Dehydration Kinetics of the Filamentous Alga *Oedogonium*

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Abstract

Algae cultivation has multiple potential applications including biofuel production, wastewater treatment, and carbon capture. However, dewatering and dehydration remain a challenge for commercialization. Research has focused mainly on microalgae, but filamentous algae have recently gained attention due to their larger size and thus relative ease of harvesting. The drying mechanics of filamentous algae has yet to be fully understood and optimized. This study investigated the drying behavior of the filamentous algae *Oedogonium* at 50℃, 60℃ and 70℃. The moisture content of triplicate samples of microalgae and *Oedogonium* (intact filaments, fractured filaments, and aggregated forms) was measured during drying. Intact *Oedogonium* filaments were fractured using a food blender. Results indicated a higher drying efficiency of *Oedogonium* in comparison to microalgae. At 50℃, fractured *Oedogonium* filaments maintained an average drying rate of -0.56±0.07% per minute for 165 minutes compared to -0.51±0.07% per minute for the microalgae and the intact and aggregated *Oedogonium*. However, this drying effect decreased significantly at 60℃, and at 70℃ all algae dried at similar rates. Thus, fracturing the *Oedogonium* filaments resulted in faster dehydration at 50℃. Reducing the duration and energy cost of drying helps to facilitate commercialization of algae cultivation.

Introduction

Due to their potential for biofuel production and various other applications, algae are becoming increasingly more relevant as the world is starting to turn to sustainable technology and solutions [1][2]. However, the costs of harvesting and drying can constitute as much as 70-75% of the total processing cost [3] and are therefore the major obstacle for viable commercial implementation. In response to this, filamentous algae such as *Oedogonium* have been gaining more attention due to their relative ease of harvesting and high productivity [1]. *Oedogonium* grows in long filaments and can be easily harvested with a net or other large-scale tools [4]. However, the drying mechanics of this type of algae is not yet fully understood. This study, therefore, aims to investigate the comparative drying of *Oedogonium* and microalgae and the effect of filament fracturing on the drying of *Oedogonium*.

Objectives

- Compare the drying mechanics of thin-sheet drying of microalgae and the filamentous alga *Oedogonium*.
- Investigate the effect of fracturing treatment and aggregate forms on the drying mechanics of *Oedogonium*.

Methods

- A literature review of drying methods and mechanics of agricultural products and algae was conducted.
- Intact *Oedogonium* filaments were fractured using a food blender.
- Prior to drying, excess water was removed from the collected algae slurry by pouring onto 10 layers of absorbing paper and pressing it with a 1 kg weight for 20 seconds, as seen in Figure 1. This was done to remove all surface moisture as a consistent starting point for drying.
- The experimental algae sheet thickness was 2mm and sample mass was 6g wet weight.
- Drying experiments were done at 50℃, 60℃ and 70℃, and were all conducted in triplicate.
- 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 was current moisture content, MC_e was the samples equilibrium moisture content when fully dried, and MC_o was the original moisture content when drying started.

