High-Rate Anaerobic Digester Design for Chobani's Wastewater

Problem Statement

The Greek yogurt industry has boomed in the past decade, taking over 36% of the $6.5 billion yogurt market in the United States [1]. The market leader is New York's Chobani, which holds over 50% of the shares in U.S. Greek yogurt [2]. The increasing popularity will increase production as well as waste from the yogurt industry. Acid whey is a yogurt by-product of particular concern due to its detrimental effects on surface water and potential for groundwater pollution. Greek yogurt production is especially challenging because it is more thoroughly strained and thus yields more acid whey than traditional American yogurt.

Every day, the Chobani production facility in New Berlin, NY, must discard 0.27 million gallons of acid whey and 0.73 million gallons of process waste from cleaning and sanitizing the production equipment [3]. The process waste can be discarded in Chobani's on-site wastewater treatment facility (WWTF), but acid whey is too acidic to be degraded in the WWTF. The acid whey has very high biological oxygen demand (BOD) and chemical oxygen demand (COD) levels, which can divert oxygen from marine and aquatic life and cause eutrophication if released into the environment without treatment [4]. The U.S. Environmental Protection Agency (EPA) requires a National Pollutant Discharge Elimination Systems (NPDES) Permit, which mandates that BOD is reduced to a level of less than 10,000 ppm, before any waste stream can be discarded into surface waters [5].

Chobani currently pays farmers to accept whey waste, where it is used as feed, land additive, or as a substrate in manure digesters [3]. However, its use as feed and fertilizer is limited due to its acidity and can only offset a relatively small portion of farm animal feed and soil fertilization needs. Soil erosion, ground water contamination, and negative effects on the quality, viability and yield of certain crops have been observed in agricultural lands where acid whey has been over-applied [4]. Finding a way to appropriately deal with increasing waste volumes without polluting New York State lands and waterways will require an innovative new approach.

Project Summary

Safe disposal of whey wastewater has been the focus of numerous studies. It has been shown that anaerobic digestion is an efficient, economical, and sustainable technology for pre-treating whey wastewater before it enters a traditional WWTF [6]. An anaerobic digestion system uses a diverse microbial community to degrade organic wastes, producing biogas composed of carbon dioxide and methane [7]. The most direct benefit of treatment with an anaerobic digestion system is the production of biogas that can be used to offset heating and power costs at the plant site. Because of their diverse microbial communities, anaerobic digesters are very flexible with regard to the types of wastes they can receive. Some types of anaerobic digesters, such as the Anaerobic Floatation Reactor (AFR) that we recommend for this facility, can efficiently remove high levels of COD and fats, which is typical of Greek yogurt wastes [8].

We have chosen a set of four one-million gallon AFRs to handle the company's one million gallons of combined wastewater a day. Each AFR has a flotation unit that continuously recirculates sludge in the reactor, yielding a high throughput reactor that can degrade both the acid whey and process waste generated by Chobani's production facility. The digested effluent will be sufficiently degraded to flow into Chobani's WWTF, thereby allowing for the onsite disposal of all of the plant's wastewater. In the process, the digester will produce biogas to offset the 4100 gallons of No.2 fuel oil burned daily in the production facility's boilers.

In summary, we chose to design an anaerobic digestion system to treat Chobani's waste stream because it is a safe and efficient means to treat their large volumes of waste that is high in COD and fats. It has the potential to significantly reduce both hazardous water pollutants and the Chobani factory's greenhouse gas emissions. This system is particularly innovative because it transforms primary waste products into a profitable resource for the facility.

Relationship to Sustainability

Implementation of an anaerobic digestion system at Chobani would have many benefits for the local environment. Transporting acid whey waste off-site in diesel powered tanker trucks is harmful to the atmosphere, dangerous for local wildlife, and disruptive to the surrounding communities [9]. On average, 39 trucks carrying 7,000 gallons of acid whey leave the site daily destined for farms up to 200 miles away. There it is used as a feed additive, soil amendment, or substrate for co-digestion with other farm waste [3]. An anaerobic digestion system would effectively eliminate the carbon emissions and noise pollution from these 39 waste disposal trucks.

