California Department of Food and Agriculture
Alternative Manure Management Program
Demonstration Project - Final Report

Project Title: Demonstration of an Advanced Manure Management System for Reducing Greenhouse Gas Emissions and Producing Valuable Products	
Grant Recipient: University of California, Davis	**Grant PI**: Ruihong Zhang
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Submitted By: Ruihong Zhang	**Email**: rhzhang@ucdavis.edu	**Date Submitted**: 12/31/2024

Grant Award Amount (A)	Amount Invoiced to Date (B)	Remaining Grant Balance (A-B)	Match/In-Kind/Other Funds Utilized to Date
$999,994.00	$999,994.00	$0.00	N/A

Demonstration Project Type

☐ Advancing Practices Farmer-to-Farmer (APFF)

☒ New Technologies and Practices (NTP)

Project Location (*address or geographic coordinates of actual project implementation site(s)*):

California Dairy Farms, 6071 Larson Ave, Hilmar, CA 95324

Alternative Manure Management Practice(s) Demonstrated:

Advanced solid-liquid separation with centrifuge, year-round composting, and production of pelletized manure compost.

Estimated Greenhouse Gas Reductions over 5 years:

- The original estimation of GHG reduction for this project using the California Air Resources Board Benefits Calculator Tool for the AMMP was 12,615 $MTCO_2e$ over 5 years. However, this only accounted for the reduction resulting from the centrifuge system added by the project (did not include the primary mechanical solid separators already in use by the dairy).
- Based on the life cycle analysis results of this study, total estimated reduction of greenhouse gas emission for the system, including all solids separation, composting, and pelletization over 5 years is 31,785 $MTCO_2e$.

Acknowledgements:

We would like to acknowledge the contributions made by the original project grantee and farm owner, Aaron Wickstrom (Wickstrom Dairies L.P.). Aaron saw the project through the centrifuge addition and pellet mill design and construction. With a significant rise in the cost of building materials, material and installation costs exceeded the original budget. Aaron helped design the pellet mill building to curb costs and contributed extra money to see the project through to completion. We would also like to thank the subsequent owners, Larry Matos and John Melo (California Dairy Farms) for continuing to support and open access to the dairy for the duration of the project. Work on the dairy would not have been possible without the help of the farm personnel. Specifically, we would like to thank farm managers, Jesus Rojas and Brett Barlass, who facilitated logistics. We would also like to thank and acknowledge the work of JPT Composting & Spreading, Inc. and owner John Faria who was consulted throughout the project.

PROJECT SUMMARY

Project Purpose

The goal of this demonstration project was to mechanically separate solids from manure to reduce its GHG emissions potential, extend the production of composting to be year-round, and facilitate the export of nutrients off the dairy by pelletizing compost produced from manure solids. This project serves one dairy (California Dairy Farms that was formerly called Wickstrom Dairies, L.P). We hypothesized that separation of solids from flushed manure, using a rotary separator followed by a centrifuge, and producing stabilized and pelletized compost product could substantially reduce the GHG emissions from the lagoon. The specific objectives were to:

- Demonstrate a manure centrifugation system on California Dairy Farms (previously known as Wickstrom Dairy) and evaluate its technical and economic performance,
- Develop and characterize pelletized composted manure products from the solids separated from the system,
- Develop an economic and life cycle model for the production of pelletized manure compost products, and
- Conduct outreach activities and disseminate project results to stakeholders and the public.

Project Approach

A centrifuge was added to an existing two-stage rotary separation system to remove fine solids from flushed manure and a full-scale pelletizing system was installed to produce pelletized manure compost. A visual diagram of the existing system on the dairy and the project elements can be found in the Project Pictures section of the report. The pelletizing system included a feeding and handling auger conveyer, a hammer mill, a conditioning system, and pelletization mill. A building to house the pelletizing system was also designed and constructed. The efficiency of the rotary separation system and centrifuge for the removal of solids from manure was evaluated by measuring the amount of inflow and outflow of manure and separated solids, and sampling and analyzing different streams for total solids. Different streams were also characterized for volatile solids. The solids separated from the rotary separator and centrifuge were characterized for nutrients and used to produce compost in different seasons. The produced compost was used to determine the proper moisture content for pelletization of manure compost. The compost was also used to evaluate the performance of the full-scale pelletization system. Biochemical Methane Potential (BMP) of the inlet and outlet of the rotary separation system and centrifuge was determined in batch reactors. Based on solid separation efficiency and results of the BMP, the potential methane reduction from the studied dairy was calculated. The cost of producing pelletized manure compost was estimated based on the capital and operational costs of the pellet mill. A partial life cycle analysis was conducted to determine the savings of greenhouse gas emission by integrating manure solids separation and pelletization of manure compost processes.

Project Outcomes

- Developed and demonstrated a state-of-the-art integrated manure management and pelletized soil amendment production system that would serve as a model for the California dairy industry.
- Reduced the emissions of greenhouse gas emissions from the mechanically separated manure solids and the manure storage lagoon
- Developed pelletized manure compost products that facilitate the export of excess nutrients to cropping lands farther away from the dairy and protects the soil and ground water on and around the dairy
- Evaluated the economics of the production and transportation of pelletized compost and dried manure products generated from the solids separated from flushed manure by the integrated processing system
- Developed a life cycle analysis of manure management and production of pelletized manure product
- Increased the dairy income by selling the pelletized products to crops (orchards and specialty crops)
- Improved ground water quality by conducting and composting on concrete pads that prevents the seepage of leachate from manure solids

Summary of findings:

The efficiency removal from each unit operation (the first and second stage of the rotary separator and centrifuge) was calculated as: (1) percentages of the total amount of solids that enters system (i.e., total solids enter the rotary separator); and (2) percentages of the amount of solids enters each unit operation. Based on the total solids content of flushed manure entering the rotary separator system, the removal efficiency of the first stage ranged from 5.8% to 8.7%, the second stage ranged from 9.6% to 14.6%. The removal efficiency of the centrifuge ranged from 2.1% to 5.7%. While, based on the solid's inlet to the centrifuge, the efficiency of the centrifuge ranged from 23% to 65%. Considering the settling tank, the removal efficiency of the rotary system ranged from 73.2% to 87%; and the removal efficiency of the integrated rotary separator and centrifuge ranged from 78.9% to 91.0%. Methane reduction potential for the integrated system ranged from 84.9% to 90.6%. The full-scale pellet mill can pelletize manure solids at a moisture content ranging from 20% to 30%. It was found that screening of manure solids to remove rocks and adjusting the moisture content to the right level was necessary for successful operation of the pellet mill. It is expected that operating the pelletization system at the rated capacity of one ton/hour, the cost of pellet production could range from $35 to $42 per wet ton when operating the system for 8 to 16 hours per day assuming 260 days of operation. The life cycle analysis showed that diverting solids from the lagoon and using the solids to produce pelletized compost product could achieve a total GHG emission saving of 31,785 tonne CO_{2e} per five years (i.e., 0.2 tonne CO_{2e}/tonne of total solids). More research is needed to optimize the performance of the full-scale pelletization system by studying the effect of different feeding rates and sizes of the holes of the pelletizing mill's die.

