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Exobiology

OMEGA Farm Project

The world is currently facing shortage of vital resources in part due to climate change and in the future it will only get worse. Humans are now looking for solutions and finding ways to more efficiently use what they currently consider wastes as they are among the most promising resources. This idea is particularly relevant to farmers who can use their animal wastes as a resource more effectively than simply converting it to biogas and fertilizer.

The OMEGA Farm Project uses ponds on farms to create a link between animal manure and energy, feed/food, and clean water to improve overall efficiency and economics of animal farming. It works by dispersing manure from pigs, cows, or chickens in water to make a nutrient-rich liquid and a carbon-rich sludge. The liquid is clarified by electrocoagulation (EC) and used to cultivate fast-growing microalgae in photobioreactors (PBRs) floating in a nearby pond. The sludge is used for biogas and CO2 production in anaerobic digesters (AD) on land or in a pond. The biogas produced in the AD is used for heat, electricity, and CO2 that contribute to algae growth. The algae biomass is feed for livestock or for caged fish grown in the pond. The algae and fish wastewater is processed by filtration and reverse osmosis to provide water for the livestock, while the retentate from the water purification is cycled back to the PBRs or the AD. Water-cooled solar panels and wind turbines provide additional energy for heat and electricity.

Experiments and calculations undertaken during the internship support the feasibility of the OMEGA Farm concept. Nutrients (NH3/NO3/PO4) in the extracted liquid were measured and the amount of CO2 from the AD plus combustion of biogas were calculated. Results suggest the OMEGA Farm Project will help close loops between waste, food, water, and energy.

National Aeronautics and Space Administration

The OMEGA Farm Project

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Abstract

The world is already facing shortage of vital resources in part due to climate change and in the future it will only get worse. People are now looking for solutions and finding ways to more efficiently use what we currently consider wastes as they are among the most promising resources. This idea is particularly relevant to farmers who already use manure from their livestock as fertilizer and for making biogas—we think they can do more.

The OMEGA (Operational Marinas for Economic Growth and Abundance) Farm Project proposes to use ponds on farms to create a link between animal manure and energy, feed/food, and clean water to improve the overall efficiency and economics of animal farming. (see Fig. 1) It works by dispersing manure from pigs, cows, or chickens in water to make a nutrient-rich liquid and a carbon-rich sludge. The liquid is clarified by electrocoagulation (EC) to ensure transmissivity to sunlight and used to cultivate fast-growing microalgae in photobioreactors (PBRs) floating in a nearby pond. The sludge is used for biogas and CO_2 production in anaerobic digesters (AD) on land or in the pond. The biogas produced in the AD is used for heat, electricity, and CO_2 that contribute to algae growth. The algae biomass is feed for the livestock on the farm or for caged fish grown in the pond. The algae and fish wastewater is processed by filtration and reverse osmosis to provide water for the livestock, while the retentate from the water purification is cycled back to the PBRs or to the AD. Water-cooled solar panels and wind turbines provide additional energy as heat and electricity.

Our experiments and calculations done during the internship support the feasibility of the OMEGA Farm concept. We measured nutrients (NH_3/PO_4) in the extracted liquid and calculated the amount of CO_2 produced in the AD plus combustion of biogas. Our results suggest the OMEGA Farm Project wil help close loops between waste, food, water, and energy, which should improve the overall economics of animal farms.

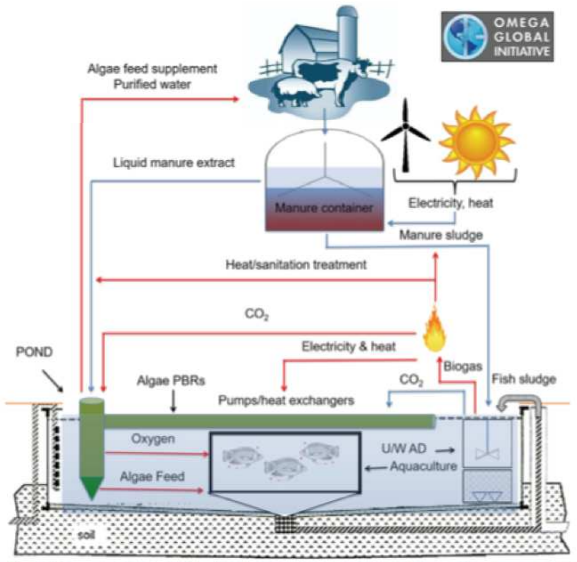

Fig. 1: Resource flow in the farm/pond system from manure to biogas, algae biomass, feed, aquaculture and recycled purified water (Trent, 2017).

Methods

To determine if this system's approach to using manure on farms would be feasible, outputs were calculated based on published data for the production and composition of animal manure (see Table 1) and laboratory measurements. Two critical steps in using manure are 1) Nutrient extraction and 2) Color removal.

