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Anaerobic Digestion at Patterson Farms, Inc.: Case Study

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Anaerobic digestion overview

Digester type	Complete mixed
Digester designer	RCM Digesters, Inc.
Date Commissioned	2005
Influent	Raw manure, food waste (whey, milk processing waste)
Stall bedding material	Separated raw manure solids
Number of cows	950 lactating cows
Rumensin® usage	Yes; used on all dairy cows and all heifers
Dimensions (width, length, height)	100' x 110' x 19'
Cover material	Flexible; multi-laminate
Design temperature	100°F
Estimated total loading rate	45,000 gallons per day
Treatment volume	1.2×10^6 gallons
Estimated hydraulic retention time	22 days
Solid-liquid separator	Yes; separated raw manure solids used for bedding
Biogas utilization	Two engine-generator sets (180-kW and 225-kW)
Carbon credits sold/accumulated	Yes; initial stages of trading on Climate Action Registry
Monitoring results to date	Yes; Previously monitored with ASERTTI protocol

Farm overview

- Patterson Dairy Farms, Inc. (Auburn, NY) a family farm for the past seven generations, is owned and operated by Mrs. Connie Patterson with her son, Jon and his wife, Julie and Dairy Manager Bob Church
- The farm has about 950 dairy cattle
- The farm raises forage crops on 2,400 acres of land
- Patterson farms experienced their first major odor emission issues in 2000 after constructing a 4.5 million-gallon earthen manure storage, completed in 1999
- The farm's first attempt to reduce odor emissions from the long-term storage was to perform mechanical solid-liquid separation of barn effluents. The separated liquid was piped to the existing long-term storage while separated solids were stored under aerobic conditions in a three-sided shed. Separated manure solids were primarily used as bedding material in deep-bedded free-stalls (in order to displace otherwise purchased sawdust bedding), while any surplus solids were sold. The farm reported that this manure treatment system reduced or eliminated odor emissions from the solids and seemed to reduce odor emissions from the long-term liquid storage; however, more odor control was desired from the long-term storage. Various manure treatment system technologies were investigated consuming significant time and effort. Considerable time was also spent identifying, investigating, and responding to multiple financial grant opportunities.
- After receiving grant funds from several sources, digester construction started in August 2004 with commissioning in October of 2005. A flow diagram for the digester is shown on the following page in Figure 1.

<u>Why the digester?</u>

Well-designed and operated anaerobic digestion systems can reduce a farm's odor emissions, preserve nutrients in treated manure for use by field crops, and reduce the risk of run-off and leaching of nutrients when properly applied to land with a growing crop in accordance with the governing comprehensive nutrient management plan (CNMP). Combined heat and power generation can offset purchased heating fuels and electrical power. These were the major drivers for constructing the digester along with the desire to continue being a good neighbor. The farm selected a mixed digester over a plug flow digester due to the flexibility of the mixed digester to handle comparatively low solid concentration influent as well as food waste from outside sources. Food waste generators pay a tipping fee to the farm which can substantially improve the economics of on-farm anaerobic digestion.

Digester System

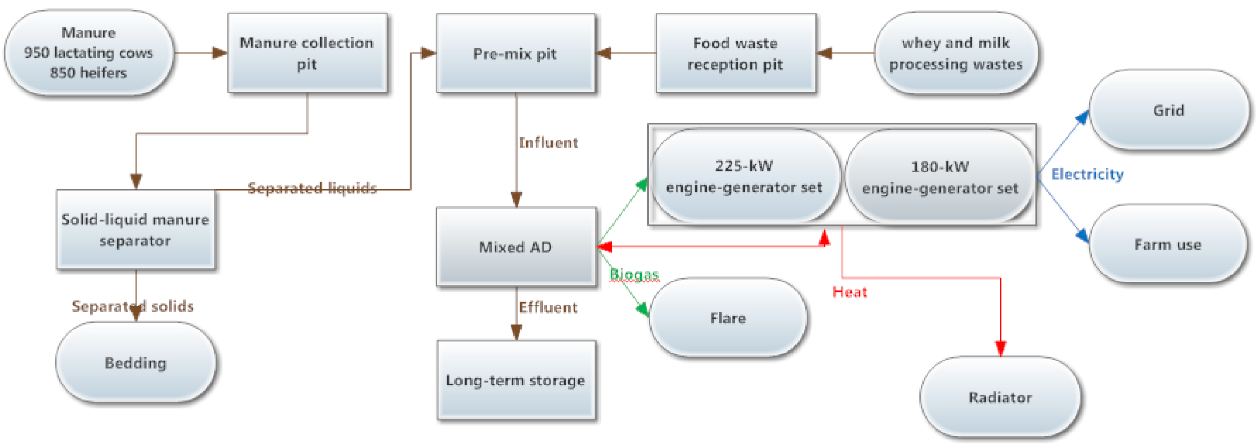

Figure 1. Patterson Farm AD system flow diagram

<u>System and process description</u>

A 1.2 million-gallon mixed digester with a design hydraulic retention time of approximately 20 days, based on manure from 1,000 dairy animals and up to 18,000 gallons of food waste per day, was designed by RCM Digesters, Inc. The concrete digester vessel and pre-digestion substrate holding tanks and support buildings were constructed by hired contractors. Over 3,000 hours of on-farm labor were required to assemble all the system components in 2005.

