Using simulated flue gas to rapidly grow nutritious microalgae with enhanced settleability

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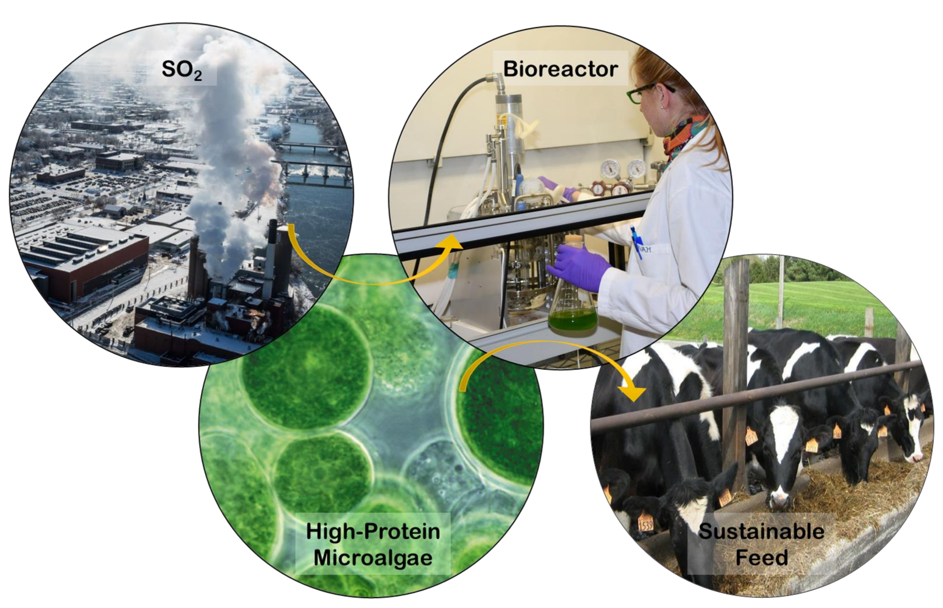
Abstract

Favorable microalgal nutrition from waste resources and improved harvesting methods would offset costs for a process that could be scaled-up to treat pollution and produce valuable animal feed in lieu of soy protein. Co-benefits include avoidance of carbon dioxide emissions, which may provide an additional revenue stream when carbon markets begin to flourish. To achieve these goals, barriers to microalgal production such as tolerance for waste streams and dramatic improvement in dewatering and settleability of the microalgae must be overcome. Presently, it is largely assumed that nutritious microalgae, including *Scenedesmus obliquus*, would be inhibited by SOx and NOx in flue gases and settle slowly as discrete particles. Studies conducted with a 2-L photobioreactor, sparged with simulated power plant emissions, demonstrated that both biomass productivity and settling rates were increased. Modeled settling showed rapid coagulation, likely facilitated by extracellular polymeric substances (EPS), and compaction when the cultures were grown with simulated emissions. The stress of simulated-emissions exposure decreased the *S. obliquus* protein contents and altered the amino acid profiles but did not decrease the fraction of methionine, a valuable amino acid in animal feed.

Introduction



To use waste, algae must tolerate waste

Inexpensive inputs (waste) and high growth rates are required to make microalgae competitive with soy.

If microalgae are intolerant of the toxic components in combustion emissions, biomass productivity will be compromised.