Lessons Learned and Future Expectations

- Sand removal from flush manure would be necessary to prevent the overheating of the centrifuge bearings.
- Screening machine to remove rocks and a mechanism to adjust moisture content of composted manure prior to pelletization would be needed in order to improve the efficiency of the pelletization system.
- There is a need to add a packaging machine to produce small packages of pelletized manure for nurseries and gardening applications.
- The augers for feeding the material to pellet mill were oversized. They were sized the R-150 pellet mill (150 HP); however, the actual pellet mill was the R-30 (30 HP). Modifications were made to the feeding equipment in order to operate the pellet mill.
- Manure management systems incorporating a centrifuge must have better upstream sand removal for, otherwise the quality of the solids will
- Pellet mill system designed for dairy manure should incorporate an upstream system for compost screening and conditioning as well as a better downstream drying system.

MATERIALS AND METHODS

Project Tasks

Task 1. Obtain project permits

An ATC permit was obtained from the Air Board for the construction of the building and Merced County Building Division for a building to house the pelletizing system.

Task 2. Construct a building for the pelletizer and a cement pad for the centrifuge

A 30' X 100' X 16' tall building was constructed to house the pelletizing system. A 12' X 12' X 1' thick cement tank pad was installed to support the centrifuge system. The building was designed by Ag Processing Solutions Inc. and constructed by CalCoast.

Task 3. Purchase, install, and test the centrifuge and pelletizing system

A centrifuge was purchased from Daritech. The centrifuge was installed and then tested in four seasons. A pelletization system that is composed of a feeding, auger conveying system, a hammer mill, a conditioning system, and pelletizing mill was purchased from Colorado Mill Equipment (CME) and tested on composted manure solids. An engineering consulting company, Ag Processing Solutions Inc., was used to provide engineering designs for every aspect of the pelletizing system. The tests of the centrifuge and pelletization system are described below. The photos of centrifuge and pelletization equipment are shown at the end of the report.

Task 4. Evaluate the performance of the centrifuge system

The research team tested the performance of the centrifuge. The samples of manure from the inlet and outlet of the first and second stage of the rotary drum separators were collected. Samples were also collected from the inlet and outlet of the centrifuge and settling tank. The collected samples were analyzed for total and volatile solids (TS and VS). The flow rate of manure that is fed to the first stage of the rotary drum separator was measured. The separated solids from the rotary drum separators and centrifuge, during the sampling times, were weighed.

Total and volatile solids, pH, and nutrient analyses

Collected samples were analyzed for total (TS) and volatile (VS) solids, and pH. The TS and VS were measured according to standard methods (APHA, 1998). pH of every fourth or fifth sample was measured by using an Orion™ pH meter. Nutrient analysis on composite samples was performed by Denele Analytical Labs (Woodland and Turlock, CA).

Determination of solids removal efficiency and methane potential reduction

The on-dairy measurements and the laboratory data were used to determine the TS and VS removal efficiencies, and methane potential reduction. The removal efficiency of TS and VS from the separator and centrifuge and methane potential reduction from the storage lagoon, were determined as follows:

$$TS_{removal} = \frac{TS_{Solids}}{TS_{In}} \times 100\%$$

$TS_{removal}$ = total solids removal efficiency in %;
TS_{Solids} = mass of the weighed total solids in dry tons;
TS_{In} = mass of total solids entering the inlet of the first step separator during the sampling period, in dry tons.

$$TS_{In} = \emptyset_{m\ In} \times TSc_{In}$$

$\emptyset_{m\ In}$ = mass flow of flush manure in wet tons;
TSc_{In} = Average inlet total solids concentration in %.

$$TS_{Out} = TS_{In} - TS_{Solids}$$

TS_{Out} = mass of total solids exiting the separator outlet during the sampling period, in dry tons.

$$VS_{removal} = \frac{VS_{Solids}}{VS_{In}} \times 100\%$$

$VS_{removal}$ = volatile solids removal efficiency in %;
VS_{Solids} = mass of the weighed volatile solids in dry tons;
VS_{In} = mass of volatile solids entering the separator or centrifuge inlet during the sampling period, in dry tons.

$$VS_{In} = \emptyset_{m\ In} \times VSc_{In}$$

VScIn = Average inlet volatile solids concentration in %.

$VS_{Out} = VS_{In} - VS_{Solids}$
VSOut = mass of volatile solids in the effluent of the separator or centrifuge, in dry tons.

In addition to calculating the removal efficiency of TS and VS, for each unit process (i.e., first stage of the separator, second stage, and centrifuge) based on the total amount of solids and volatile solids entering the first step, it was also calculated based on the influent of each unit process.

The efficiency of the solid separation of the entire system (i.e., mechanical separator and centrifuge) was calculated, as percentage of the total solids at the inlet of the system, as follows:

$$\text{TS removal} = \text{TS removal}_{first\ stage} + \text{TS removal}_{second\ stage} + \text{TS removal}_{centrifuge} + \text{TS removal}_{settling\ tank}$$

Biochemical Methane Potential (BMP) Tests and Methane Reduction Potential

Biochemical Methane Potential (BMP) was measured on the manure samples collected from the centrifuge and separator stages. Batch anaerobic reactors with an effective volume of 400 ml were incubated at 50°C. Other parameters of BMP are shown in Table 1. The amount of biogas produced from each reactor was determined using the ideal gas law after measuring the increase in the pressure in reactors headspace. The composition of the gas in the headspace was measured periodically using gas chromatography equipped with a thermal conductivity detector.

