Isolation of Lipid Classes from *Nannochloropsis Oculata* Microalgal Biomass for Cosmetic Applications

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Easy Lipids Sustainable Lipids

INTRODUCTION

- Microalgae is a good source for polyunsaturated fatty acids, natural pigments, essential minerals, vitamins, and enzymes
- Phospholipids (PLs), glycolipids (GLs), and neutral lipids (NLs) can be extracted from microalgae
- Cosmeceutical, nutraceutical, and pharmaceutical industries have been extracting lipids from microalgae in the past years
- *Nannochloropsis oculata (N. oculata)*, a marine-water single-cell microalga was chosen for the extraction of lipids

Figure 1. Microscopic and macroscopic view of microalgae. http://www.femonline.it/activities

GOALS AND MOTIVATION

- Provide a sustainable alternative for the supply of lipids by designing a large-scale plant for the extraction of lipids from *N. oculata*
- Supply phospholipids, glycolipids, and neutral lipids grouped by class to specialty chemical manufacturers as part of the supply chain
- Easy growing conditions; can grow on non-arable land using non-potable/waste water or saline water
- *N. oculata* does not compete as a food source

Table I. Average Prices of Different Lipid Classes

	Average Market Price per g (>99% Purity)
Phospholipids	\$551.00
Glycolipids	\$551.00
Neutral Lipids	\$20.00

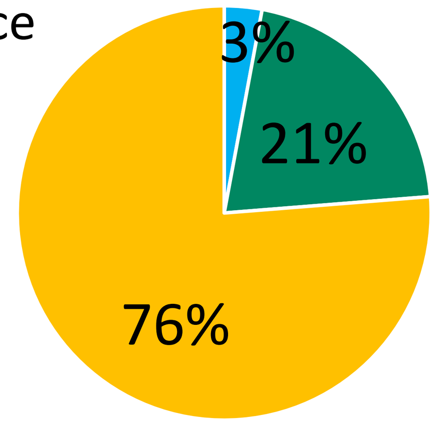
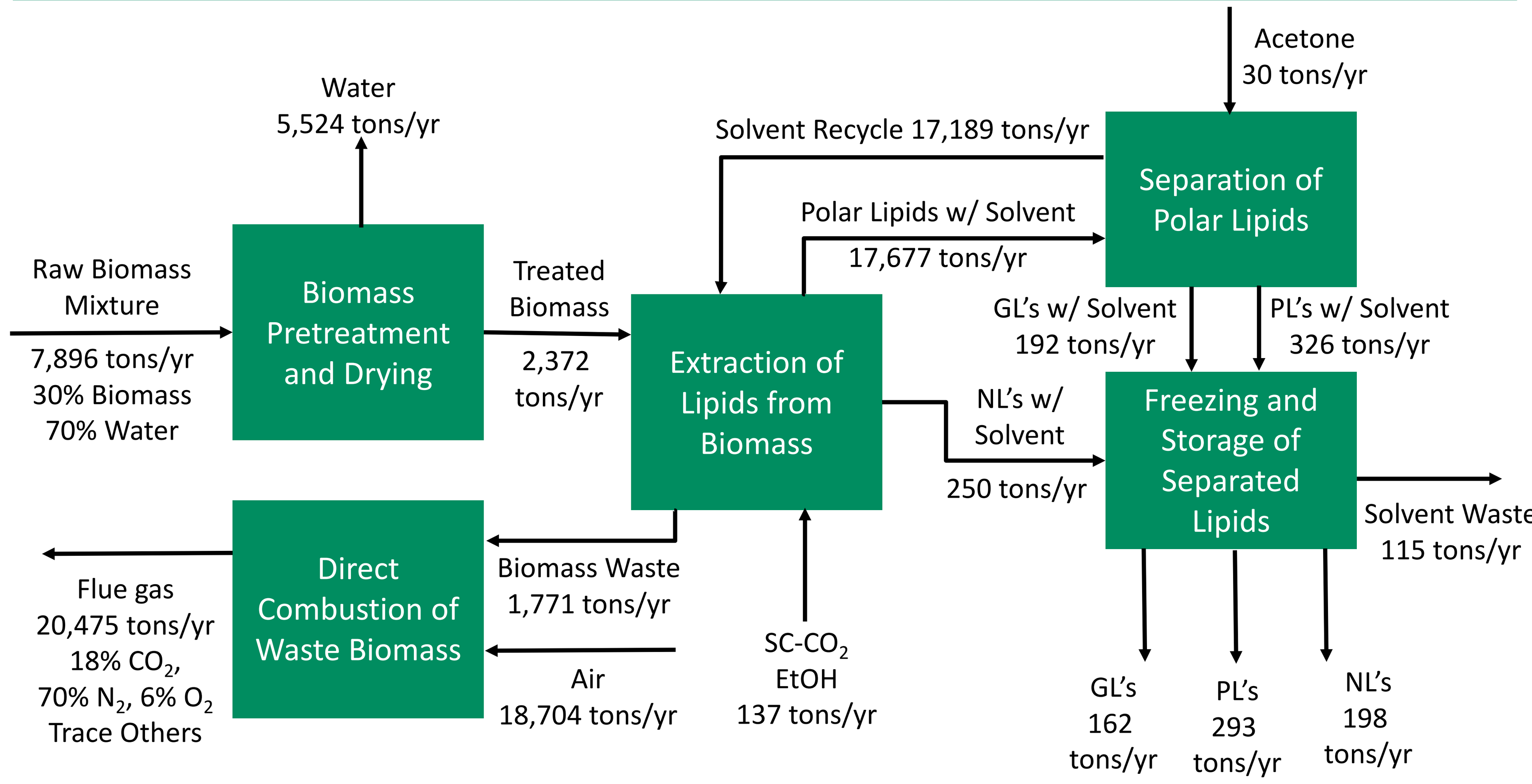


