Optimization of Algal Dehydration Kinetics

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Abstract

Algae cultivation has multiple environmentally-oriented applications including biofuel production, wastewater treatment, and carbon capture. However, costs associated with extraction and dehydration remain a challenge for viable commercialization. Research has focused mainly on microalgae, but filamentous algae such as *Oedogonium* have gained attention due to their larger size and resulting ease of harvesting. *Oedogonium* has also been seen to occasionally self-entangle and form spherical aggregates which further facilitates harvesting. These aggregates generally dry slower than unaggregated *Oedogonium*. This study investigated drying optimization by using a blender to reduce the aggregates to a slurry and fracturing the *Oedogonium* filaments. Blended and unblended triplicates of aggregates with spherical diameters of 4-6mm, 9-11mm, and 13-15mm were dried in an oven at 50℃, and the blended samples dried 29%, 6%, and 41% faster, respectively, than the unblended aggregates. Further, while the total drying times of the 4-6mm and 9-11mm unblended aggregates were relatively similar at 255min and 240min, respectively, the total drying time of the 13-15mm aggregates was 330min, which is significantly longer. These findings confirm that processing aggregated *Oedogonium* can significantly reduce its drying time and that, if no processing is done, total drying time will greatly increase when aggregates exceed a certain size.

Introduction

Algae farming is becoming increasingly more relevant as the world is starting to turn towards renewable energy and sustainable solutions [1][2]. However, large costs associated with harvesting and drying of algae remain a significant challenge [3]. Filamentous algae have gained attention due to their larger size and resulting ease of harvesting [4]. Under conditions of high-water agitation, *Oedogonium*, a filamentous alga, can self-entangle to create various volumes of aggregated spheres, as seen on the bottom row in Figure 1. These aggregates can easily be harvested with a net or strainer and reduce costs otherwise associated with complex extraction methods [3]. It has been shown that these spheres generally dry slower than unaggregated *Oedogonium* but also that subjecting unaggregated *Oedogonium* to a fracturing treatment will increase its drying efficiency [5]. This study, therefore, aims to investigate if a fracturing treatment could also be used to increase the drying efficiency of aggregated forms and thus allow for both easy harvesting and effective drying.

Objectives

- Compare the drying mechanics of differently sized *Oedogonium* aggregates
- Assess the effectiveness of a fracturing treatment used on different sizes of *Oedogonium* aggregates