Table 1. Parameters of BMP Tests.

Parameter	**Value**	**Units**
Organic Loading	5	g [VS]/L
Food/Microorganisms	1/1	ratio
Temperature	50.0	°C
Initial pH	8.0	pH units
Effective volume	400	mL
Run time	40	days

Methane reduction potential is defined as the difference in the biomethane potential in the inlet and outlet divided by the biomethane potential in the inlet. The total methane potential reduction by the system (%) was calculated as follows:

$$\text{Total methane reduction potential (\%)} = \frac{\left[(TS_{In}.BMP_{TS-in} - \left(1 - \left(\frac{\text{TS removal}}{100}\right)\right) TS_{In}\,.BMP_{Ts-Centrifuge\ outlet}\right]}{TS_{In}.BMP_{TS-in}}(100)$$

$BMP_{TS\text{-}in}$ = biomethane potential of the inlet of the first stage of the separation system m^3/ton of total solids.

$BMP_{TS\text{-}centrifuge\ outlet}$ = biomethane potential of the centrifuge outlet m^3/ton of total solids.

Task 5. Evaluate the dairy manure composting process employed at California Dairy Farms (previously known as Wickstrom Dairies L.P.)

Two composting rounds were carried out. In the first round of composting, piles were setup on 5/7/2021: 1 pile of fine manure solids from the second stage of the separator and 1 pile of fine manure solids combined with centrifuge solids at a ratio of about 60:40, which was roughly estimated to be the rate of production of the two solid streams. Active composting continued for 6 weeks. Compost piles were turned once weekly. On 6/17/2021 the temperature sensors used to measure pile temperatures were pulled and the farmer continued to turn the piles several times a week to dry it down in preparation for pelletization testing. Photos of composting as well as a diagram identifying temperature sensor locations can be found in the project site pictures section of this report. The second round started in August 2021.

Windrows were constructed with initial dimensions of approximately 100-120 feet long, 4 feet high, and 10 feet wide with between 80,000-100,000 lbs of starting material on a wet basis. Active composting was monitored for a minimum of 6-11 weeks. During this time, compost temperature, bulk density, moisture content, and windrow dimensions were monitored on a weekly basis. Following active composting, compost was assembled in static piles and covered for protection from the rain for a 2-4 month curing period prior to pelletization and application.

Figure 1 shows the dimensions of an example windrow and locations of temperature sensors. The sensors were installed in major sections of each windrows' length to measure the internal temperature continuously throughout the experiments. The placement of these probes was determined by dividing the length of each windrow into four sections and inserting a probe (four in total) at the midpoint of each section (intersection of red and green lines), halfway down into the material's depth. One temperature probe was also installed immediately above each windrow for ambient temperature measurement. Weekly measurements were taken of windrow length (1x), width (2x), height (3-4x), angle of repose (3-4x), and bulk density (3x) at the time of compost turning. A weekly composite sample of the compost was also collected for laboratory analysis after windrows were turned. This data was used to estimate the mass of the windrows and monitor changes over time. The mass of material in the windrows were also measured at the beginning and end of the composting period. Data collected during the composting experiment include temperature, bulk density, height, length width, and angle of repose of composting piles. Compost samples were collected to analyze for solids and moisture content.

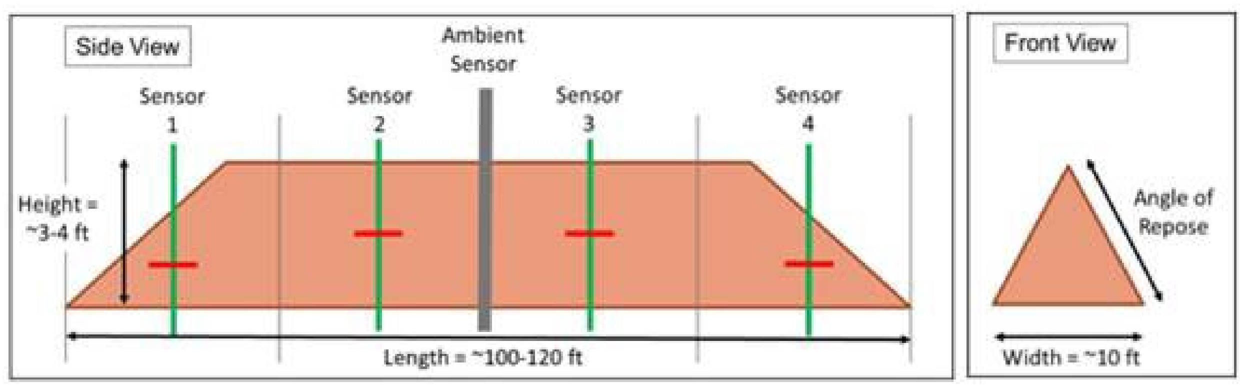


Figure 1. Dimensions of a compost pile and locations of temperature sensors.

Measuring Compost Bulk Density

Bulk density was measured by filling a 5-gallon bucket with compost, weighing, and determining the mass of the compost in the bucket, and calculating bulk density based on the known volume of the bucket. A method commonly used industry to measure the bulk density of compost is to fill a 5-gallon bucket a third of the way full, tapping the bucket down by dropping it consecutively from 1 foot height 10 times, filling the bucket to two thirds of the way full, tapping it down again 10 times from the height of 1 foot, then filling the bucket to the top, tapping it down as before, and finally filling the bucket completely before weighing. This method resulted in a windrow mass estimate within 5% of the total mass whereas the initial bulk density measurement underestimated windrow mass by about 20%. During the second round of composting, the more accurate bulk density measurement method was used.

Task 6. Produce and characterize pelletized dairy manure compost products

Small Scale Pellet Mill Moisture Test

We used our 5 HP flat die lab scale test mill (Buskirk) to study the effect of moisture content of pelletization. Compost from the dairy was adjusted to 25%, 30%, and 35% moisture and processed through the mill (photos below). The pellets have not been characterized for durability. What was measured in the experiment was the moisture content of the input material, the final moisture content of the pellets, and the ratio of fines to pellets from the pelletization at each moisture. The 35% moisture material had a lower pellet yield (produced more fines), whereas the 25% and 30% material had a roughly similar fine to pellet yield. Due to concerns about 25% being too dry and plugging the pellet mill, it was decided that 30% would be the optimal moisture to run through the full-scale mill.

