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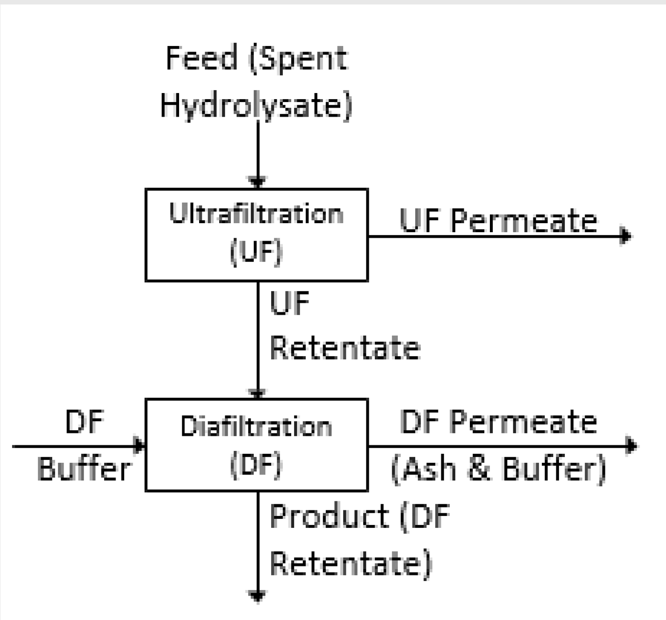
ALGAL OMEGA 3 LTD

MARA RENEWABLES CORPORATION™

Development of Microalgae Waste Stream Co-Product through Membrane Filtration and Scale-up Design

Introduction

- Mara Renewables Corporation (Mara) is a biotechnology company that creates algal oil that is rich in omega-3 fatty acids. Algal Omega 3 Ltd (AO3) is their main manufacturing facility.
- Mara generates a large waste stream from this process that is rich in cell debris, unused fermentation media, protein and carbohydrates. The desirable nutritional profile of this stream makes it an excellent candidate for a value-added co-product, specifically animal feed.



- Thus, the scope of this project is to concentrate the waste stream through means of ultrafiltration and wash out the ash content with diafiltration.

Design Process

- To determine the optimal settings required for optimal scale-up design, a factorial design of experiments was carefully created and is outlined below:

Table 1. Pilot Scale System Settings

Trial No	A: FCV Setting [% Open]	B: Pump Setting [% of Max RPM]
1	12	40
2	11	50
3	20	60
4	18	50
5	14	50
6	18	50
7	18	50

- A- Recirculation Pump Settings
- B- Flow Control Valve (FCV) Settings

- The FCV low setting was 10% (open) and the high setting was 20% (open). The pump's low setting was defined at 40% and high setting as 50%.
- Through testing, trials 4, 6, and 7 had the same operating conditions and yielded the best permeate volume to feed volume ratio and as an extension of these results, the best permeate volume to feed volume to processing time ratio. Thus, a high FCV and high pump setting offered the optimal settings which was used in scale-up calculations.
- Furthermore, it was determined that the chiller setting should be 50 °C.

Objectives

- Determine Optimal Flux
- Determine Number Of Required Diafiltration Passes
- Determine Production Time Of 20%< Solids
- Determine Solids Lost During DF & UF To Retentate Streams
- Design a P&ID for the industrial scale process
- Design and size a batch system to process 145,000 L of final product in 24 hours
- Design a CIP process for the membrane filtration system
- Perform capital and operational costs of industrial membrane filtration unit

Details of Design

- The goal of this design was to achieve the following settings for the final product:

Table 2. Product Starting Point and End Goal Parameters

Parameter	Solids Content (%)	Moisture	Crude Protein Content (% Solids)	Ash Content (% Solids)	Fat Content (% Solids)	Carbohydrates (% Solids, by difference)
Product Start Point	10-15	10-15	20-35	15-25	5-15	0-38
Product Goal	20 – 30	N/A	≥ 35	≤ 10	N/A	N/A

- As shown in Table 2, all product goals were met which are detailed in Figure 1. As shown in Figure 1, the percent solids after the first diafiltration sample remain consistent therefore, two diafiltration passes will be used in the scaled-up design.
- Below in Figure 2 is a simplified PFD of the overall membrane filtration system with the CIP system and the diafiltration buffer.
- The PFD is with respect to ultrafiltration therefore, NC means closed to the CIP and diafiltration systems.
- Retentate is recirculated until the goal of 20-30% solids is achieved.

