Nutrient recycling potential of algal biomass grown in eutrophic water

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Introduction

Two of the most pressing issues in today's environment are clean water and climate change. According to the EPA, water nutrient pollution is one of the most costly problems facing America [1]. Nutrient can have a far-reaching effect on water quality, health, and the economy. Excess nitrogen and phosphorus in water promotes algal blooms, which lead to a reduction in the amount of oxygen in water and can be toxic [2]. Algal blooms are already frequent and are predicted to increase due to climate change [3, 4]. To address these environmental concerns, as well as the concern over energy security, alternative fuels have been suggested as substitutes for fossil fuels.

Algal biomass represents a feedstock for biofuel production. Algae can produce 30–100 times more energy per hectare compared to other terrestrial crops [5]. Algae, like most biomass, is composed of lipids and carbohydrates that have the ability to be converted into biofuels.

Previously, ATS ™ grown algae have been successfully used for the removal of nitrogen and phosphorus from water contaminated with animal manure [6]. ATS ™- Algal Turf Scrubber technology, is used to grow attached, filamentous algal species that capture the energy of sunlight, excess nutrients, and CO_2 to build algal biomass, as a "turf". This research focuses on characterizing algal biomass in order to evaluate product potential and to reuse the nutrients incorporated into the biomass.

The goals of this study are:

•To determine the overall nutrient composition of the algae grown in eutrophic water. This information is need to estimate the lipid, carbohydrate and protein value of the biomass. The nitrogen and phosphorus content is need to evaluate the value of the biomass as a fertilizer.

•Determine the carbohydrate composition in the algal biomass. This information is needed to evaluate the bio-ethanol potential from algae grown for nutrient removal.

• Evaluate the heavy metal composition of the biomass.

•This knowledge is required in order to establish how the biomass can best be used and applied.

Methods

<u>Algal production:</u> Algal biomass was grown using the ATS ™ system. Eutrophic water from Goldsworth Pond, Kalamazoo, MI was pumped over the growing algal biomass. The biomass was harvested every few weeks.

<u>Heavy Metals:</u> Algal biomass was digested using concentrated sodium hydroxide at 400°C for 30 minutes then diluted using 18.2 MΩ water. Lead, arsenic, chromium, copper, cobalt, cadmium and molybdenum were determined using ICP-OES.

<u>Organic Carbon, Inorganic Carbon, Nitrogen, Hydrogen</u> were evaluated using a CHN analyzer (LECO). Inorganic carbon was determined by measuring the difference between the carbon in the dried and ashed biomass.

<u>Phosphorus</u> was determined by digesting algal samples in a sodium hypobromite solution and the orthophosphate product was extracted with H_2SO_4. Phosphorus content was analyzed by the molybdenum blue colorimetric method.

<u>Monosaccharides</u> were extracted by digesting dried algal biomass in 5% H_2SO_4 for 90 min and then autoclaving the samples at 120°C for 30 minutes. The saccharides were reduced, acetylated and measured by GC/MS.

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Results and Discussion

Carbon, Hydrogen, Nitrogen

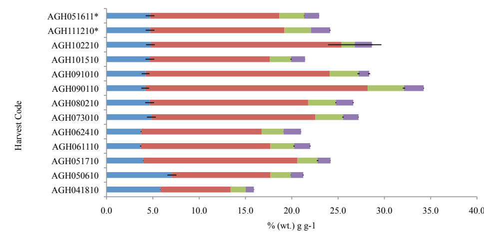

Figure 1. Percent (■) organic carbon, (■) inorganic carbon, (■) hydrogen and (■) nitrogen in dry algal biomass. AGHMMDDYY stands for the month, day and year of the harvest. Error bars represent sample standard deviation. The asterisk represents samples where inorganic carbon was estimated and not directly calculated.

The total nutrient content in the Goldsworth Pond algae ranges from 16% to 31% dry weigh. The organic carbon content is lower during the late fall 2010 months. The decrease in organic carbon is likely due to cooler water temperatures and decreased levels of sunlight.