First Full-Scale Pellet Mill Test

A full-scale pellet mill test was conducted using the conditioned compost. A small batch was loaded into the hopper. However, this test failed. Material was not being pelletized. The auger and hammer mill seemed to be getting clogged again. It was concluded that the material was too wet and was sticking to the auger and hammer mill screens. It was decided to spread out and dry the material further down to 20-25% and to test again.

Upon the conclusion of this test, the team also reached out to the Pellet Mill manufacturer, Colorado Mill Equipment (CME) for advice. The team reached the conclusion that further training was needed on the Pellet Mill operation. Thus, a trip was planned to CME's headquarters in Canon City, Colorado.

Continued Full-Scale Pellet Mill Testing

Upon returning from Colorado, Hossein Edalati and other team members purchased tools and materials to perform maintenance and inspection of the system. The system was inspected prior to using it for more tests. All bearings and motors were greased and lubricated in preparation for the test. The compost was split into two batches, a "wetter" (approximately 20-25% moisture content) and a "drier" (approximately 15-20% moisture content) batch. After some troubleshooting over the phone with CME, the first batch was run to completion. Data on the system's energy consumption was collected. The team learned that the auger was still running at too high a speed, even after reducing the speed using a larger pulley wheel and supplying the pellet mill with too much material. This was expected as the auger is a 10" auger and the R-30 pellet mill observed in Colorado functioned with a 4" auger. To address this issue, the team operated augers intermittently to limit the supply of material to the pellet mill. Furthermore, the feeder speed was dropped to the lowest setting. Finally, after consultation with CME, it was determined that the team should add moisture back to the compost right before it enters the die by supplying water at the conditioner, which has a port for this purpose. With all these adjustments, the first batch was successfully pelletized. Pellets were produced at a rate of 830 lb per hour.

The drier batch was not successfully pelletized to completion. Every time the mill was run it would overload the mill within minutes. Consequently, the team had to open the pellet mill feed cone, remove excess material, and unplug the die, which was an arduous process. It was not clear if the issue was moisture, a higher fixed solids content in this second batch due to there being more sand, or the adjustment on the pellet mill rollers. This batch was partially pelletized and continuation of pelletization was abandoned.

Task 7. Conduct an economic analysis of manure compost pellets

An excel sheet model was developed for evaluating the economics of pellets production. The parameters used for economic analysis are shown in Table 2. The capital cost of a system with a throughput of 1.0 ton/ hour was obtained from a vendor. The annualized costs included the capital, installation, building and manual maintenance costs. The production costs were estimated based on 260 working days per year and one to three shifts per days. The model was used to estimate the production cost of producing pelletized manure compost under one and two shifts. Two scenarios were carried out. The first scenario was based on the rated capacity of the system (1 ton per hour) and the second scenario was 0.42 ton per hour, which is capacity of the system with the unrated feeding system.

Table 2. Parameters used in the cost analysis.

Parameter	Value
Total Capital costs	$239,365
Interest rate	8%
Annualized capital cost	$27,965 /year
Number of working days	260 day/year
Cost of electricity	$0.102/kWh
Pellet mill throughput	1.0 ton/hour

Task 8. Conduct life cycle analysis of the integrated alternative manure management system

Life cycle analysis

A life cycle analysis (LCA) was performed to quantify the lifetime greenhouse gas (GHG) emissions of the baseline manure management practice on California Dairy Farms (previously known as Wickstrom Dairies L.P.) as well as the GHG emissions after implementation of a centrifuge and pelletizing system. A life cycle inventory (LCI), the most important aspect of any LCA, was created based on available information in the literature and the on-farm collected data; assessment across one impact category, global warming potential (GWP), was completed based on the LCI.

Goal, Scope, and Functional Unit

The goal of the LCA was to quantify the baseline and expected project GHG (CO_2, CH_4, and N_2O) emissions from manure management at California Dairy Farms (previously known as Wickstrom Dairies L.P.). The scope of the baseline analysis included animal housing, manure flushing and existing separation system, the solids removed from the existing system, the manure stored in the lagoons, the transportation of solids to surrounding farms, and the incorporation of compost products to the fields (Figure 2). The scope of the analysis after project implementation is identical except it also includes the proposed inclusion of a centrifuge separator prior to the lagoon storage, and pelletizing operation to densify the compost. Notable exclusions from the system boundary are the removal and transportation of solids from the lagoon and the incorporation of these solids into agricultural soils because these operations require further investigation, especially after project implementation. The functional unit of the LCA was the treatment of 1 metric ton of dry manure solids.

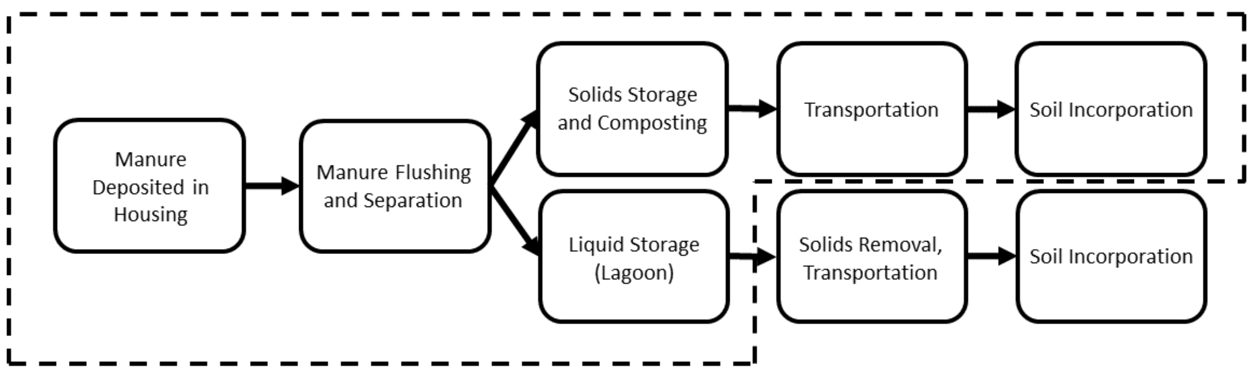


Figure 2. System boundary of the LCA for manure management on California Dairy Farms (previously known as Wickstrom Dairies L.P.) as a model for California Dairies.