Soy is protein-rich but resource-intensive

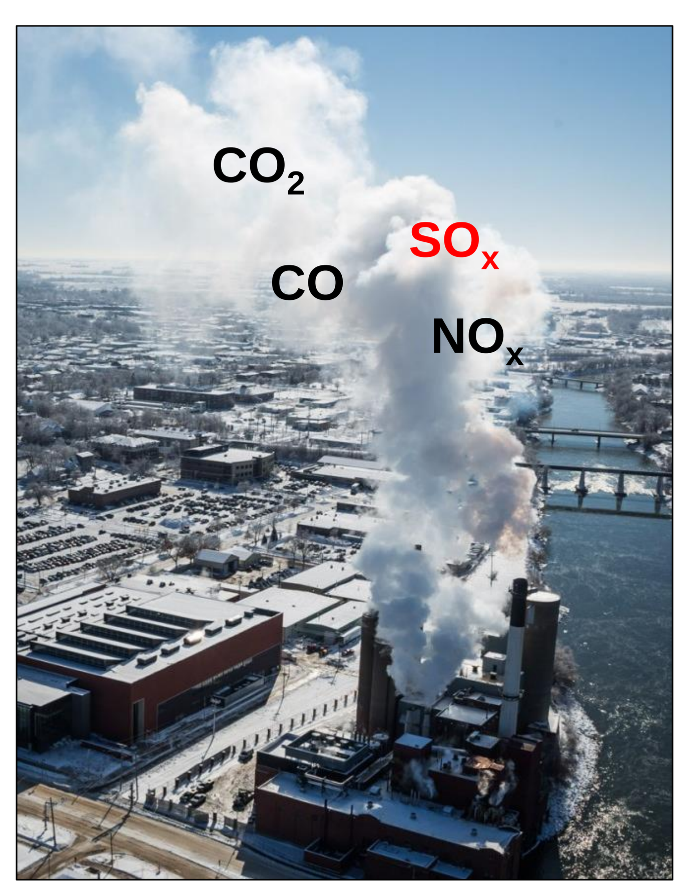
Soybean meal is the primary protein source in cattle feed.

Global agriculture utilizes 3% of annually produced energy, 70% of freshwater, and occupies 11% of land area.[2]

Microalgae require fewer resources and produce nutritious biomass rapidly.

Table 1. University of Iowa Boiler 10 Coal Combustion Emissions Composition

Component	Percent
H_2O	12.6%
CO_2	11.6%
O_2	5.8%
CO	0.048%
SO_2	0.045%
NO_2	0.022%
N_2	69.9%



Results

Simulated emissions alter microalgal composition:

Control:

$$H_2PO_4^- + 92CO_2 + 0.3SO_4^{2-} + 15NO_3^- + 16.6H^+ + 73.2H_2O \rightarrow C_{92}H_{165}O_{48}N_{15}PS_{0.3} + 129.7O_2$$

With simulated flue gas:

$$H_2PO_4^- + 130CO_2 + 0.5SO_4^{2-} + 14NO_3^- + 16H^+ + 102.5H_2O \rightarrow C_{130}H_{223}O_{59}N_{14}PS_{0.5} + 175.75O_2$$