Figure 2. Global market share of major industries involving lipids: \$1.4 Trillion USD (2016).

APPROACH

Model Lipid Compounds in Aspen → Estimate Thermodynamic Properties in Aspen → Model Process with Hand Calculations and Aspen → Equipment Sizing and Costing → Economic Analysis → Safety and Environmental Analysis

PROCESS FLOW DESCRIPTION



- Biomass is pretreated in industrial microwaves to break down cell walls and cell membranes to release the lipids into solution
- Excess water is removed via centrifuges and dryers
- Supercritical CO_2 and ethanol are used as the solvent for the batch extraction of lipids from the biomass and separation of neutral lipids
- Polar lipids are separated into phospholipids and glycolipids using a silica-packed column with countercurrent acetone and ethanol streams

SAFETY AND ENVIRONMENTAL IMPACT

- HAZOP completed for batch extraction unit and biomass waste-disposal furnace as shown in the full report
- NO_x, CO, and CO_2 from the furnace are the primary contributors to the PEI (Potential Environmental Impact)
- The process CO_2 emissions are equivalent to 6,121 vehicles driven for one year
- Total energy required is 8,200 MJ/hr
- Due to the solvent recycle system, the PEI/hr is reduced by 95% shown in figure 3, and the operating cost is reduced by \$10 Million per year

Table II. CO2 Emissions from Process and Utility

Compounds	Annual Emissions of Greenhouse Gases [Tons per Operating Year]
Total CO_2 Emissions	**19,408**
Flue Gas	3,686
Solvent Waste	22
Electricity (Natural Gas)	15,700

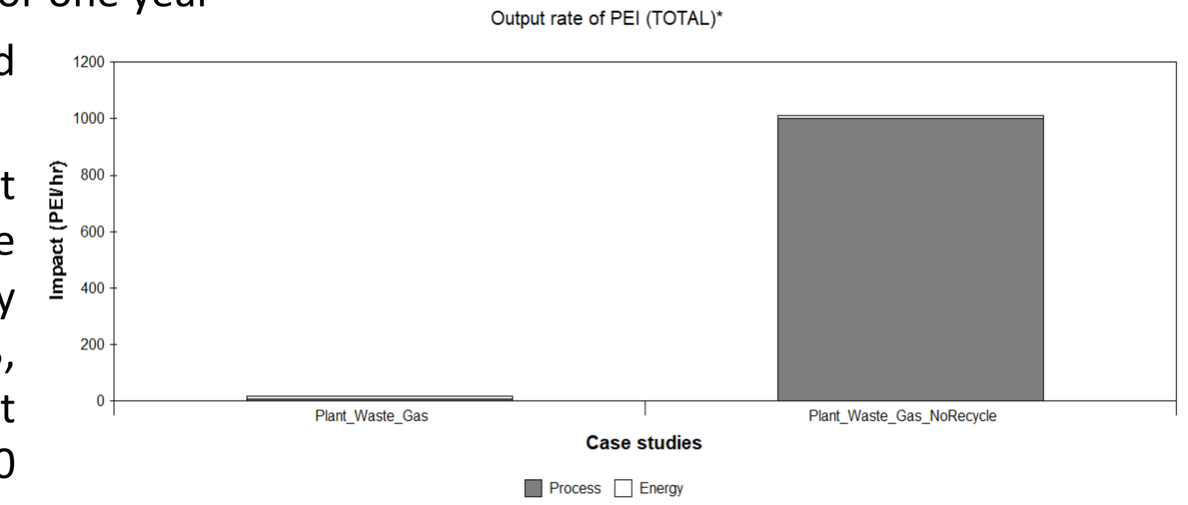
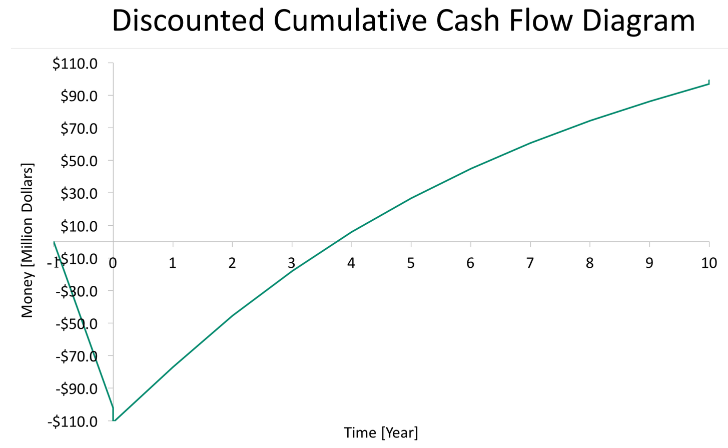