LCA Methodology

Life Cycle Inventory

The life cycle inventory included the specific operations, manure production amounts, and characteristics that have been observed on California Dairy Farms (previously known as Wickstrom Dairies L.P.). A summary of the LCI and related assumptions are shown in Table 3.

Table 3. Life cycle inventory and associated assumptions.

Inventory description and assumptions	Value	Source
Number of lactating cows	2,620	Dairy
Energy use of flush and existing separator (kWh/d)	1,911	California Dairy Farms (previously known as Wickstrom Dairies L.P.)
Energy use of centrifuge and pelletizer (kWh/d)	2,352	Estimated
Rotary screen separator volatile solids (VS) removal efficiency (%)	74.6	Our on-site samples in this study and our unpublished data from a previous study on the separation systems
Centrifuge separator VS removal efficiency (%)	45.13	This study
Manure flow to separator inlet (gal/d)	1,000,000	California Dairy Farms (previously known as Wickstrom Dairies L.P.)
Rotary separator inlet total solids (TS, % w.b.)	2.04	Our on-site samples in this study and our unpublished data from a previous study on the separation systems
Rotary separator inlet VS (% w.b.)	1.36	
Separator efficiency for TS (%)	21.9	
Separator efficiency for VS (%)	18.5	
Area of manure floor covering in the five barns (m^2)	13,192	
Ambient temperature (°C)	27	
N content in manure solids (% d.b.)	1.42	
Methane production potential of separated solids (m^3 CH_4/kg VS)	0.159	
Methane production potential of liquid post-rotary separator (m^3 CH_4/kg VS)	0.26	
Compost moisture content (% w.b.)	39.4	Estimate
Compost density (kg/m^3)	321	Estimate
Compost pellet moisture content (% w.b.)	20	Estimate based on our unpublished data
Compost pellet density (kg/m^3)	642	Estimate based on our unpublished data
Diesel use on-farm (baseline) (gal/yr)	4,800	California Dairy Farms (previously known as Wickstrom Dairies L.P.)
Diesel use on-farm (project) (gal/yr)	6,000	Estimate
Transportation distance of compost products (km)	10	Estimate
Area of compost application to orchards (acre)	1,000	Estimate
CO_2 sequestration from compost application (tonne CO_{2e}/yr)	4,489	Comet Planner

*The estimated values are based on the expected values after project implementation

Animal Housing

The methane emissions associated with the deposition of manure in the animal housing was estimated using the methodology of Rotz et al. (2004):

$E_{CH4floor}$ = max (0.0, 0.13T)*A_{barn}/1000
where $E_{CH4floor}$ is the daily rate of CH_4 emissions from the barn floor (kg CH_4/day), T is the ambient barn temperature (°C), and A_{barn} is the area of the barn floor covered with manure (m^2).

Flush, Separation, and Pelletizing Systems

The total energy consumption of the flush, existing separation, proposed centrifuge separation, and pelletizing systems were estimated based on data gathered on the farm and quotes supplied from vendors. The emissions associated with the CA grid were used to estimate the GHG emissions associated with these operations (21 kg CO_{2e}/MWh).

Solid and Liquid Storage

The amount of solids produced from the baseline and proposed systems were estimated based on their estimated solids removal efficiencies that we were determined for the mechanical separation system at California Dairy Farms (previously known as Wickstrom Dairies L.P.). The methane production from the solids in solid storage (baseline) and in compost (project) was estimated based on the methodology and emission factors of IPCC (2014). The methane conversion factors (MCF) used were 0.8 for anaerobic lagoon, 0.05 for solid storage, and 0.015 for composting. The N_2O conversion factors used were 0 for lagoon, 0.005 for solid storage, and 0.01 kg N_2O-N/kg N for composting.

Transportation

Solids (compost and pellets) were assumed to be transported 10 km in dump trucks with fuel economies of 6.4 km/gal and capacities of 9.2 m^3. Emissions of CO_2 from diesel combustion on-farm and off were assumed as 10.4 kg CO_{2e}/gal.

Soil Incorporation

The Comet Planner tool available at the CDFA website was used to estimate the yearly GHG sequestration that is associated with the incorporation of compost with C:N ratio > 11 over 1,000 acres.

References

IPCC, 2014. Climate Change 2014, THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. https://doi.org/10.1073/pnas.1116437108

Rotz, C Alan, Coiner, C.U., 2004. The Integrated Farm System Model. Cornell Univ. Crop Sci. Res. Ser. R04-1

RESULTS and DISCUSSION

The average total and volatile solids of different manure streams collected during the evaluation of the separator and centrifuge systems are shown in Table 4. The average TS in the inlet of the first stage of the separator ranged from 1.81% to 2.36% wet basis (w.b.), while the outlet ranged from 1.51% to 2.41%. The inlet of the second stage ranged from 4.24% to 6.07%, while the outlet ranged from 2.93% to 9.84%. The inlet of the centrifuge ranged from 2.09% to 4.43% while the outlet ranged from 1.35% to 2.94%.

Table 4. Average Total (TS, % wet basis (% w.b.)) and Volatile solids (VS, % of TS)) contents of samples collected from different streams.

	February 2022		**June 2022**		**May 2023**	
Sample sources	**TS (%, w.b.)**	**VS (% TS)**	**TS (%, w.b.)**	**VS (% TS)**	**TS (%, w.b.)**	**VS (% TS)**
1st Stage (first rotary drum separator) Inlet	2.36 ± 0.14	71.62 ± 1.44	1.81 ± 0.23	64.75 ± 4.56	1.94 ±0.2	63.91 ± 1.25
1st Stage Outlet	2.40 ± 0.16	66.02 ± 3.42	1.51 ± 0.49	63.11 ± 2.02	2.00 ± 0.21	59.42 ± 2.35
2nd Stage (second rotary drum separator) Inlet	4.43 ± 0.73	74.56 ± 1.08	4.24 ± 1.23	65.30 ± 2.71	6.07 ± 0.86	56.23 ±4.42
2nd Stage Outlet	2.94 ± 0.22	54.45 ± 3.59	3.72 ± 0.83	38.76 ± 6.07	9.84 ± 4.47	19.71 ±13.57
Centrifuge inlet	2.17± 0.09	66.21 ± 1.34	2.09± 0.30	60.01± 3.26	2.58 ± 0.31	50.76 ± 3.81
Centrifuge outlet	1.61± 0.05	68.79± 0.38	1.35 ± 0.18	66.89 ± 0.89	1.57 ± 0.10	64.93 ± 3.61
Surge tank	2.26 ± 0.13	65.08 ± 0.62	2.45± 0.00	58.08± 0.00	---	---
Coarse solids	20.27 ± 0.12	87.58 ±0.33	23.21 ± 0.88	86.19 ± 1.28	21.01 ±0.73	87.81 ±1.97
Fine solids	23.28 ± 0.59	79.81 ± 0.45	23.92 ± 0.64	77.94 ± 0.21	22.51 ± 0.51	67.66 ±0.80
Centrifuged solids	30.51 ± 0.97	53.29 ±1.64	35.36 ± 0.24	47.38 ± 0.07	33.94 ± 1.41	34.37 ±1.30

The proximate analysis of centrifuged solids collected on April 6, 2021, is shown in Table 5.