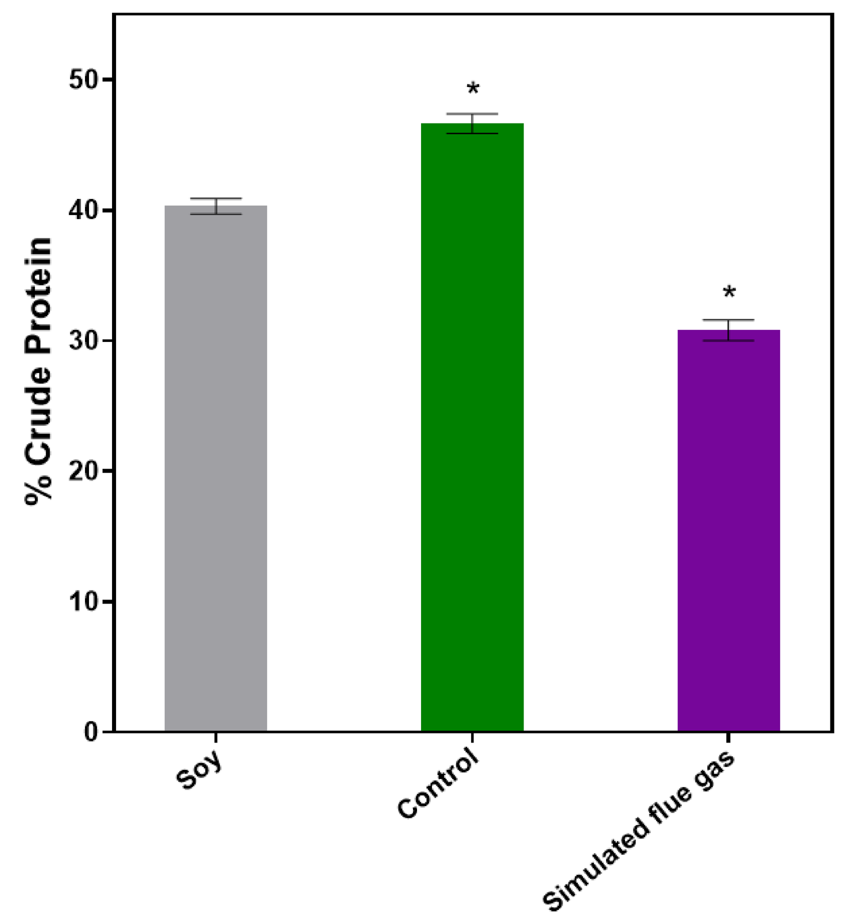


Figure 3. Percent crude protein comparison among whole soybean, *S. obliquus* grown in 3N-BBM and CO_2 blended with Ultra-Zero air, and *S. obliquus* grown in sulfur-free 3N-BBM and simulated coal-fired power plant flue gas. Error bars represent standard deviation (n=3). *Indicates statistical difference from the soy control at $p < 0.01$, $\alpha = 0.05$.

