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Assessing Impact of Reactor Scaling on Carbohydrate and Lipid Yields from Saline and Fresh Water Algae

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Introduction

Effective deconstruction of algal biomass is a major challenge associated with algal biofuels/bioproduct production. Improving biomass conversion requires understanding how reaction parameters affect the scale-up of bench scale processes to move to cost-effective conversion. Pretreatment of both aquatic and terrestrial feedstocks, using similar reaction conditions, identical feedstock and pretreatment chemistries have reported wide ranges in total sugar yields. This has been attributed to differences in reactor size or scale, type of operation (batch vs continuous), method of heating, reactor geometry and solids loading (w/w). These factors can impactt both mass and heat transfer affecting both yield and reaction kinetics. To understand how total sugar yields in algal biomass are affected by different dilute acid pretreatment configurations we evaluated total sugar and lipid release at three reactor scales ranging from 4 ml to 300 ml, operated under mixed and non-mixed regimes.

Materials and methods

Algae biomass: *Desmodesmus armatus* was provided by The Arizona Center for Algae Technology and Innovation (AzCATI) at Arizona State University (ASU). The algae were grown in flat panel PBR's using ammonium chloride as the nitrogen source and was in artificial seawater. The algal strain was harvested 5-days post N-depletion using a continuous centrifuge.

***Compositional* analysis**: Carbohydrate, FAME, protein and ash content in whole and pretreated algae were determined using NREL standard Laboratory Analysis Procedures (LAPS) (et al. 2015), (Laurens and Van Wychen et al., 2015).

Pretreatment: Dilute sulfuric acid pretreatment was carried out in three reactors shown in Figure 1 and Table 1, **CEM microwave** (**a**) (7.5% DCW solids loading), **Sand Bath Reactor** (**b**) (20%DCW solids loading and (**c**) **ZipperClave reactor** (20% DCW solids loading). A central composite design was used (Design-Ease) (Table 2) using two variables, temperature and concentration of sulfuric acid and used for all reactors. After pretreatment aliquots of the algal slurry were analyzed for both FAME's and monomeric sugars. **Two sets of pretreatment experiments were conducted, one focusing on the Response Surface Design , the second focusing on the impact of solids loading.**

Figure 1. Reactor used in pretreatment study

A

B

C

Table 1. Reactor and operating variables

Reactor type	Capacity (g)	Mixing	Mode of heating
Microwave	0.5	no	Microwave
Sand Bath	4.0	no	Sand Bath
ZipperClave	300	yes	Steam injection

Table 2. Expt. conditions

Run #	Temperature	Acid%	Time (min)
1	140	2.75	15
2	155	2	15
3	170	1.25	15
4	155	2	15
5	170	2.75	15
6	155	2	15
7	155	0.94	15
8	155	2	15
9	140	1.25	15
10	155	3.06	15
11	134	2	15
12	176	2	15

Table 3. Acid concentration versus acid loading

Acid Conc. (%)	Solids loading % (w/w)	Acid loading % (w/w)
1.0	7.5	0.123
2.0	7.5	0.246
3.06	7.5	0.370
1.0	20	0.04
2.0	20	0.08
3.06	20	0.122

Results and Discussion

- Total sugar yield across all three reactors was highly variable but the yield trend was Microwave > ZipperClave> Sand bath (Figure 2).
- Yield responses for ZipperClave and Microwave were similar, but yields lower in the ZipperClave, 60% vs 95%.
- FAME yields were >100%, consistent and tracked well for the Sand Bath and ZipperClave (Figure 3).
- Reducing solids loading in the Sand Bath and ZipperClave reactor (From 20% to 12.5%) increased both acid loading and total sugars yields (Tables 3 and 4).
- The solids loading (g solid/total g) was a significant factor affecting the acid loading (g acid/g dry biomass), higher solids loading decreased acid loading (Table 3) and sugar yield.
- Pretreatment of saline D. *armatus* required a higher acid loading and pretreatment severity compared to dilute acid pretreatment of other fresh water strains (data not shown).

Figure 2 Response surface for sugar yield for the Sand Bath (a), ZipperClave(b) and Microwave reactor(c)

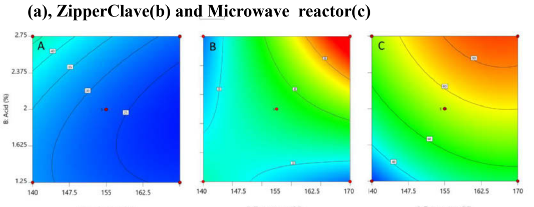
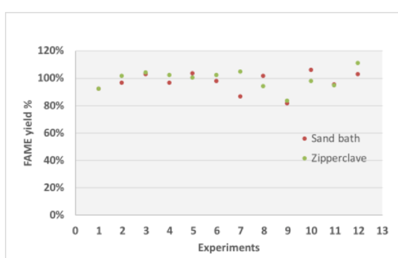


Table 4 monomeric sugar yields across reactor type and identical solids loading (12.5%)

Pretreatment	Scale	Temp C°	acid-to-biomass	Time (min)	Monomeric sugar yield	FAME yield
Microwave	Small	155	0.153	15	97	95.5
Sandbath	Small	155	0.16	15	97.1 ± 0.3	91.4 ± 0.5
Zipperclave	Large	155	0.16	15	98.1 ± 5.1	97.0 ± 0.1
Microwave	Small	170	0.138	15	88.5	101.0
Sandbath	Small	170	0.144	15	76.5 ± 1.2	95.3 ± 0.9
Zipperclave	Large	170	0.144	15	81 ± 7.4	98.3 ± 0.0

Figure 3 FAME yields obtained from small- & large-scale pretreatment



Conclusions

- Pretreatment of algal biomass grown in saline conditions is challenging
- Higher cation content may require higher acid loading or reducing solid loading to achieve higher sugar yields
- Higher protein and ash content (compared to fresh algae) may increase biomass recalcitrance

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