Table 5. Proximate analysis of solids separated by the centrifuge solids.

Parameter	Unit	Result
Moisture Content	%	62.6
pH	pH units	6.7
Electrical Conductivity	mmhos/cm	4.24
Total Nitrogen	% db	1.22
Total Phosphorus	% db	0.270
Potassium	% db	0.710
Sodium	% db	0.230
Organic Matter	% db	87.0
C:N Ratio	N/A	41:1
Sulfur	% db	0.270
Calcium	% db	2.00
Magnesium	% db	0.530
Boron	mg/L	28.0
Zinc	mg/L	124
Iron	mg/L	4,090
Manganese	mg/L	141
Copper	mg/L	22.0
Soluble Salts	mg/L	2,710

Efficiency of solid removal from the separation system and centrifuge

The efficiency of solid separation was determined on one day in each of the four seasons. However, the data of the flow rate of the centrifuge during September 2022 was not available from the company records. Therefore, the efficiency of the other three seasons is reported in Table 6. Based on the inlet of the first stage, solid removal in the first stage ranged from 5.8% to 8.7%; in the second stage it ranged from 9.6% to 14.6%, while in the centrifuge it ranged from 2.1% to 5.7%. Solid removal efficiency for the entire system ranged from 78.9% to 91.0%. The solid removal efficiency was also determined for the second stage of the mechanical separator and the centrifuge based on their inlet. As can be seen, based on the total amount of solid in the inlet of the second stage of the separator, its efficiency ranged from 28.1% to 39.4%. While the efficiency of the centrifuge ranged from 23% to 65%.

Table 6. Efficiency of solid separation and methane reduction potential from the mechanical separator and centrifuge.

Stage	Feb, 2022	Jun, 2022	May, 2023
1st stage	5.9%*	8.7%	5.8%
Settling Tank	67.6%	49.9%	71.0%
2nd Stage	9.6%*	14.6%	10.2%
	(28.1%)**	(39.4%)	(38.8%)
Rotary separator system	83.1%*	73.2%	87.0%
Centrifuge	2.1%*	5.7%	4.0%
	(23.0%)**	(47.4%)	(65.0%)
Rotary separator system + Centrifuge (i.e., entire system)	85.2%*	78.9%	91.0%
Methane reduction potential for the entire system	84.93%	77.40%	90.59%

* Total Solid Removal efficiency values were calculated based on the inlet of the 1st stage, except those in parentheses

** Values in the parentheses represent removal efficiency calculated based on the inlet of the unit operation itself

Biochemical Methane Potential

Figures 3-6 show biomethane potential (BMP) for the inlets of the first and second stage of the mechanical separator, and the inlet and outlet of the centrifuge during the four sampling events. There was a lag phase of about one week before methane production was started. Table 7 shows BMP data for each stream during every sampling event. For the same sampling event, the outlet of the centrifuge had the highest methane yield followed by the inlet of the first stage of the separation. The inlet of the centrifuge has higher methane yield than that of the inlet of the second stage of the mechanical separator.

Table 7. Biomethane potential (mL/g[VS]) of inlets of the first and second stage of the mechanical separator, and the inlet and outlet of the centrifuge.

Stream	February 2022	June 2022	September 2022	May 2023
Inlet of the first stage of the separator	286.7 ± 49.9	272.8 ± 18.1	289.9 ± 29.4	303.0 ± 10.8
Inlet of the second stage of the separator	243.4 ± 13.0	234.4± 27.4	228.9 ± 16.9	251.5 ±22.5
Inlet of centrifuge	260.1 ± 21.8	260.7 ± 17.1	275.3 ± 8.9	296.1 ±10.0
Outlet of centrifuge	303.9 ± 3.8	282.9± 10.0	301.7 ± 3.6	311.8 ± 9.6

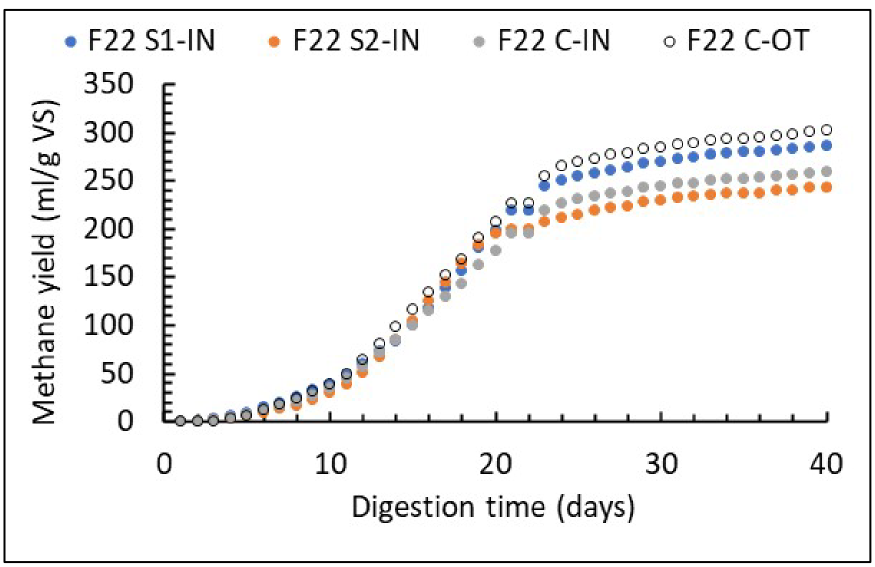


Figure 3. Methane yields of different streams during the sampling event that was carried out in February 2022.