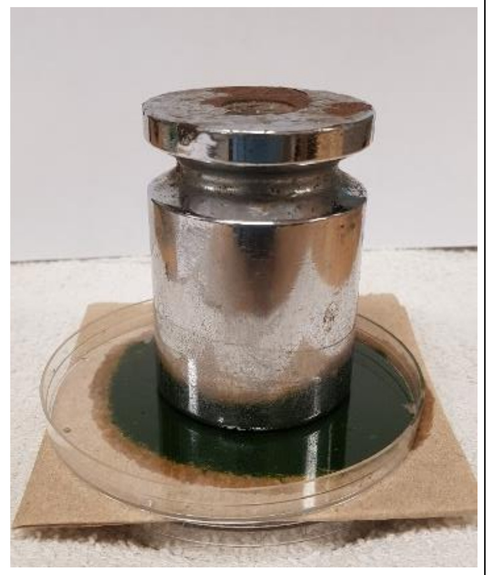

Figure 1. Surface Moisture Removal

Results

Microalgae vs *Oedogonium*

- *Oedogonium* dried faster than microalgae at all temperatures.
- The drying of *Oedogonium* and microalgae was found to occur in an initial constant rate period before transitioning to a falling rate period.
- Table 1 shows that *Oedogonium* had a shorter falling rate period, resulting in a shorter total drying time.
- During the falling rate period, the drying rate of *Oedogonium* decreased more slowly than for microalgae which in turn allowed its MR to reduce faster. This is seen in Figure 2 by how the MR of the intact filaments catches up with the microalgae at 190 min.
- The more efficient drying during the falling rate period suggests *Oedogonium* is better able to expel internally bound moisture to its surface where it can evaporate.

