Critical Analysis Of Current Microalgae Dewatering Techniques

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Introduction

Microalgae are microscopic, unicellular species that are typically found in freshwater and marine environments. They are capable of fixing CO2 and converting solar energy into chemical energy, thus making them a promising feedstock for biofuel. However, harvesting and dewatering algae in a cost-effective, efficient manner is difficult because microalgal biomass is fairly dilute in cultures (up to 0.3-0.5 grams of dry biomass/L). When working with commercial-scale dewatering and recovery processes, traditional harvesting processes may involve two steps -- primary harvesting and secondary dewatering. Several techniques for dewatering have been developed and are described in this summary.

Primary Harvesting:

Flocculation:

Used as a pretreatment in order to form flocs of microalgae. These flocs than coagulate, in which the particles aggregate to form a bigger particle that makes it easier to separate. This works by adding cationic flocculants in order to neutralize and attract the negatively-charged microalgae cells.

Flotation:

With the aid of pressurized water, microalgal cells are trapped on micro air bubbles and float to the surface. The efficacy of this method relies on successful collision and attachment of bubbles and particles, working best when algal cells are hydrophobic. Other important factors are the air bubble size, solubility and the pressure difference of the air, the hydraulic retention time, and the floated particle size. Flocculation must be completed before dissolved air flotation (DAF) can be completed.

Sedimentation:

Allow time for gravity to settle the microalgal cells. This method is most commonly used but is both slow and requires the algal cells to be larger than 70μm in size.

Secondary Dewatering:

Centrifugation:

Centrifugation is a separation process that promotes the settling out of particles in a mixture through centrifugal force, which acts outward on a system moving around a central point. This is the ideal method for rapid harvesting of algae containing high-value products. However, it has high operating costs and is considered to be too expensive. There are several different types of centrifuges of various shapes and sizes.

> Desk stack centrifuge – This is used in commercial plants for high-value algal products and in algal biofuel pilot plants. It consists of a shallow, cylindrical bowl (stack) and closely spaced metal cones (discs).
>
> Decanter centrifuges – These are as effective as solid bowl centrifuges, but have higher energy consumption.
>
> Spiral plate centrifuges – These are relatively new to the industry. Suspension flows outward in thin films over vertical plates. Solid sediment and microalgae is forced to collect on the bottom edges.

Filtration:

There are many methods of filtration, including microstrainers, vibrating screen filters, and micro- and ultra-filtration. The major disadvantage of these methods is the high capital and operating cost required to avoid filter blinding and disruptive pressure changes. Although slower than centrifugation, the primary benefit of filtration is its simplicity and lower price.

Drying:

After secondary dewatering and before oil extraction, the water content of algal paste should not exceed 50%. Thermal drying and mechanical drying have high costs, so a harvesting method that produces low water content is favorable. Common methods of microalgae drying after secondary dewatering include spray drying, drum drying, freeze drying, and sun drying.

Technoeconomic Assessment

The table below compares the cost of microalgal bioprocessing harvesting methods.

	Single step	Primary			Secondary	
	Centrifugation	Sedimentation	Flotation (1)	Flotation (2)	Filtration	Centrifugation
Total energy consumed (kWh/10 m^3)	55†	–	7.4–8.4‡	0.150§	1–3 [4]	5.5†
Energy cost (AU$)¶	12.10#	–	1.62–1.84#	0.033	0.22–0.66#	1.21#
Dosage required (g)	–	100 @ 10 mgl^{-1} [1]	30 @ 3 mgl^{-1} [3]	100 @ 10 mgl^{-1}	–	–
Chemical cost (AU$)	–	2.50 (chitosan @ $25/kg)	0.24 (CTAB @ $8/kg)	0.8 (CTAB @ $8/kg)	–	–
pH adjustment dosage	–	1.5–2 l acetic acid††	–	–	–	–
pH adjustment cost (AU$)	–	1.20–1.60 @ $800/ton	–	–	–	–
Total cost (AU$)	12.10	3.70–4.10	1.86–2.08	0.833	0.22–0.66	1.21