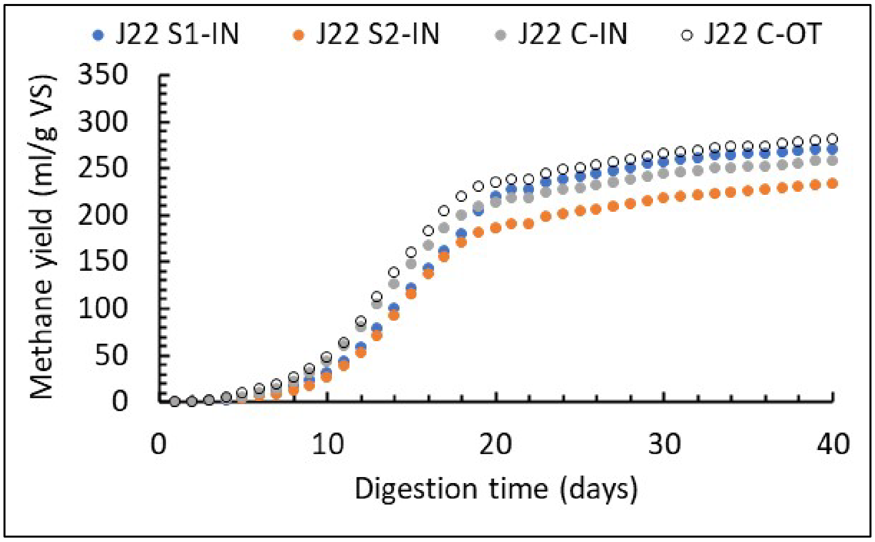


Figure 4. Methane yields of different streams during the sampling event that was carried out in June 2022.

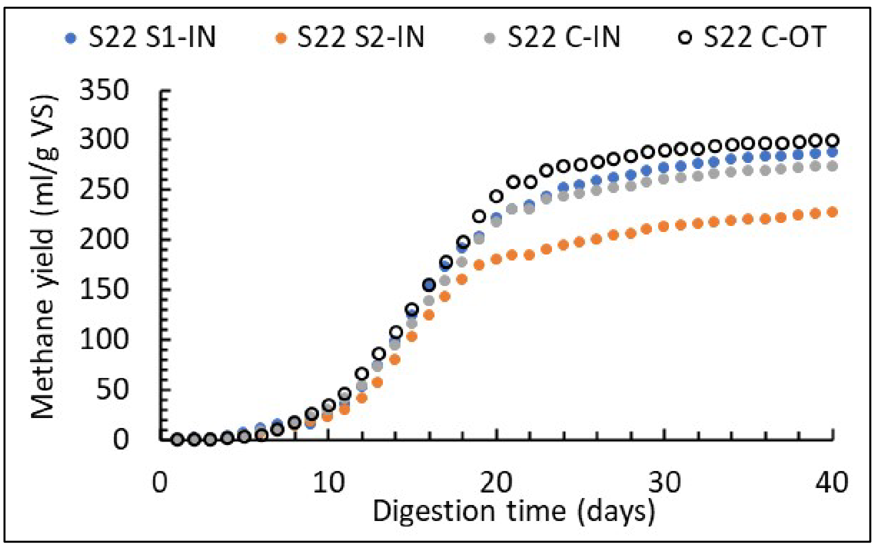


Figure 5. Methane yields of different streams during the sampling event that was carried out in September 2022.

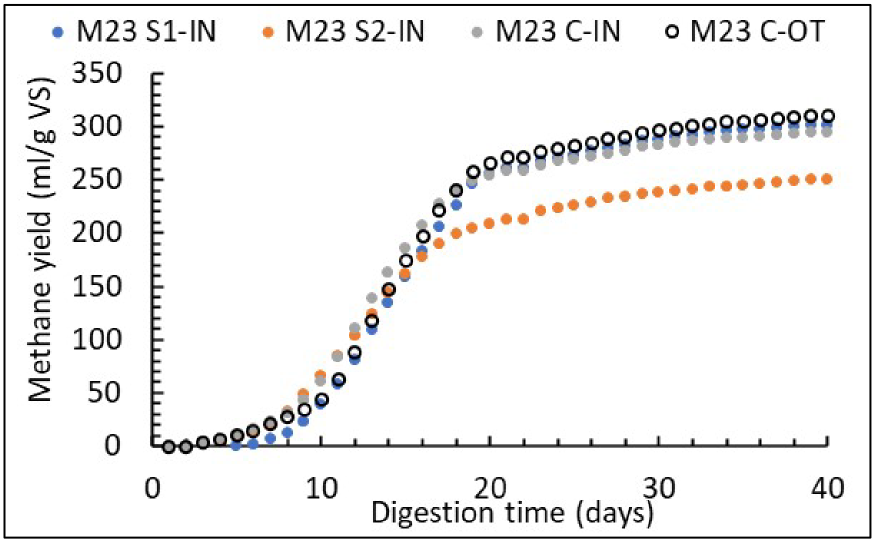


Figure 6. Methane yields of different streams during the sampling event that was carried out in May 2023.

Composting of manure

Figures 7 and 8 show temperature profiles at different locations of compost windrows that were carried out during the spring/summer of 2021. Locations -1 and -4 are the ends of the windrow. Locations -2 and -3 were in the middle of the windrows. Two windrows were setup: (1) Pile 1, fine and centrifuge solids mixed at a ratio of 60:40, and (2) Pile 2, fine manure solids only. Solids from the dairy's coarse separator (screen size 3.175 mm) were not used for composting. Fine solids were obtained from the dairy's fine rotary drum screen separators (screen size 0.533 mm). Centrifuge solids were obtained from the new centrifuge added to the dairy's separator system. The dairyman approximated that the fines were produced at about 3 or 4:1 compared to the centrifuge solids by volume. The project team determined the bulk density of the centrifuge solids (65 lb/cubic feet) to be about 1.5x that of the fine solids (45 lb/cubic feet), hence, the chosen ratio for the mix pile.