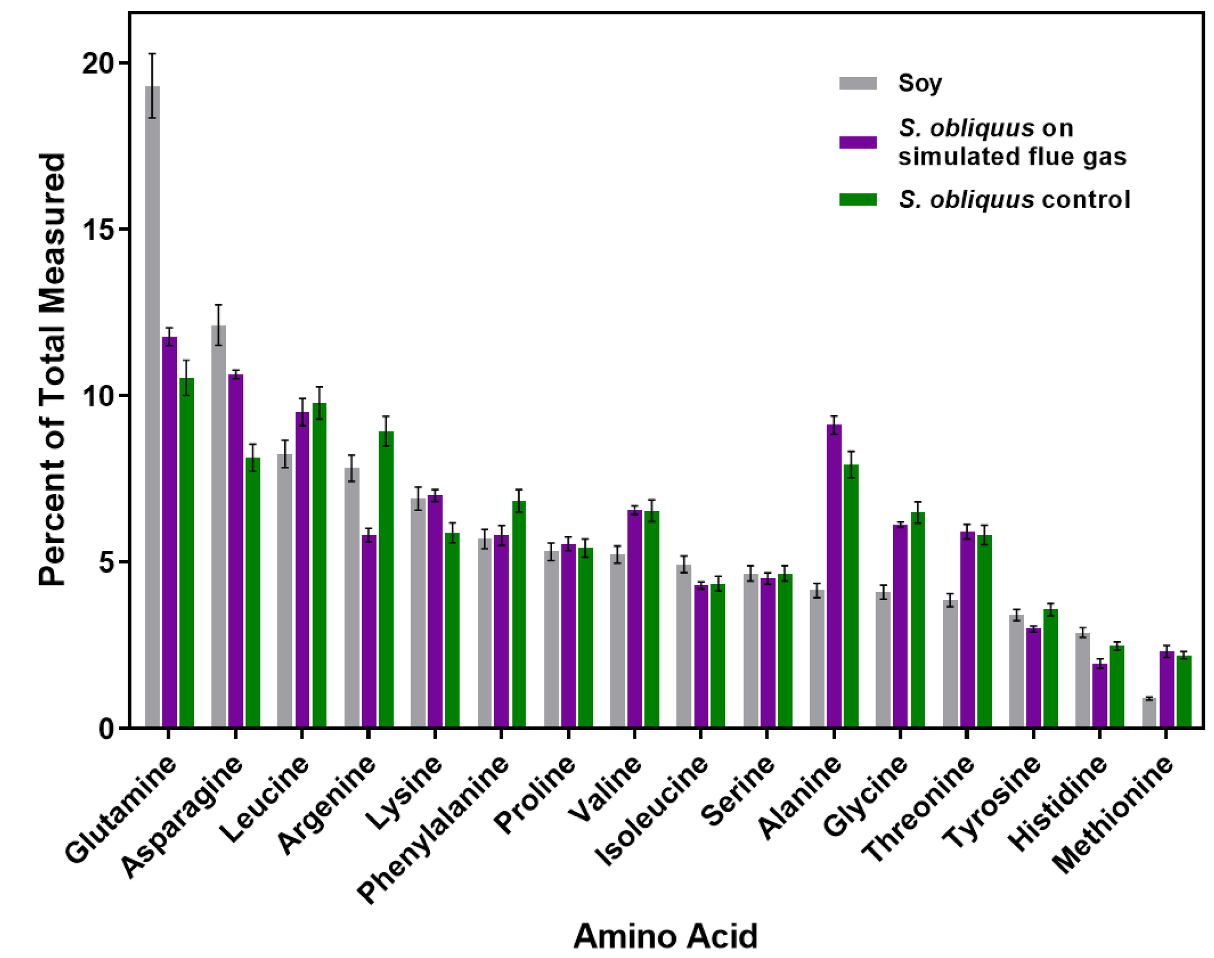


Figure 4. Percent amino acid comparison among *S. obliquus* grown with simulated flue gas, *S. obliquus* grown with CO_2 in Ultra-Zero air, and whole soybean. Error bars represent standard deviation (n=3).

Microalgal biomass productivity was improved by simulated emissions:

The average maximum biomass productivity was 700 ± 40 mg L-1 d-1, which significantly exceeded that of the control culture (510 ± 40 mg L-1 d-1).

Microalgal settleability was improved by simulated emissions:

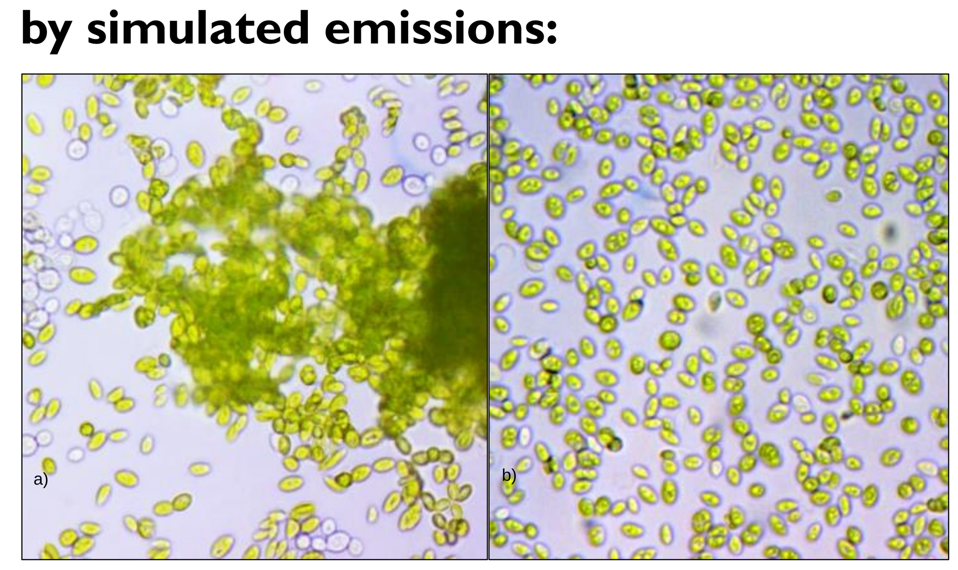


Figure 5. Comparison of a) *S. obliquus* grown with simulated flue gas, which coagulated, with b) *S. obliquus* grown in control conditions, which did not coagulate.