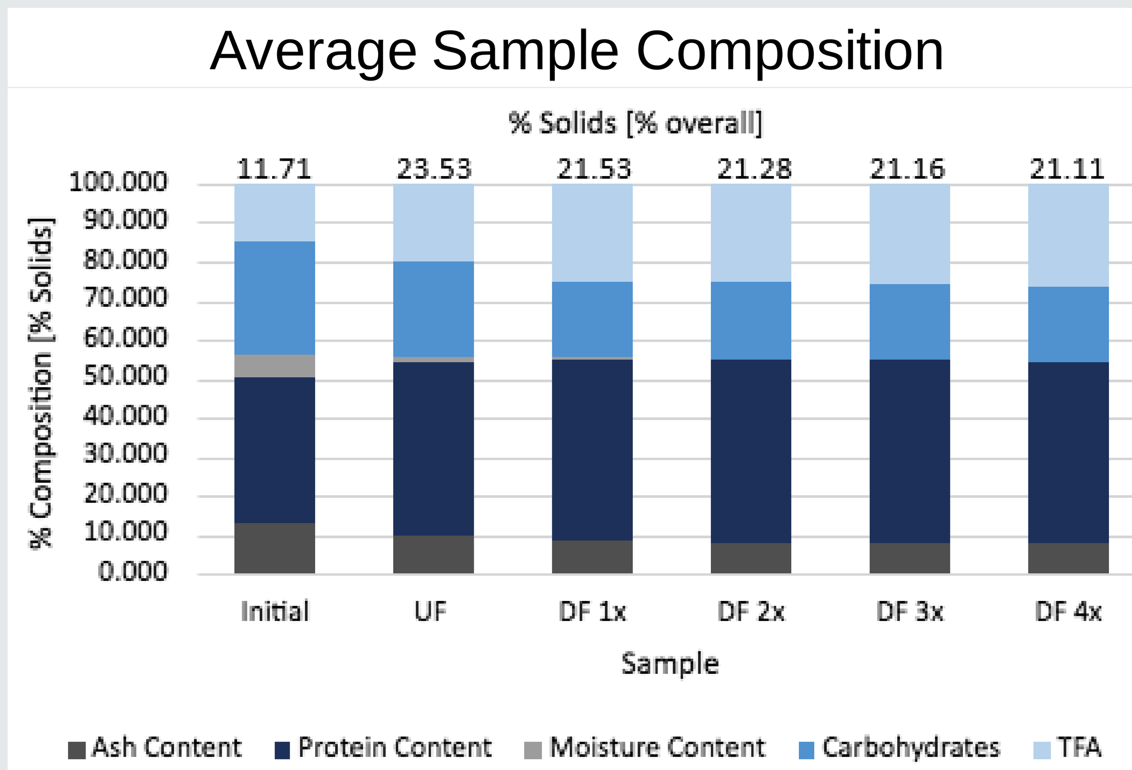


Figure 1. Average Sample Composition

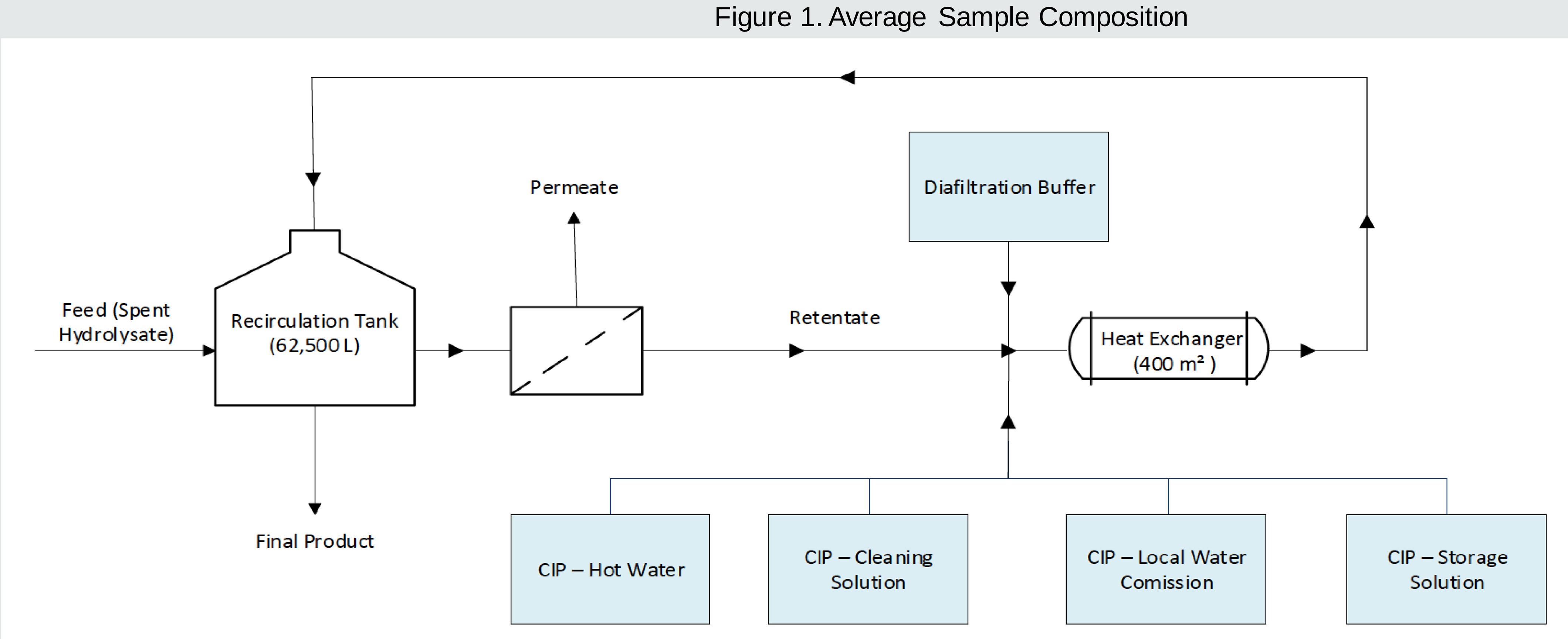


Figure 2. PFD of Membrane Filtration Unit

Conclusion and Recommendations

- It was determined the size of batch should be 50,000 L, with a 62,500 L recirculation tank
- Two membrane filters in series are required
- Optimal Operating Conditions: FCV - 18% open, Pump 50% of max RPM and Chiller - 50 °C
- Model created to estimate operating time based on starting solids, where x is initial solids concentration and y is UF operational time

$$Y = 4470.6x^{-1.328}$$

- CIP includes a regular water rinse, a hot water rinse, a cleaning solution rinse, finishing with a regular water rinse, each taking 10 minutes, for a total of 0.67 h per batch
- Less than 2 diafiltration passes required, at 1.5 h each, totalling to 3 h per batch.
- Total Processing time based on avg initial solids: 6.67 h

Future Work & Recommendations