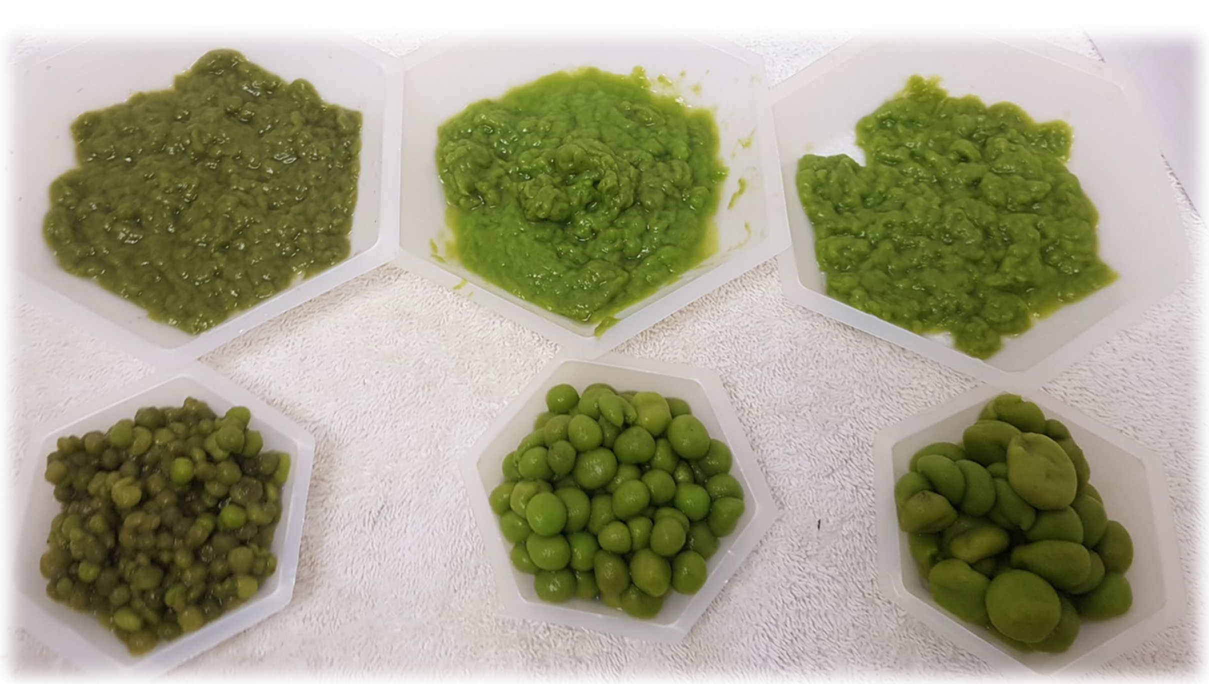


Figure 1. Blended and Unblended Oedogonium Aggregate Groups

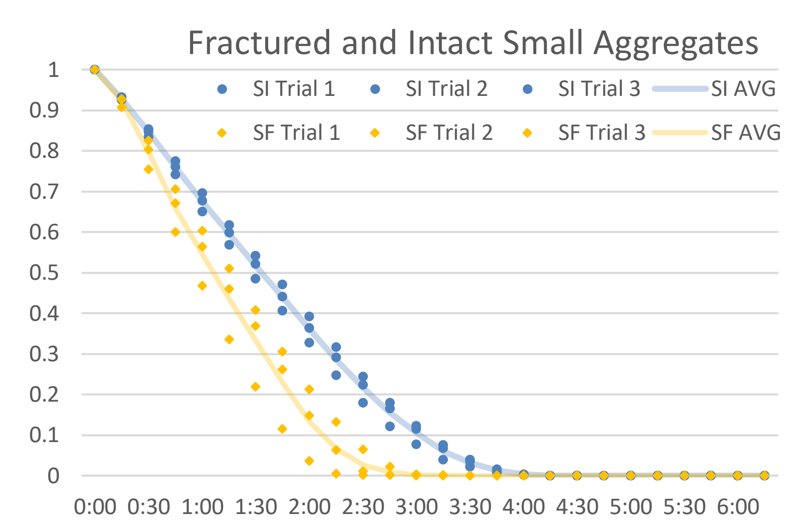
Methodology

- Spherically aggregated *Oedogonium* was cultivated by subjecting *Oedogonium* to high levels of water agitation.
- *Oedogonium* spheres were sorted into 3 categories based on their diameter, 4-6mm, 9-11mm, and 13-15mm.
- Subsamples of each size group were processed and reduced to a slurry by running them through a commercial blender. This created the 6 groups seen in figure 1.
- To create a consistent starting point for drying, excess surface moisture was removed from the spherical aggregates and slurry by placing/pouring a volume of 15ml of algae onto a 10-layered absorbing paper and pressing it with a 1 kg weight for 20 seconds.
- 6g of pressed algae was then transferred to aluminum dishes and dried at 50℃ while measurements of tray weights were taken every 15th minute.
- For data processing, the Moisture Ratio (MR) of each sample over time was calculated using the equation: $MR = \frac{MC - MC_e}{MC_o - MC_e}$