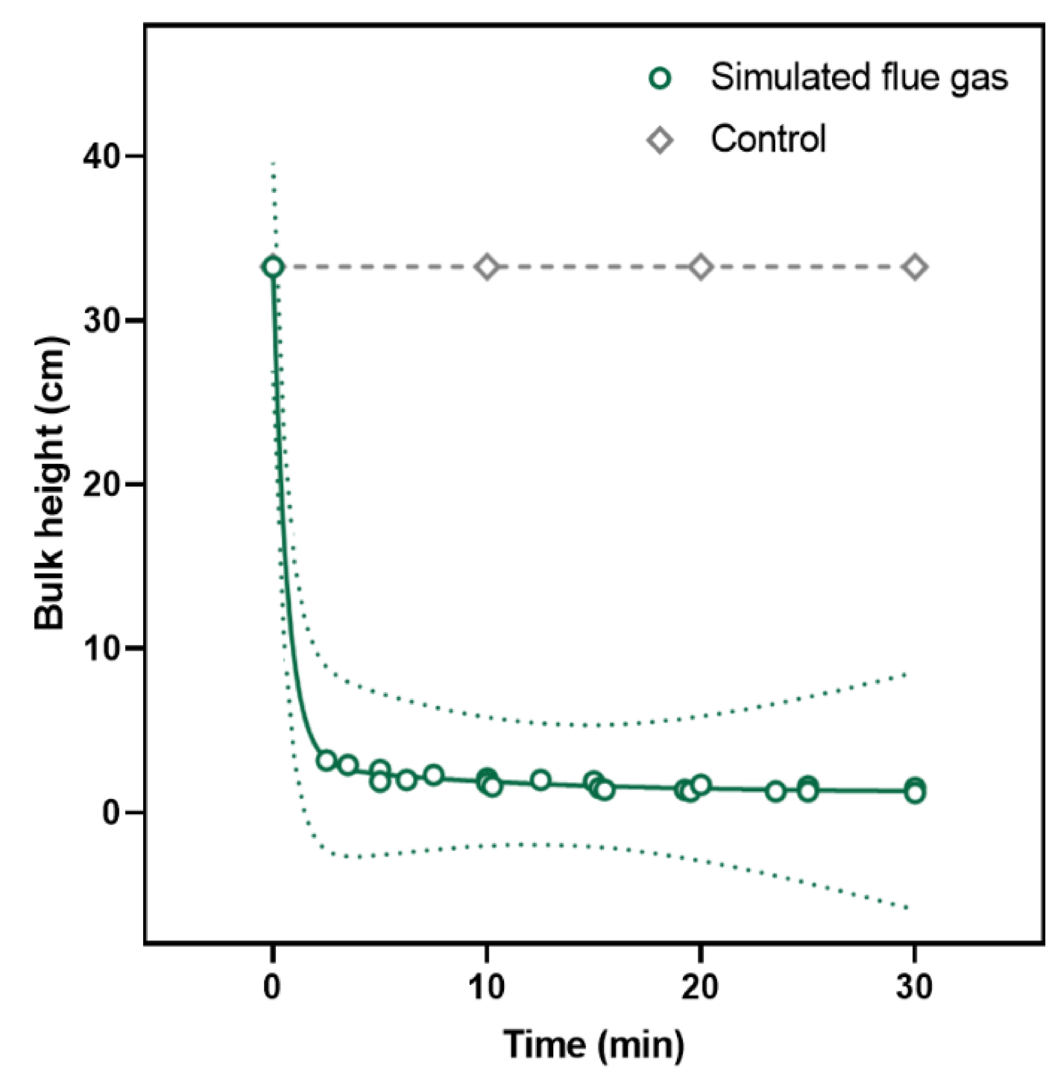


Figure 6. Modeled bulk settling, through coagulation and compaction, of microalgae grown on simulated power plant emissions. Model error is represented with a 95% confidence interval. Settling of control microalgae was not observed within the 30-minute period.

Methods

Figure 1. A 2-L Sartorius Biostat A, fitted with two red and blue LED panels and sparged with two custom gas tanks, served as a photobioreactor and pH-stat system for microalgae cultivation.

Cultivate axenic *S. obliquus* 3N-Bold's Basal medium, pH 6.8
Control: 12% CO2 in Ultra-Zero Air
Experimental: Simulated coal-fired power plant flue gas (Fig. 1)

Model algal growth & calculate biomass productivity (Fig. 2)

Composition analyses

- Elemental analysis
- Crude protein (Fig. 3)
- Amino acid profiles (Fig. 4)

Measure & model settleability (Fig. 5 & 6)