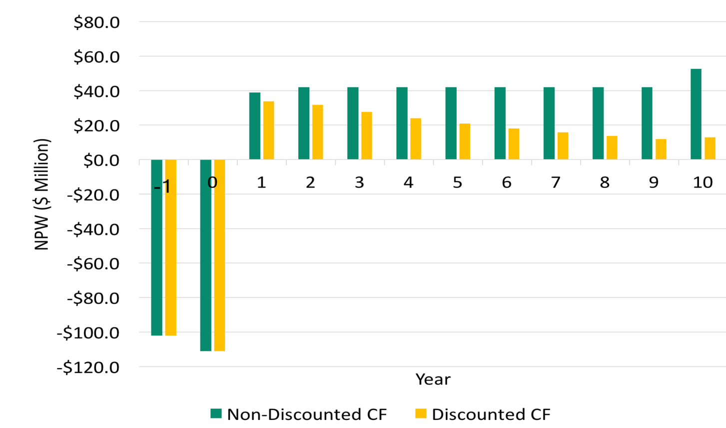
Figure 3. Potential Environmental Impact (PEI) of process with and without solvent recycle

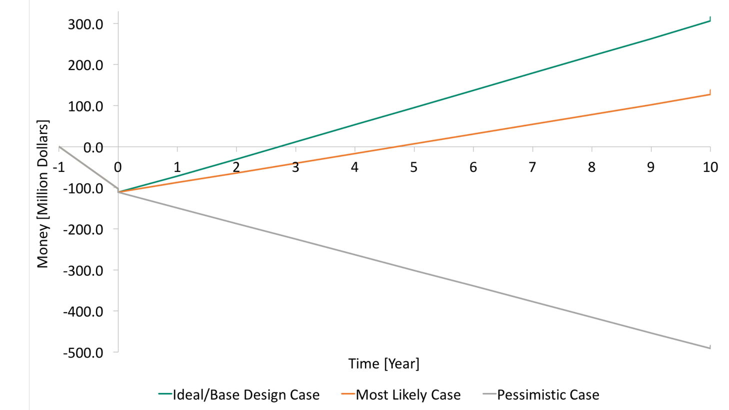
ECONOMIC ANALYSIS

Feasibility	
Expenses	
Fixed Capital Cost	\$88.7 Million
Working Capital	\$8.9 Million
Start-up Expenses	\$4.5 Million
Avg. Annual Expenses	\$86.1 Million/year
Profitability	
Revenue	\$134.7 Million/year
Avg. Annual CF	\$42.6 Million/year
NPW	\$99.2 Million
DCFRR	35.4%
Return on Investment	31.9%
Pay-Back Time	3.8 years

Plant Capacity and Sale Prices		
Phospholipids	265,800 kg/yr	\$300/kg
Glycolipids	147,000 kg/yr	\$300/kg
Neutral Lipids	179,600 kg/yr	\$60/kg







CONCLUSION AND RECOMMENDATIONS

Feasibility is uncertain:

- Separation efficiency and NPW are susceptible to variations due to uncertainty in scaling-up laboratory processes
- Prices for groups of lipids on the commercial market are relatively unknown, so design project prices are highly susceptible to change
- Sale prices of lipid classes were estimated to be roughly 1/2000th of 99% pure individual lipid prices by keeping the project at a maximum DCFRR of 35%
- Market is unsaturated, and alternative sources of lipids (soybeans and fish oils) compete with food sources
- Earning potential is extremely high if separation efficiency can be maintained above 70% and sale prices are elastic

Recommendations:

- Investment for a pilot plant with the plant capacity based on one microwave to collect experimental data on separation efficiencies of each process
- Further market research to estimate variability of product prices with respect to lipid purity
- Investigate feasibility of further fractionation of lipids from groups to individual compounds

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