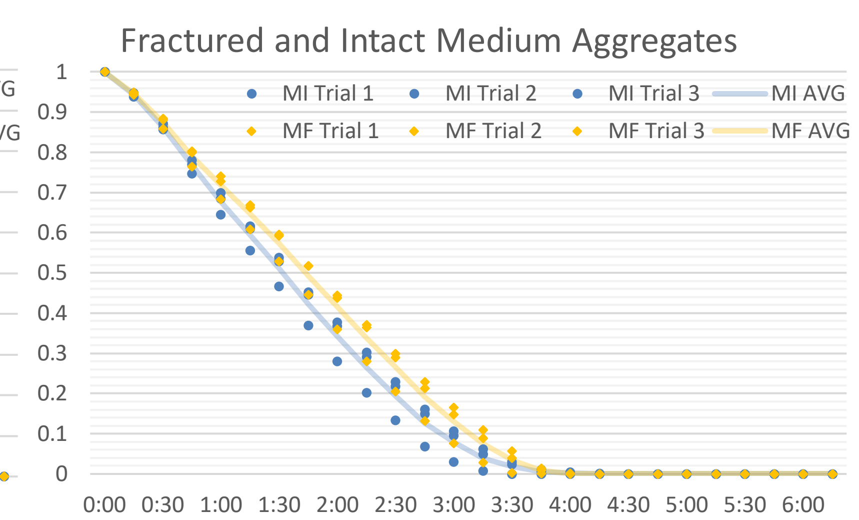
  where MC: Current moisture content, MC_e: Equilibrium moisture content when fully dried, MC_o: Original moisture content.

Results

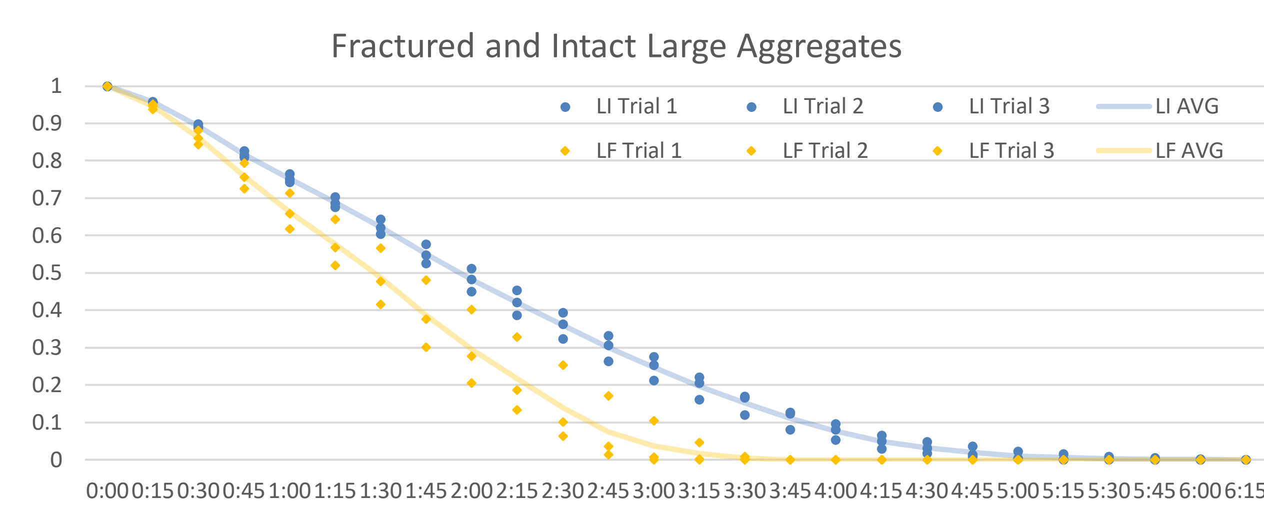
- The dewatering method used was effective at bringing the moisture content of all *Oedogonium* samples down to the same level of about 89.7% with a standard deviation of 0.4%.



Graph 1. MR of Small Intact (SI) and Small Fractured (SF) Aggregates



Graph 2. MR of Medium Intact (MI) and Medium Fractured (MF) Aggregates



Graph 3. MR of Large Intact (LI) and Large Fractured (LF) Aggregates

- As seen from Graphs 1-3 and Table 1, there was not a large difference in drying time between the medium and small unblended aggregates (total time was 4h 15min and 4h, respectively). However, the large group had a significantly longer drying time (5h 30min).
- The fracturing treatment was successful in reducing the average total drying time of all aggregate sizes but had an almost negligible effect on the medium-size group.
  - This is possibly due to the medium-sized aggregates having an optimal volume to surface area ratio, but this should be investigated further.
- Table 1 shows that the falling rate period of drying is shorter for all fractured samples than for intact aggregates, indicating that fractured samples evaporate more of their moisture content before transitioning to a falling rate phase.