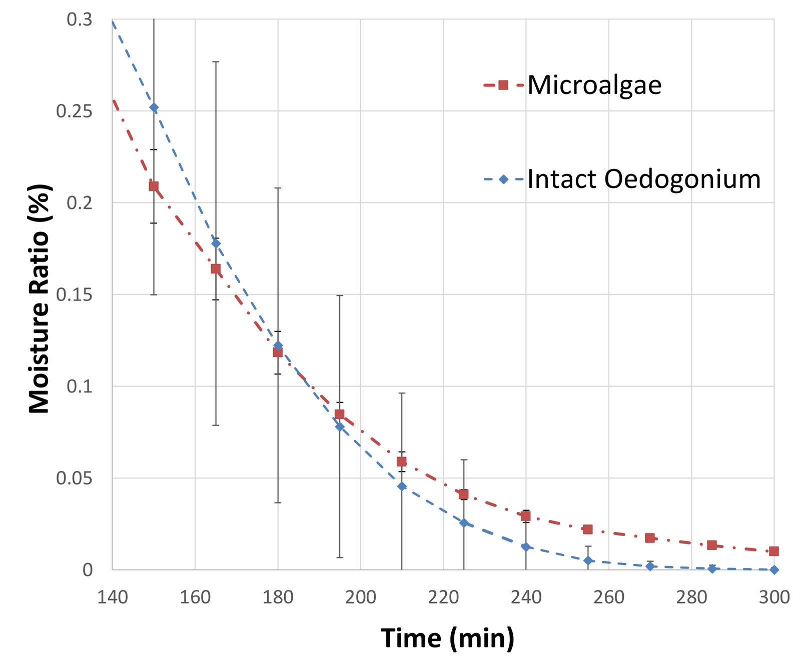

Figure 2. MR of Microalgae and Intact Oedogonium Filaments at 50℃

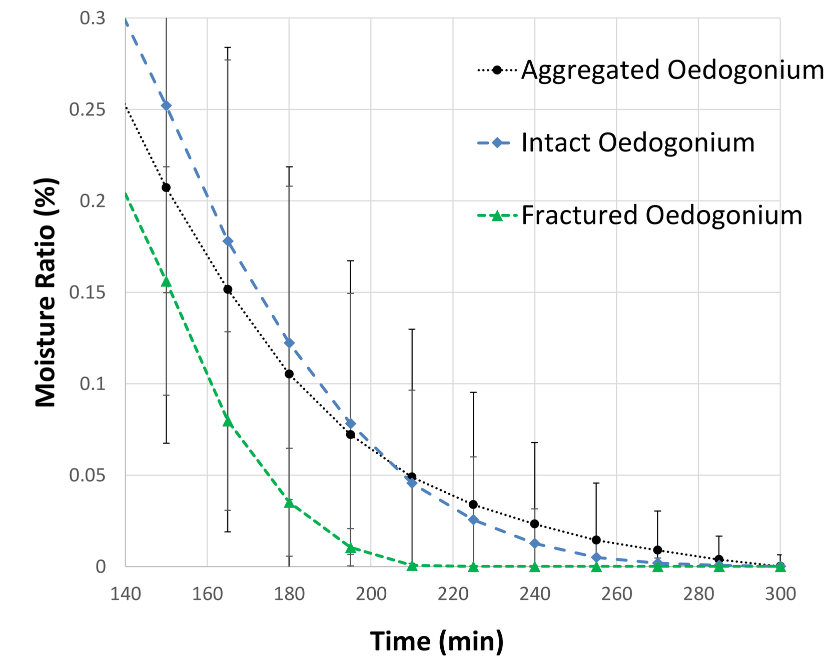

Figure 3. MR of all Oedogonium samples at 50℃

Treatment effect

- Fractured *Oedogonium* dried significantly faster than intact samples at lower temperatures. See Figure 3 and Table 1.
- The falling rate period of fractured samples did not decrease at higher temperatures, and the effect of the treatment was negligible at 70℃.
- The fracturing treatment should be considered for optimization of lower temperature drying.

Figure 4: Filament deformation during drying. Top row: intact; Bottom row: fractured

- During drying, fractured samples were seen to crack and break into several smaller pieces while intact samples only contracted and remained intact during drying, as seen in Figure 4.
- This behavior could result in fractured samples exposing more internal moisture which would otherwise be encapsulated in the solid sheet, thus explaining the shorter falling rate period.
- As seen in Table 1, aggregated forms dried slower or at the same speed as intact *Oedogonium*.
- Aggregated forms would not be effective for the optimization of drying. However, *Oedogonium* cultures that self aggregate could be more easily harvested and this benefit should be considered in comparison to the reduced drying efficiency.

Table 1. Drying phases and total drying time
****Measured at 15 min intervals with a precision of ± 1% Moisture Ratio***

	Constant rate period (min)	Falling rate period (min)	Total drying time (min)
50℃			
Microalga	150	150	300
Intact *Oedogonium*	165	90	255
Fractured *Oedogonium*	165	45	210
Aggregated Forms	150	135	285
60℃			
Microalga	105	75	180
Intact *Oedogonium*	105	60	165
Fractured *Oedogonium*	105	45	150
Aggregated Forms	120	75	195
70℃			
Microalga	75	60	135
Intact *Oedogonium*	75	45	120
Fractured *Oedogonium*	75	45	120
Aggregated Forms	75	60	135

Conclusion

- This study documents a higher drying efficiency of *Oedogonium* in comparison to microalgae.
- Results indicate that fractured *Oedogonium* dries faster than intact *Oedogonium* at lower temperatures with a decreasing difference at higher temperatures.
- Aggregated forms dry less effectively than intact *Oedogonium*.

Future Work

- As the fracturing treatment was seen to be most effective at the lowest of the tested temperatures, further studies should investigate the effectiveness of the treatment at a lower temperature range.
- Only thin-sheet drying (2mm) was investigated in this study. Further studies should also investigate if the same effects are seen with increased sheet thickness.
- Since aggregated forms were observed to dry less effectively than intact filaments, it should be investigated if treating the aggregate forms by fracturing would improve drying efficiency.

References

1. Zhang, W., Zhao, Y., Cui, B., Wang, H., & Liu, T. (2016). Evaluation of filamentous green algae as feedstocks for biofuel production. *Bioresource Technology*, 220, 407-413. doi:10.1016/j.biortech.2016.08.106
2. Cole, A. J., Neveux, N., Whelan, A., Morton, J., Vis, M., Nys, R., & Paul, N. A. (2016). Adding value to the treatment of municipal wastewater through the intensive production of freshwater macroalgae. *Algal Research*, 20, 100-109. doi:10.1016/j.algal.2016.09.026
3. Show, K.-Y., Lee, D.-J., & Chang, J.-S. (2013). Algal biomass dehydration. *Bioresource Technology*, 135, 720-729. doi:10.1016/j.biortech.2012.08.021
4. O'Connell, R., & Wilkie, A. C. (2018). Comparing Harvest Productivity of the Filamentous Alga Oedogonium with Microalgae. *University of Florida Journal of Undergraduate Research,* 20(1). doi:10.32473/ufjur.v20i1.106221

Acknowledgements

This research was conducted as part of the *2019-20 CALS University Scholars Program* and SWS 4911: Supervised Research in Soil and Water Sciences, at the Bioenergy and Sustainable Technology Laboratory, Soil and Water Sciences Department, UF/IFAS.