- Generate viscosity vs. percent solids data to quickly determine retentate solids composition.
- Use heat integration from another part of plant to reduce heat exchanger operational cost

Economic Analysis

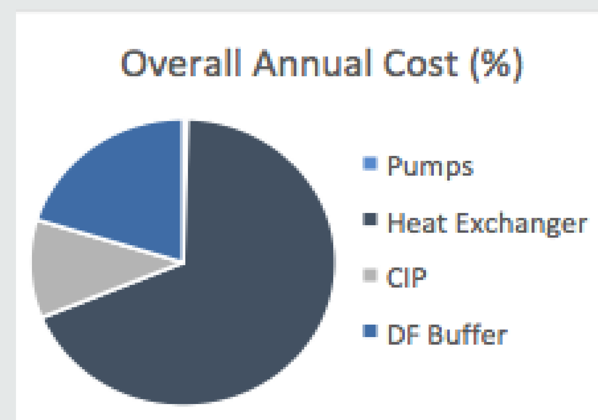


Figure 3. Overall Operational Cost Analysis

- Overall water, electricity and chemical costs associated with CIP taken into consideration.
- Other operational cost factors such as operator salary and electricity cost of actuated valves and human interface screen considered negligible.

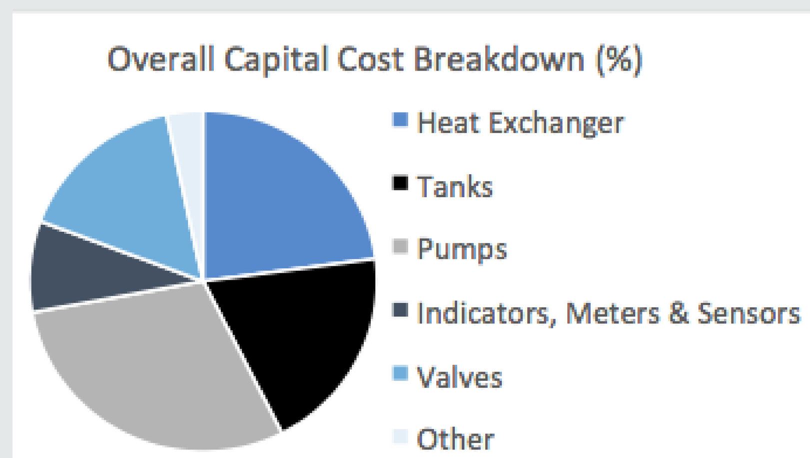


Figure 4. Overall Capital Cost

- Specifics include Recirculation tank, level, pressure and temperature indicators, CIP tote tanks, actuated, gate and check valves, electromagnetic flow sensors and human interface

References

SmartFlow Technology. (2020). SmartFlow Technologies. https://smartflow-tech.com/technology.html.

Mercer, P. *Mara Renewables Corporation*. Personal Communications. 2022.