Table 1. Drying phases and total drying time

****Measured at 15 min intervals with a precision of ± 1% Moisture Ratio***

Drying group	Constant rate period (min)	Falling rate period (min)	Total drying time (min)
Small Intact Aggregates	120	135	255
Small Fractured Aggregates	75	105	180
Medium Intact Aggregates	120	120	240
Medium Fractured Aggregates	150	75	225
Large Intact Aggregates	150	180	330
Large Fractured Aggregates	120	75	195
Microalgae Control Group	120	105	225

Conclusion

- Drying mechanics are similar for small and medium sized aggregates but increases dramatically when aggregates exceed a certain size.
  - This is likely due to an increasing ratio of volume to surface area
  - $V_{sphere} = \frac{4}{3}\pi r^3, \ A_{sphere} = 4\pi r^2$
- The fracturing treatment reduces falling rate duration and total drying time for all aggregate sizes.

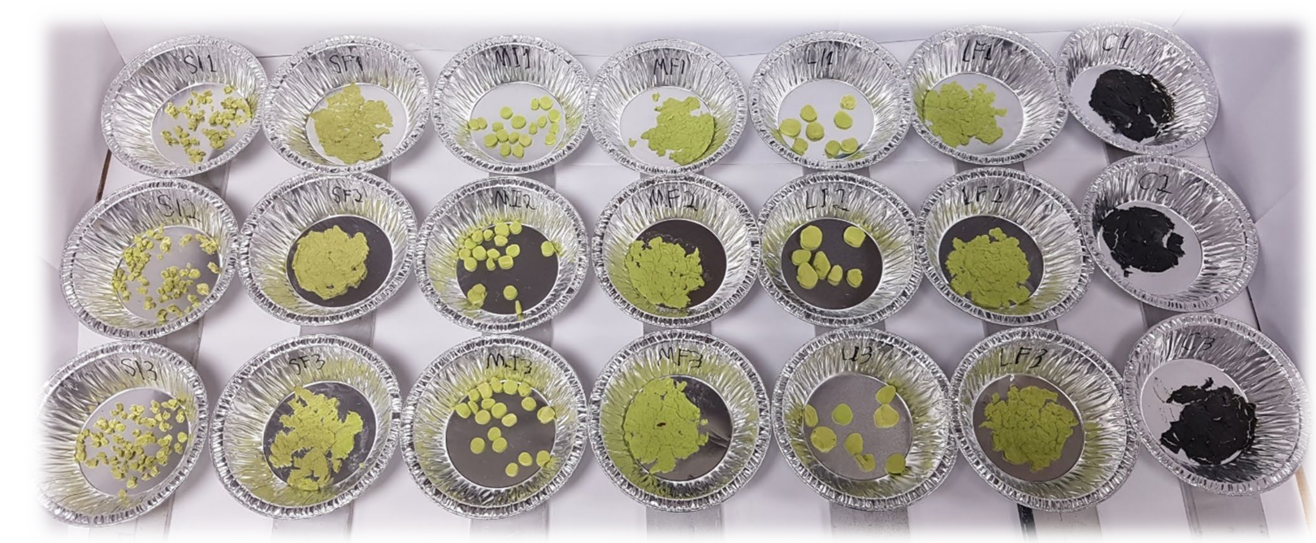


Figure 2. All Dried Samples, Including the Microalgal Control Group to the Right

Next steps

- The small difference between the total drying time of intact and fractured medium-sized aggregates was unexpected and should be further researched.
- Further data analysis should be conducted to determine the critical moisture content at which each group transitions from constant to falling rate drying.
- Sherwood's analytical solution of Fick's Second Law of Diffusion should be used to determine the effective diffusivity of each group.

References

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