†An Evodos centrifuge was used for this study.
‡Flotation cell considered is Jameson cell and energy consumption was determined using various published studies as well as our own published [3] and unpublished data.
§Flotation cell considered is column flotation cell and energy consumption was determined using work done by Coward *et al.* [85].
¶1 AU$ = ~US$1.04.
#Electricity prices were calculated based on AU$0.22/kWh.
††The volume was estimated by doing an experiment with 1 l of algae culture.
CTAB: Cetyl trimethyl ammonium bromide.

From the table it is determined that floatation is the most cost-effective method for primary dewatering. However, if used with centrifugation, the overall setup costs will increase and would result in higher capital costs. Some harvesting techniques are more feasible than others when considering costs only, but some of these may not be as environmentally friendly. One example of this is the cetyl trimethyl ammonium bromide chemical used for flotation. It is toxic to the environment and also makes the biomass unfit for human and animal consumption.

Classification of current harvesting processes

Combinations of different processes and techniques can be used in order to optimize results or goals, such as cost reduction or environmental impact. There are three general classification of processes: mechanical, biological, and chemical.

Future perspective

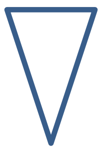
Microalgae will play a vital role in the future for biofuel and wastewater purification as fossil fuels continue to deplete and greenhouse gas emissions pollute the atmosphere. However, the current harvesting methods for algae are costly and labor intensive. Within the next 5-10 years it is predicted that newer harvesting methods will be developed to increase the efficiency of harvesting processes as well as lowering their costs while also having a low environmental impact.

Conclusion

Research has produced a lot of information on harvesting microalgae. Optimizing current processes, developing technology, and in-depth analyzing of species of marine algae are needed to understand more about dewatering techniques for algae.

Algae Dewatering Laboratory Worksheet

Centrifuge



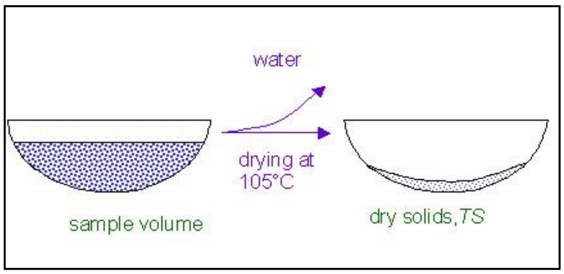
Weigh empty centrifuge tube ______________________________Units ____________

Place 1 ml algae suspension in tube. Centrifuge at 10,000 rpm for 5-10 minutes. Remove water. Dry tube.

Weigh centrifuge tube ______________________________Units _____________

Calculate mg/L of algae **____**

Evaporation



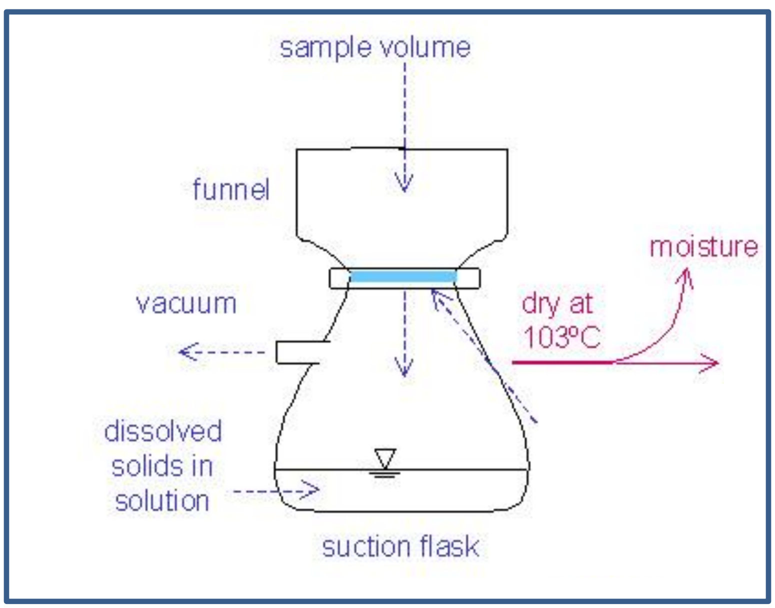
Weigh empty crucible __________________Units _____________