Additionally, the digestion of acid whey and process wastes in the AFR could theoretically produce enough biogas (70% methane) to replace 4,100 gallons of fuel oil No.2 currently burned in the plants boilers annually. Therefore, the anaerobic digester not only reduces potentially hazardous water pollutants, but it also reduces the Chobani factory's greenhouse gas emissions significantly. There are environmental health and safety concerns regarding the piping of methane from the reactor to the boilers, but we accounted for purchasing appropriate piping, safety equipment, and gas scrubbers in the budget to ensure that Chobani's employees are safe and that potent greenhouse gas is not leaked into the atmosphere [10].

One potential trade-off we explored was that digesting and treating acid whey on-site will increase water flow to the Unadilla River. Water impact assessments and water footprints are not usually employed in life cycle assessments (LCA) in New York State because there is a plentiful freshwater supply, but we wanted to check if there were trade-offs associated with flooding or river bank erosion [11]. We contacted the Susquehanna River Basin Commission storm water project, which is responsible for ensuring all the rivers and waterways in the basin will be able to tolerate large scale storm events, and were assured that the Unadilla River can easily accommodate the proposed increased volume of treated water discharged into the river [12].

Lastly, when popular international market leading brands, such as Chobani, make such large strides towards being greener and more sustainable enterprises, it puts both public and industry pressure on other similar operations to follow suit. Thus, by incorporating an on-site AFR to treat its waste, Chobani will be indirectly promoting large-scale corporate agribusiness sustainability, as well as local and regional sustainability.

Materials and Methods

We visited the New Berlin Chobani plant, toured their wastewater treatment facility, and met with representatives on October 28, 2013. Since process waste has a fat content of about 70%, we chose a system of AFR reactors for their ability to handle the high fat process wastes. Our design included a schematic, sizing, LCA, and recommendations of feasibility. While we considered putting the biogas through a Combined Heat and Power (CHP) system, we found that boilers would be more economically feasible for Chobani, and mitigate more CO_2. We presented our design to peers and stakeholders on Dec. 11, 2013. Based on feedback, we re-assessed the design in March, 2014. Economic and utility rates were nearly the same as the December 2013 values originally used. The poster was finalized and printed on April 15, 2014. We will present the scientific poster at the competition on April 22, 2014.

Each member contributed 25%. Team member 4 was in charge of reactor and system design. The final schematic included the AFR reactors and boilers system with appropriate safety features. Team member 3 was in charge of the economic analysis, including calculating the NPV and payback period of the system. This method included all of the economic costs and benefits of the system. Team members 1 and 2 were in charge of the Life Cycle Analysis and environmental sustainability of the system.

With the anaerobic digestion system, both process waste and acid whey will enter the existing equalization tank in Chobani's WWTF (Figure 1). In this tank, lipids can aggregate and float and acidity can be neutralized. From the equalization tank, this waste stream will be pumped into the AFR system. Four 1.07 million gallon AFRs will be able to treat all of the acid whey and the process wastes. The treated effluent from the AFRs will enter the aerobic WWTF where it can be further clarified before discharging into the river.

Biogas will have to be stored and treated before it can be used as fuel in turbines or boilers. A low-pressure gas balloon will be used to store the gas because of their relatively low up-front cost, flexibility, and widespread use in industry [10]. Biogas is a valuable fuel because it is 70% methane, which is the primary energy source in the gas. Although valuable, this methane is lighter than air, highly flammable, and a very potent greenhouse gas [10]. Therefore, a flare after the gas scrubber will allow for the safe release of biogas if the boilers have no demand for it (Figure 1). The flare burns off the methane so that carbon dioxide, which is a less potent greenhouse gas, enters the atmosphere instead. A flame trap will be installed prior to the flare and the turbines or boilers, so they do not ignite the gas lines.

Biogas can also contain up to 1% hydrogen sulfide (H_2S), which is very corrosive to piping and engine components [13]. It is also very toxic and perceptible in only low concentrations. H_2S is heavier than air, so special care must be taken that it does accumulate in recesses. A desulphurization system can remove H_2S so that the biogas can be safely run in the turbines or boilers. A fine mesh filter can further refine the gas after the scrubber. Independent gas meters and pressure gauges allow the operator to assess the amount and composition of the gas flowing to each system component. Figure 1 details the flow of water and gas through the anaerobic digestion system and highlights the important safety features. Overall, we estimate that this system and its installation will cost approximately $30 million.