Statistical analysis indicates that nitrogen and hydrogen are positively correlated with organic carbon content ($p=0.029$ and $p < 0.000$). Nitrogen is also positively correlated with hydrogen content ($p=0.001$).

Other data not shown here indicate that the remaining portion of the biomass is mostly made-up of silica and oxygen.

Total Phosphorus

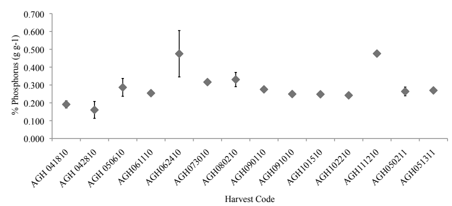

Figure 2. Percent Phosphorus in algae harvest. Error bars represent the sample standard deviation.

The level of phosphorus, P, in algal biomass harvests was expected to be elevated because of surrounding urban runoff. The measured total phosphorus in the Goldsworth Pond flow-way water ranged from 35.1 to 182 ug L^{-1}. P content in the algae remained stable over the harvesting period with an average of 0.290 ± 0.073 % P in dry biomass. Phosphorus concentrations remained stable for harvests, even when the nitrogen and carbon levels fluctuate. Peak P concentrations did not coincide with any particular month.

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Monosaccharides

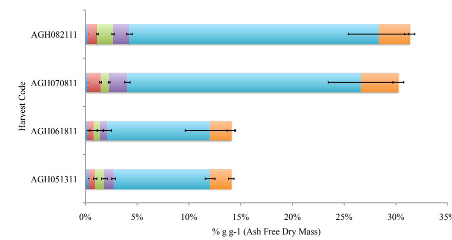

Figure 4. Monosaccharide profile in algae biomass.. (■)Ribose (■)Arabinose (■) Xylose (■) Mannose (■) Glucose and (■) Galactose. Numbers are based on ash free dry biomass. Error bars represent the sample standard deviation of triplicates.

The algal biomass contains ribose, arabinose, xylose, mannose, glucose and galactose. The total carbohydrate content in the ash free dry biomass ranges from 14.09% to 31.33% . Glucose is the most abundant saccharide present in all samples tested followed by galactose. Ribose is the least abundant. These sugars have the capability to be fermented to produce bio-ethanol.

The carbon in the monosaccharides account for 1.5% to 4% of the the total quantity of carbon in the dried algal biomass.

Heavy Metals

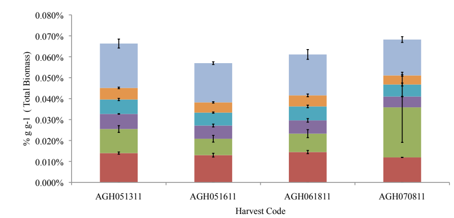

Figure 3. Percent of (■) lead, (■) chromium, (■) copper, (■) molybdenum, (■) cobalt, (■) cadmium, and (■) arsenic in algae harvests. Error bars represent the standard deviation of triplicate samples.

The quantity of arsenic in AGH051311, AGH051511, AGH061811 and AGH070811 was 0.0212, 0.0187, 0.0195 and 0.0171%, respectively. These levels are above the EPA ceiling concentration limit for arsenic. The concentration of metals in the algae follow the trend of As > Cr≈ Cu > Mo ≈Co > Cd.

Conclusions

•Nutrient levels in the algal biomass remain high even during the cooler months, such as in the fall.

•The inorganic carbon content in the biomass remains fairly stable in each sample.

•The arsenic content in the biomass is relatively high.

• The carbohydrate profile of the algae shows that the algae is composed of both 5 and 6 carbon sugars, with glucose being the most plentiful. Research suggests algae harvested from nutrient removal systems can produce in excess of 1.33 L/ m^2 /year of ethanol, which represents a increase compared to the 0.27 L/ m^2 /year produced from corn grain [7].