Determining the Temporal and Spatial Variability of Biomass Productivity in a Pilot-scale Algal Resource Recovery Unit Treating Agricultural Wastewater

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Abstract
Idaho dairy cows produce an estimated 3 million tons of dry manure annually; each ton contains 4.5 kg of nitrogen (N) and 0.82 kg of phosphorus (P). Excess application of manure as crop fertilizer can contaminate aquifers and surface water due to leaching of N and P. We constructed three replicate Algal Resource Recovery Units (ARRU) at the University of Idaho dairy facility, in ID to test their utility to manage nutrients and produce algal biomass as a secondary commodity. Each ARRU was inoculated with a mixture of algal cultures consisting of Chlorella vulgaris, Scenedesmus obliquus, and Synechococcus leopoldii, as well as a consortium of algae species obtained from the Boise River and received one of 3 treatments: A) lagoon wastewater, B) a mixture of 90% PHAE and 10% anaerobic digestate effluent (ADE); or C) 100% effluent from a polyhydroxyalkanoate reactor effluent (PHAE). Daily Nitrogen and Phosphorous removal were 83.6, 82.1, and 83.7% and 86.2%, 78.7%, and 68.7% P removal for treatments A, B, and C, respectively. Biomass productivity was 11.8, 19.5, and 17.6 g/m²/day for each 5 day composite treatment and 6.3, 12.9, and 11.6 g/m²/day for each 6 day composite treatment. Algal growth and nutrient removal rates are being evaluated for nutrient management and as a potential feedstock for use in the production of biofuel.

Objectives
• Design and continuously operate a pilot scale-ARRU for up to 6 months that is treating effluent from 1) Dairy Lagoon water, 2) a mixture of PHAE and ADE effluent, and 3) PHAE reactor effluent (Effluent process shown in Figure 1).
• Determine feasibility of large scale nutrient removal from dairy waste using an ARRU.
• Analyze phosphorus and nitrogen removal over time and across various different wastewater streams.
• Measure temporal stability in algal productivity within each treatment.
• Analyze spatial variability of algal biomass production within each replicate ARRU and across treatments.

Methods
Construction:
• Three ARRUs (one for each treatment) were constructed at the University of Idaho dairy utilizing a white 500 micron nylon mesh substrate with a 10.7 m² harvestable area.
• Each ARRU was inoculated with a mixture of algal cultures consisting of Chlorella vulgaris, Scenedesmus obliquus, and Synechococcus leopoldii, as well as a consortium of algae species obtained from the Boise River.
• Each ARRU received a treatment of lagoon wastewater, 10% ADE 90% PHAE, or 100% PHAE. Temperature, pH, and photosynthetically active radiation (PAR) values are being monitored throughout each ARRU.

Sampling:
• Each ARRU was allowed to grow for either 5 or 6 days at a time. 5 and 6 day composite samples were taken from each ARRU using random samples from 50% of警卫algal cultures.
• Biomass was collected using a shop-vac apparatus that accumulated biomass separately for each treatment into a container for temporal biomass productivity measurements.
• Spatial biomass productivity measurements were sampled in the same manner with the exception that each sampling segment was stored individually.
• Samples obtained using the shop-vac apparatus were sub sampled and preserved for carb, protein, and lipid content analysis as well as cell counts and AFDW measurements.

Nutrient Analysis:
• Total dissolved N, and dissolved NO3, soluble reactive P, and total P were measured using standard colorimetric assays as per Hach method 10020, 8048, and 8190.

Algal Biomass Productivity Measurements:
• Algal biomass was measured by estimating Ash Free Dry Weight (AFDW) using standard methods. Briefly, each sample was weighed, dried at 54°C for 24 hours, the total dry weight determined, and then combusted at 500°C for 30 minutes to determine ash content of the biomass. AFDW = total dry weight – ash content.
• Biomass productivity for each ARRU raceway was determined by calculating the net AFDW produced per m² per day.

Results

Nutrient Removal:
• Average total phosphorous removal across treatments was 86.2, 78.7, and 68.7% for the 5 and 6 day composite lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively and 6.3, 12.9, and 11.6 g/m²/day for the 6 day composite lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively.

Biomass Productivity:
• Spatial variability in 10% ADE 90% PHAE treatments respectively and 6.3, 12.9, and 11.6 g/m²/day for the 6 day composite lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively. Variation in biomass productivity between treatments may be due to a number of factors including but not limited to nutrient content, light attenuation, and competition from other microorganisms for resources.

Discussion

Temporal Biomass Productivity:
• Average algal biomass productivity was 11.8, 19.5, and 17.6 g/m²/day for the 5 day composite lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively and 6.3, 12.9, and 11.6 g/m²/day for the 6 day composite lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively.

Total Phosphorous Removal:
• Average total phosphorous removal across treatments was 86.2, 78.7, and 68.7 percent for the lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively.

Nitrification Removal:
• Average ammonia removal across treatments was 95.5, 93.3, and 87.34 percent for the lagoon wastewater, 10% ADE 90% PHAE mixture, and 100% PHAE treatments respectively.

On-going work is determining NO3, and Total N removal rates.

Algal Biomass Quality:
• On-going work is determining algal biomass quality (i.e. carbfraction/lipid content) to evaluate the use of algal biomass as an economic commodity in the form of bio-crude or caffeine feed.

References
1APHA, AWWA and WEF (2012) Standard methods for the examination of water and wastewater, AWWA.

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