Add 50 mL algae suspension. Evaporate the water at room temperature.

Weigh crucible __________________Units _____________

Calculate mg/L of algae __________________________________

Filtration



Weigh aluminum pan with 0.45 micron filter paper __________________Units _____________

Filter 50 mL algae suspension. Dry filter paper in pan

Weigh aluminum pan with 0.45 micron filter paper __________________Units _____________

Calculate mg/L of algae __________________________________

Coagulation-Flocculation

Microorganisms carry an electric charge, usually negative. This characteristic prevents the collision and the aggregation of the particles. The addition of certain chemicals to colloidal suspensions can enhance destabilization and aggregation processes, leading to the formation of **flocs** of considerable dimensions. These flocs can then be further, removed by sedimentation or filtration. A typical flocculation process is shown in Figure 1.

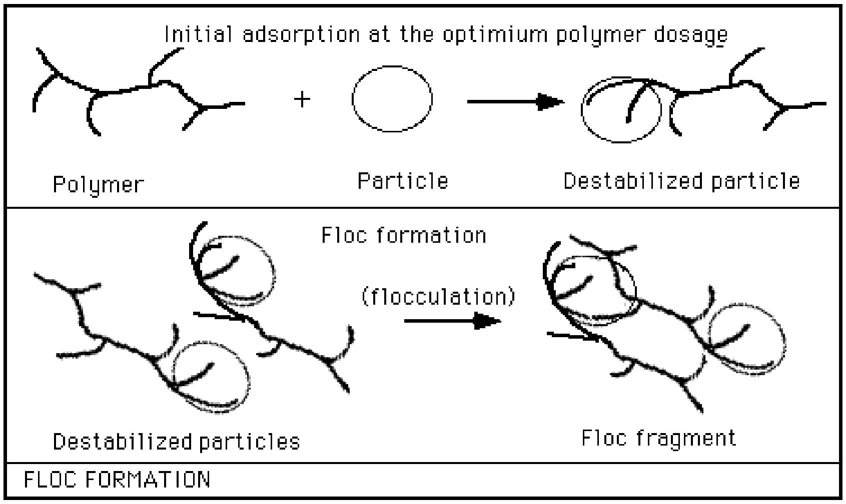


Figure 1: Typical Flocculation Process

Flocs can be formed by adding trivalent salts of Iron and Aluminum. The process of adding chemicals to form flocs and settle them out is called coagulation. The common coagulants in water treatment are the trivalent salts of Iron and Aluminum. Jar tests are used in water treatment plants to determine the optimum dose of a coagulant. The following reaction takes place when alum is added to the water:

$$AL_2(SO_4)_3 \cdot 18H_2O + 3Ca(HCO_3)_2 \leftrightarrow 3CaSO_4 + 2Al(OH)_3\downarrow + 6CO_2 + 18H_2O$$

Place 900 ml of algae suspension into the beakers provided with the apparatus.

1. Add the required alum dose to each jar.
2. Rapid mix for 40 seconds followed by slow settling for 5 minutes. Stop stirring and allow settling.
3. Measure optical density/turbidity (units NTU) for each jar. Do not disturb precipitate.
4. Plot turbidity versus Alum dose to determine optimum alum dose.

Jar #	Alum mg/L	Turbidity (NTU)
1		
2		
3		
4		
5		
6