The digester processes 45,000 gallons per day of raw manure pre-mixed with 15,000 – 22,000 gallons per day of whey. Manure is supplied by approximately 950 lactating cows, 100 dry cows and 850 heifers. Whey is delivered to the farm from two different sources, the Kraft Foods cream cheese plant located in Lowville, NY and a yogurt manufacturing plant. The farm formerly accepted several other waste streams such as potato starch water, culled onions and corn syrup waste. The whey is received and stored in a designated food waste pit - an 18,000-gallon rectangular concrete pit. Cow and heifer barn manure alleys are cleaned with alley scrapers. Alley scrapers deposit collected manure in under-the-barn storages where it is subsequently pumped to a 75,000-gallon manure storage pit located adjacent to the digester. Contents of the food waste pit are added to the pre-mix/digester influent pit before the digester is fed.

From initial digester commissioning in October 2005 until May 2006 raw manure was pre-mixed with whey and was used for digester influent. In May 2006 the farm switched to separating raw manure and mixing solid-liquid separator effluent with whey as described above. This change was made in an effort to reclaim more separated solids from the screw-press separator for bedding and off-site sales. The Ridgeline Dairy Farm (Formerly Matlink Farm) (see case study AD-4) also experienced insufficient recovery of separated manure solids to meet the bedding demand due to the high rate of solid consumption by the digester. A commonality between both farms is the importation of food waste for co-digestion. The farm then returned to separating only the digester effluent for several more years, but in 2011 reverted back to separating raw manure and including separated liquids to the digester.

Digester feeding and mixing is performed automatically up to 21 times daily by a Pro-Logic controller. A 20-Hp J. Houle & Fils agitator and Vaughn chopper pump are located in the pre-mix tank to mix influent and to feed the digester, while five 17-Hp Bauer submersible MSX mixers provide in-vessel mixing.

Biogas is contained by a flexible, multi-laminate flat top as shown in Figure 1. Insulation is sandwiched between the impermeable inner and outer layers. Electric blowers are used to transfer biogas from the digester to the biogas utilization building where it is used to fire a 180-kW Caterpillar G379 engine-generator set and as of August 2009, a 225-kW Guascor engine-generator set. The original 4-in. power flare was upgraded to a 12-in. gravity flow flare so excess biogas could be combusted even when there is no electrical power.

Figure 1. Patterson Farms' anaerobic digester with flexible top cover

Liquids and solids process description

Mechanical liquid-solid separation is achieved by using a DODA® screw-press separator. Material flow was changed in 2011 so the separator processed raw manure before pre-mixing with the food waste (please refer to page 4 for specific dates). Raw manure is now pumped from the cow and heifer barns to a below-grade storage pit, from this storage pit it is transferred to the solid-liquid separator, then separated liquids are transferred back to a pre-mix tank where they are mixed with the food waste. Separated solids are used for freestall bedding and the excess is sold. The pre-mix pit feeds the digester, and the digested effluent is transferred to the long-term storage lagoon.

Heat and electricity generation

Biogas produced by the digester is first sent through a biologically activated hydrogen sulfide (H_2S) scrubber; the farm observes that the system brings the H_2S level from approximately 2,600 ppm to 100 ppm, when it is functioning at optimal levels. Biogas is then utilized in a CAT G379 engine to drive a 180-kW generator procured from Martin Machinery and a second 225-kW Guascor eng-gen set. Generated power is used on-farm and excess is sold to the grid under the provisions of the New York State net metering law (see Fact Sheet No. NM-1). Excess biogas is automatically routed to and burned by a flare. If the H_2S levels remain low (around 100 ppm), engine oil changes are performed after every 750 hours of operation, however, if the scrubber is not removing sufficient quantities of H_2S, then oil is changed every 300-400 hours. Specialized oil is required to reduce damage to the engine from the corrosive hydrogen sulfide component of biogas.

Data was collected by the Dairy Environmental Systems group at Cornell University, through monitoring efforts following the AD monitoring protocol prepared by the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). The following data and performance values were obtained through this project for the time period of March 2008 to March 2009. Biomass was converted to biogas at a rate of 13 ft^3 biogas per 1 lb of TVS. On average, the digester produced 171,585 ft^3 biogas per day that had a methane content of 60.6% and a thermal value of 502 Btu/ft^3. Of this amount, the original 180-kW engine-generator set used on average 107,187 ft^3/day of biogas to generate 4,284 kWh of energy or 25 ft^3/kWh. Heat recovered from the engine averaged 7 mmBtu/day for the same time period. Reclaimed engine heat is primarily utilized to maintain target digester temperature of 100°F and excess heat is dispersed to the atmosphere with a heat dump radiator. If economics prove to be favorable, the farm plans to use excess heat in the milking center.

