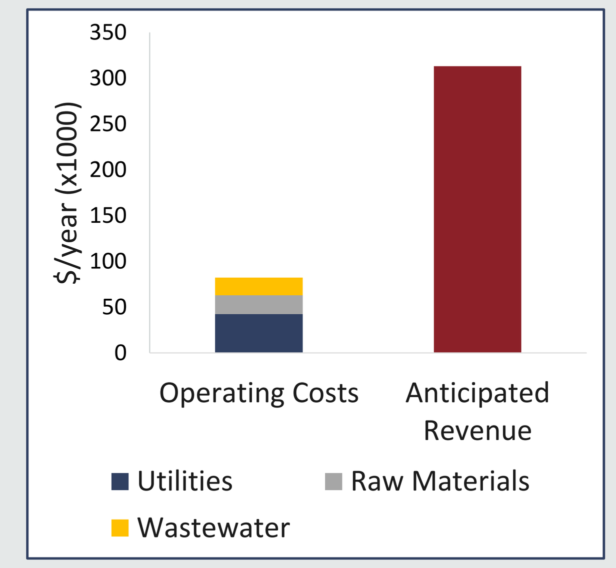

Figure 6 Annual Costs vs. Revenue

Conclusions and Recommendations

- A modular facility for the extraction of a chitosan-based biostimulant was designed with crab shell waste as the raw material.
- The facility is comprised of eight modules. All modules are 2.45 m wide and 2.89 m tall. Modules 1 and 5 are 6.06 m long, while all other modules are 12.2 m long.
- 13 600 kg of undiluted chitosan based biostimulant is produced annually. This throughput cannot increase due to filter diameter.
- Operational costs are lower than anticipated revenue. However, capital costs are high primarily due to filtration equipment cost.
- Investigating a more economical filtration method is recommended.
- Laboratory and pilot-scale testing of the process conditions is recommended to validate equipment sizing and processing times.

References

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