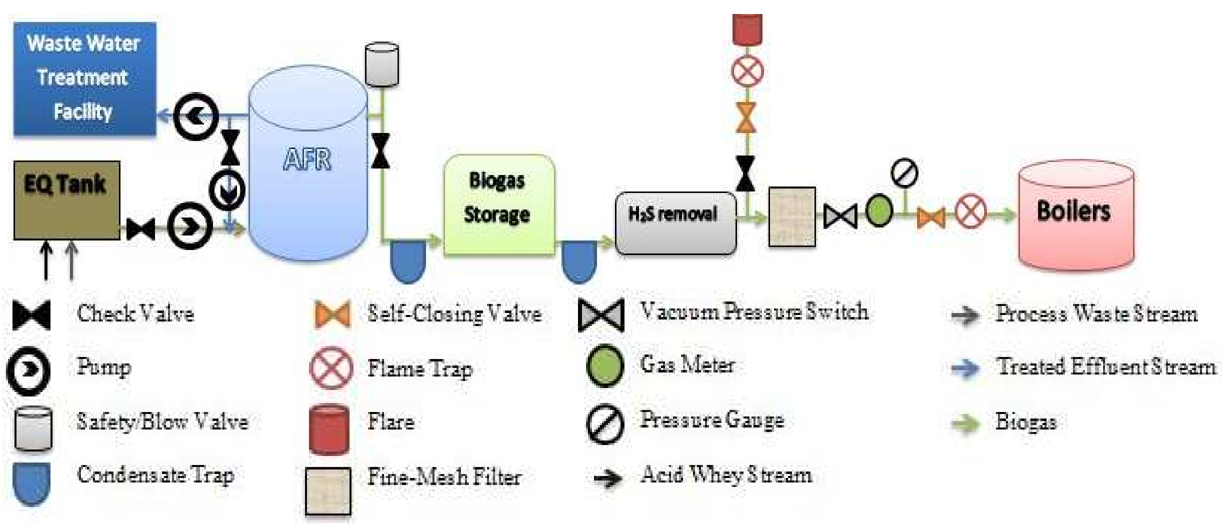

Figure 1: Anaerobic Digestion System diagram for Chobani including gas safety features.

Carbon dioxide (CO_2) from the exhaust is a marker used to assess the efficiency of an engine in fuel consumption. Thus, our life cycle analysis (LCA) used CO_2 emissions to evaluate the project's environmental effects [14]. In addition to offsetting transportation emissions, the methane (CH_4) gas produced by Organic Matter (OM) in the liquid whey is a usable energy source for the plant. Acid whey from milk is already part of the natural carbon cycle; therefore, any CO_2 released during anaerobic digestion does not increase carbon emissions.

Assuming an average of 8 miles per gallon, carbon emissions were calculated for trucking acid whey off-site. Based on the solids content of the whey and process wastes, the carbon in the wastes were converted to biogas using the standard AFR reactor efficiency. Using the efficiency of Chobani's boilers, we found the equivalent amount of No. 2 fuel oil this biogas could replace. We applied these calculations to shipping reactor sludge, animal feed, and on site anaerobic digesters.

Results, Evaluation and Demonstration

The construction and implementation of an on-site anaerobic digestion system would almost eliminate the need to truck whey off site. Eliminating these truck shipments will mitigate 22,000 lbs. CO_2 from burning diesel fuel a day, accounting for 7.9 million pounds of CO_2 each year.

If the biogas produced in the digester is used directly in Chobani's boilers, the biogas can replace 4,100 gallons of No.2 fuel oil per day, offsetting 33 million lbs. CO_2 annually. It should be noted that 20% of the whey produced by Chobani is currently digested at farms equipped with anaerobic digestion technology. It is conservatively assumed that on-farm digesters are as efficient as the high-rate system proposed for Chobani. This offsets 320,000 lbs. of CO_2 annually from their power needs. This must be subtracted from the total change in CO_2 offset by the planned digestion system at Chobani to account for current production.

In our analysis, the volume of sludge produced from acid whey is estimated to be 5.7 million gallons per year. This will take 815 trucks yearly to ship this waste. We assumed this whey will be trucked to the Madison County Landfill, 80 miles round trip from Chobani's New

Berlin production plant. We estimate this to contribute 180,000 lbs. CO_2 each year. One truck of corn feed comparable in size to those used by Chobani will need to drive 1200 miles from this plant every 34 days, equating to 36,000 lbs. of CO_2 released annually. A summary of the CO_2 emissions per day for the scenario where biogas is burned in the boilers is shown in Table 1.