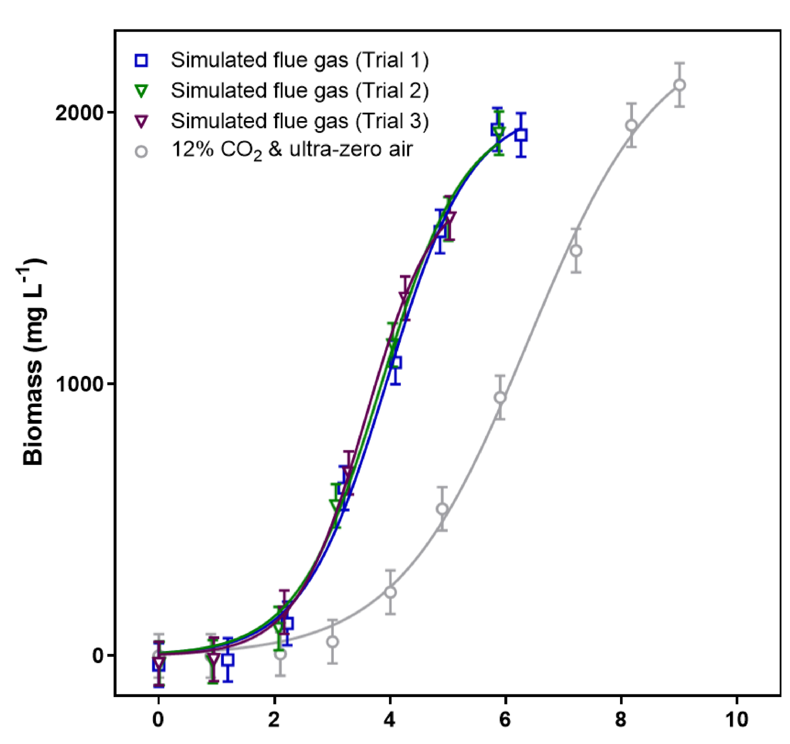


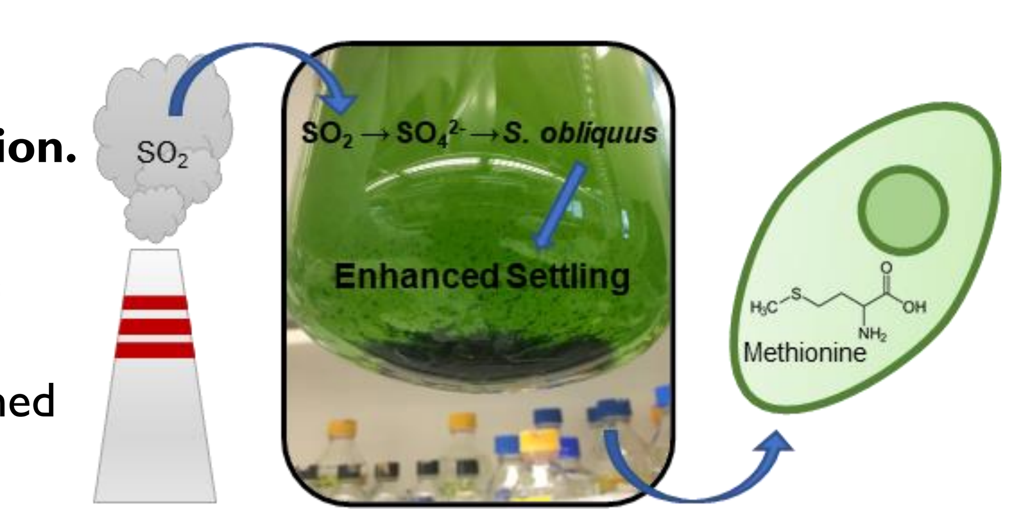
Figure 2. Modeled biomass productivity of *S. obliquus* grown with 12% CO_2 and Ultra-Zero air (control) and simulated coal-fired power plant emissions. Error bars represent standard error (n=3).

Conclusions & Next Steps

Simulated emissions increased biomass productivity, dramatically increased bulk settleability, and altered microalgal composition.

S. obliquus cells were coagulated, likely by EPS, and settled rapidly in flocs rather than slowly as discrete cells.

Microalgae grown with simulated emissions maintained their methionine content, had decreased protein content, and had greater percent mass of sulfur.



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Photos

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