Economics

The itemized capital costs for the anaerobic digestion system and equipment are shown in Table 1. Digester miscellaneous cost items include: miscellaneous construction supplies and materials, RCM Digester, Inc. employee travel, and shipping charges for equipment and materials.

Table 1. Initial capital costs for Patterson Farms

	Cost ($)
Digester	
- Site Work	62,723
- Engineering design	99,532
- Concrete digester (Including pumps, cover, concrete, and heating pipes)	495,930
- Misc.	31,893
- Family labor	68,553
Subtotal	***758,631***
Energy conversion	
- Initial engine-generator set	200,000
- Electrical wiring and control systems and plumbing	317,476
- Biogas utilization building	51,601
Subtotal	***569,077***
Solid-liquid separation	
- Building	127,775
- Separator	53,147
Subtotal	***180,922***
TOTAL	***1,508,630***

The farm received funding from the New York State Energy and Development Authority (NYSRDA), the Cayuga County Soil and Water District (CCSWD), and the United States Department of Agriculture (USDA) totaling $1,268,122. This represents 88 percent of the initial capital costs.

The farm currently sells the excess power generated back to the utility grid; in 2010, the farm received $0.03 per kWh for off-peak sales and $0.04 per kWh for peak sales. The farm previously sold carbon credits to the Chicago Climate Exchange (CCX), but after the CCX closed, they made plans to verify and trade credits according to the provisions of the Climate Action Registry (CAR). Under the CCX, from the period 2006 – 2007, the credits were valued at approximately $8,000.

Benefits and Considerations

Benefits	Considerations
• Odor control • Potential revenue from: 1) Value-added products 2) Reduction of purchased energy 3) Sale of excess energy 4) Food waste tipping fees 5) Efficient use of biogas production 6) Carbon credit sales • Nutrient conversion, allowing use by plants as a natural fertilizer, if effluent is spread at an appropriate time • Pathogen reduction	• Possible high initial capital and/or high operating costs • Long and tedious contracts with the local utility; may require special equipment for interconnection • Dedicated management of the digestion system is required • Careful attention to equipment maintenance and safety issues due to the characteristics of raw biogas • Increased land base may be required to handle the imported food waste nutrients • Specialized permits may be required to import food waste

Lessons Learned

The farm reported that the following lessons were learned as a result of operating their anaerobic digester.

(2006) A project with comparatively high capital costs requires a dedicated person to research the funding opportunities, construction specifics, and permitting requirements prior to starting construction.

(2006) Utilizing farm labor to construct the digester was a cost savings method which required the farm to be intricately involved in bringing together the several components of the systems in order to build the digester. This involvement should be valuable in the long run for maintenance and troubleshooting future problems with the systems.

(2006) Accepting food waste can substantially offset the cost to own and operate the digester. Tipping fee received is $0.06 per gallon for whey delivered to the site by the processor. A profit center approach to the manure treatment system justifies the management requirement for the digester operation. This income should also help to offset the estimated $700,000 in equipment maintenance and replacement.

(2006) Digesters are complex systems that require more time to design and build than many other components of a dairy (barns, parlors, and long-term storages). Design of the system required several months, and construction time lasted more than a year. Producers need to understand and plan for the time required before they start the process.

(2006) Subsequent to digester commissioning, it was determined that the food waste storage pits needed to be covered in order to minimize odor releases to the environment from the cheese whey.

(2009) The price paid for electricity sold back to the utility needs to be much higher in order to help make the digester system financially viable.

(2009) Proper sizing of the biogas handling and utilization systems is imperative. Raw biogas was released by the top cover due to seal imperfections and designed releases by the biogas pressure relief system. Biogas release events can result in odor emissions that can be more offensive than untreated manure stored long-term. This has presented an issue with on-farm odor that is now worse than prior to digester construction.

(2009) Currently there are no companies or entities that provide complete technical support and services for anaerobic digestion systems. There are several separate digester components designed by different companies that need to come together for successful digester operation and biogas utilization.

(2009) All digester system components need to be properly sized, constructed, installed, operated and maintained properly for the system to run smoothly.

(2009) Anaerobic digestion, biogas and their associated safety requirements are new items at the production farm level that take time and investigation to fully understand.

(2012) Operating the biologically-activated hydrogen sulfide scrubber is very time consuming and lots of work.

(2012) Older model motors are much more user-friendly than newer clean burning turbo-charged motors.

(2012) The type of food waste used in co-digestion makes a significant difference in gas quality and quantity.

(2012) Re-building an engine-generator set is expensive; it is nearly the same as the operation and maintenance cost per kW.

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