Table 1: CO_2 Emission Summary- Boiler Scenario

CO_2 Mitigated Annually (lbs.)	
Whey Shipments	7.9 million
Boiler Heat	33 million
CO_2 Added Annually (lbs.)	
Farm Digester Power Prod.	320,000
Sludge trucking	180,000
Corn Grain Shipments	36,000
Net CO_2 Offset Annually (lbs.)	
40 million	

Table 1: CO_2 Emission Summary- Boiler Scenario. The CO_2 mitigated far exceeds the CO_2 added.

For our estimated project cost of $30 million, the program estimated the initial CO_2 released to be 28.8 million lbs. of CO_2. Based on the amount of CO_2 mitigated, the initial CO_2 release will be offset in just 9 months.

The system will save money on heating and electricity, and from trucking the acid whey and purchasing fuel oils; these savings will greatly improve the NPV and IRR of the system. Chobani currently spends $0.07 per gallon to ship whey from their plant to farms around New York State [3]. For the purpose of our economic analysis, we assumed an average distance driven of 200 miles round trip to reach dairy farms [15]. As of March 20th, 2014 natural gas costs were $3.47 per mmBtu, and No. 2 fuel oil was $3.65 per mmBtu [16].

As illustrated in Table 2, we estimated that the boiler system, including the AFR, sulfide scrubbers and other equipment to cost about $30 million. The capital costs were scaled based on values that Stoneyfield Farm, an organic yogurt company, used to install an anaerobic treatment system to generate electricity [17]. The AFR, related equipment, and supervision were estimated to be about $6.8 million [18]. Remaining capital costs include piping, permits, skilled labor, inspections, construction equipment, power, electrical installation and other costs. Cost for dissolved air treatment of fats (DAF) include power, labor, and maintenance and were estimated to be $2000 per million gallons treated [19]. We assumed that the life of the system is about 20 years [20]. Operational costs were assumed to be 3% of capital costs [21].

Table 2: Cost, Savings and Returns for Boiler Systems

Costs		
Capital Cost	$ 30 million	
Depreciation	$ 1.5 million	/year
Operational Costs	$ 0.9 million	/year
Savings		
Heating Avoided	$ 6.5 million	/year
Avoided Trucking Costs	$ 6.9 million	/year
Avoided DAF Costs	$ 0.5 million	/year
Returns		
Heat Produced	200,000	mmBtu/yr
NPV 5%	$ 112 million	
IRR	38%	
Simple Payback Period	2.17	years

Table 2: Cost, Savings and Returns for Boiler Systems. Total capital costs are estimated to be $30 million; the NPV at a 5% interest rate would be $112 million.

The NPV analysis was performed at an interest rate of 5%, and included capital costs, depreciation, operational costs, incentives, and savings in DAF, trucking, and heating costs, with specific values outlined in Table 2. The boiler system would be able to produce a maximum of 562 mmBtu per day, over 90% of Chobani's heating needs. The NPV at a 5% interest rate would be $112 million. At a 5% interest rate the project would have an IRR of 38% and a payback period of just over two years.

Conclusions

Building an anaerobic digestion system at Chobani's New Berlin production facility will make it possible to dispose of acid whey on-site. Adding their process waste to the digestion system will decrease the organic load on Chobani's existing wastewater treatment facility and will allow the digesters to produce more biogas for the plant. The AFR reactor has the ability to effectively treat the yogurt process waste. Compared to other reactors, the AFR has a high sludge retention time and low hydraulic retention time, allowing high volumes of wastewater to be effectively treated. This will allow the company to turn their waste into renewable biogas, offset their current power needs, and eliminate costs and emissions associated with the off-site shipment of acid whey. Collectively, the digestion will mitigate 40 million pounds of CO_2 annually.

This will only have a minor impact on farms, as whey is only marginally useful as a feed and land additive, and farm digesters already have manure as a source fuel. Likewise, the increased flow at Chobani's WWTF will not negatively harm the Unadilla River. Using boilers to burn biogas from anaerobic digestion offers the simplest use for this energy source and will save Chobani millions of dollars annually. In turn, the project will make Chobani's yogurt production a more environmentally responsible process.

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