Animal	Cattle	Pig
Manure per day, kg	50.00	5.50
% of dry matter (DM)	15%	8%
% of water	85%	92%
% of volatile solids (VS) in DM	72%	75%
% of total N in DM	2.10%	0.57%
% of total C in DM	35.6%	4.5%
% of total P in DM	0.41%	0.14%
% of VS to biogas	20%	
% of CH4 in biogas	65%	55%
% of CO2 in biogas	35%	45%
CO2 to algae ratio	1.87:1	
Algae production, g/(m^{2}day)	15.00	

Table 1: Calculated cattle & pig outputs.

Nutrient Extraction
Fresh cow manure was mixed with water in a column with a screw cap and central mesh tube (Fig. 2). The column was loosely packed with 250g manure and 500ml of water. The capped column allowed the water/manure mixture to equilibrate for 30 min or 15 hrs. At the end of this equilibration, the extract was removed, de-colored, and sampled for ammonia measured using Hach kits.

Water Color Removal
Water samples were analyzed for pH and then transferred to the electrocoagulation column (EC) (see Fig. 3). The column, with two aluminum electrodes, exposed the flow through (FT) sample to up to 1 amp and 28 volts for 10 to 15 mins—power used was 13 to 26 watts. Cleared samples were tested for pH.

Nutrient Analysis
Ammonia was measured in 0.1 ml samples using a Hach DR-3800 instrument (Fig. 4).

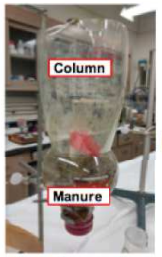

Fig. 2: Manure column with void filter.

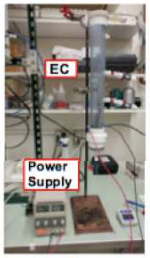

Fig. 3: EC column with power supply.

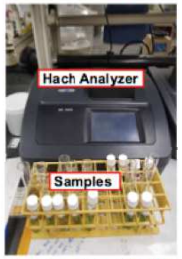

Fig. 4: Hach DR-3800 ammonia analyzer.

Results

Fig. 5: Comparison of manure extract pre EC (left) vs. post EC.

Animal	Cow	Pig
Manure weight, kg	1.00	1.00
DM, kg	0.15	0.08
Water, kg	0.85	0.92
VS, kg	0.11	0.06
Total N in DM, g	3.15	0.46
Total C in DM, g	53.40	3.60
Total P in DM, g	0.62	0.11
Total biogas, g	21.60	12.00
Total CH_4, g	14.04	6.60
Total CO_2, g	46.17	23.55
Total algae from CO_2, g	24.69	12.59
Surface for algae, m^2	1.65	0.84
Algae per animal, g	1234.49	69.26

Table 2: Calculated cattle and pig products.

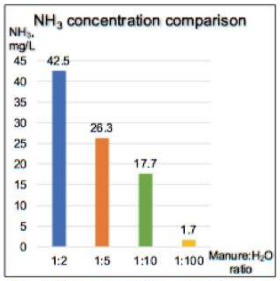

Fig. 6: NH_3 concentration comparisons of blended mixtures.

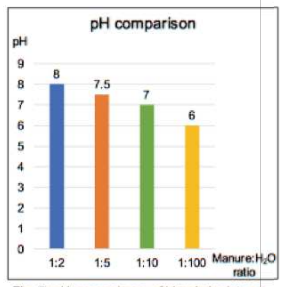

Fig. 7: pH comparisons of blended mixtures.

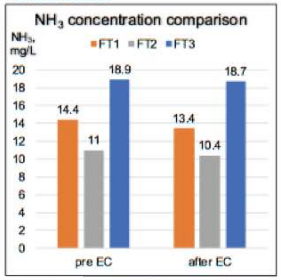

Fig. 8: NH_3 concentration comparisons of filtered mixtures; pre & post EC.

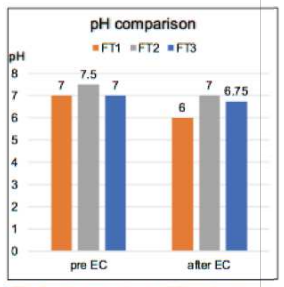

Fig. 9: pH comparisons of filtered mixtures; pre & post EC.

Conclusions

- Blended mixtures had significantly higher ammonia levels than extracted samples;
- Extracts had sufficient concentrations of nutrients for algal growth;
- pH was in acceptable range (7-9) for optimal growth of most species of algae;
- Color in manure extracts could be cleared by EC only for column samples, not for blended mixtures and EC did not impact ammonia or pH;
- It was found that longer extraction times resulted in greater ammonia concentrations;
- The next step is to determine the optimal extraction method and then construct an integrated setup to test the efficiency of the system;

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Acknowledgements

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