As can be seen from Figure 7 during the first week, a temperature of 60℃ could be measured in the first sensor location. The temperature reached about 74°C after the second week; directly before windrow turning. The temperature reached up to about 70°C in all sensor locations after the first two weeks. The temperature at the other sensor locations reached 70ºC after three weeks. Each week just before the windrows were turned, temperature sensors were removed, indicated by the sudden drop in temperature close to ambient before increasing rapidly in the range of 65-70ºC. Temperatures at locations 1 and 4 were reduced more quickly towards the end of the 41 days due to greater rates of heat transfer. Relatively similar temperature profiles were also measured in most of the sensor locations in the windrow of the manure fines only (Figure 8).

However, the temperature at the location of the first sensor reached about 78°C after the second week; directly before windrow turning.

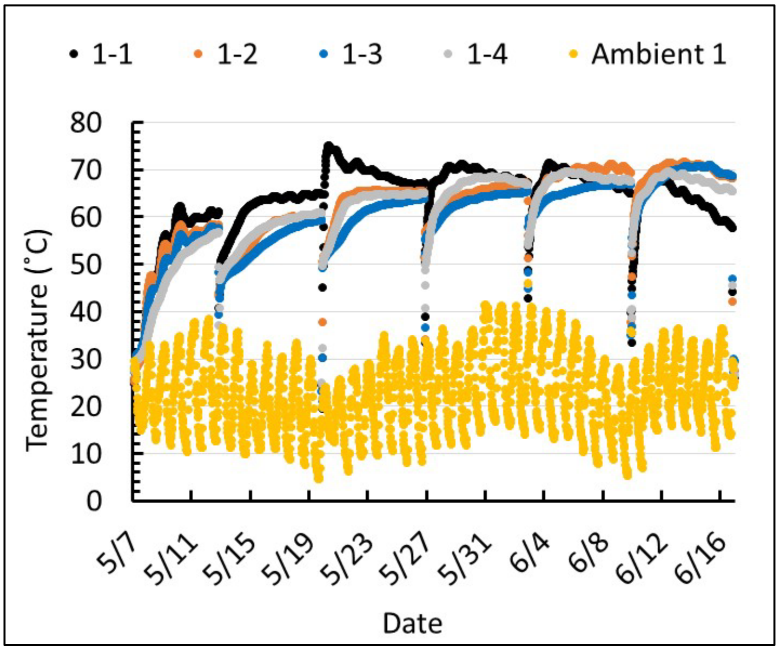


Figure 7. Compost Pile 1: manure fines and centrifuge solids (60:40) temperature profile during the Spring/Summer 2021 season.

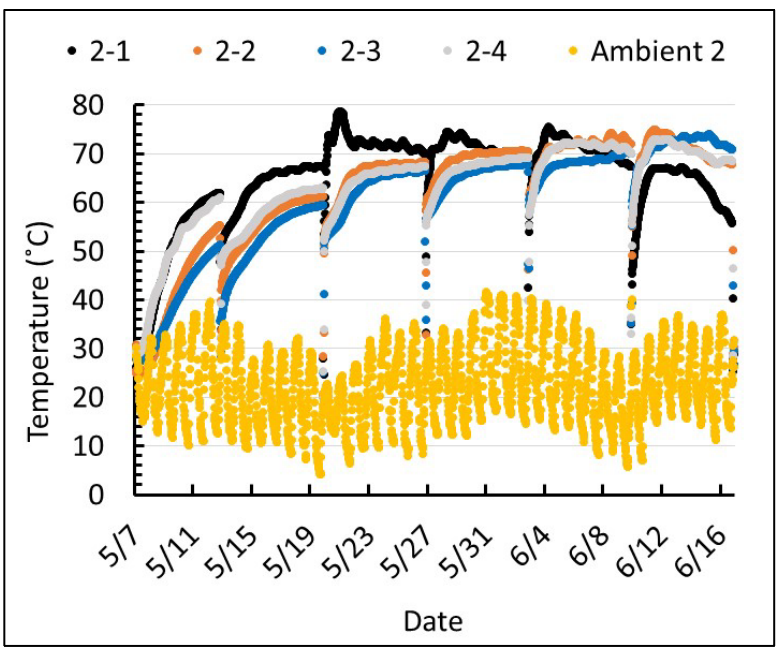


Figure 8. Compost Pile 2: Manure fines-only temperature profile during the Spring/Summer 2021 season.

After 41 days of composting, the changes in moisture content, mass of compost and volatile solids in both windrows are shown in Figures 9 and 10. For manure fines + centrifuge solids, moisture content decreased from 73.4% to 50.8%. The losses of wet mass, total solids, volatile solids, and moisture mass were 58%, 22.1%, 43.5 and 70.9%, respectively. For manure fines only, moisture content decreased from 77.4% to 59.9%. The losses of wet mass, total solids, volatile solids, and moisture mass were 64.4%, 36.8%, 43.2 and 72.5%, respectively.

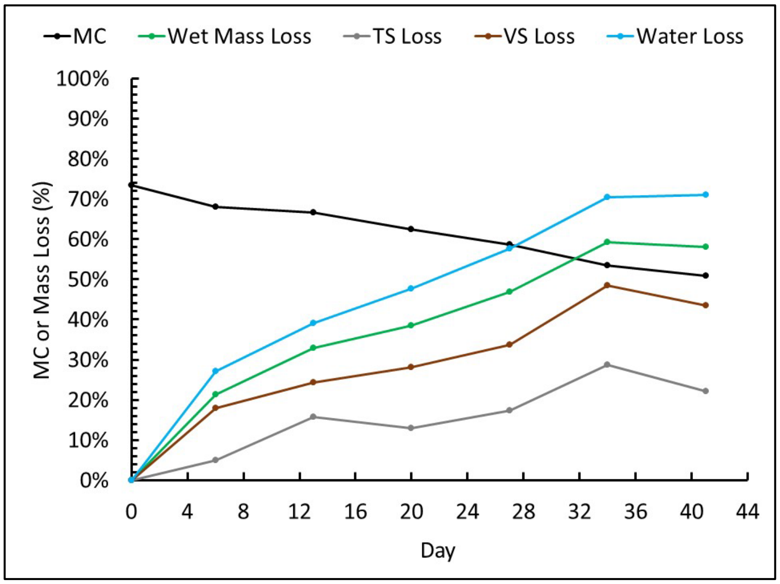


Figure 9. Changes of moisture content, mass of compost, and volatile solids in compost pile 1 (manure fines + centrifuge solids).

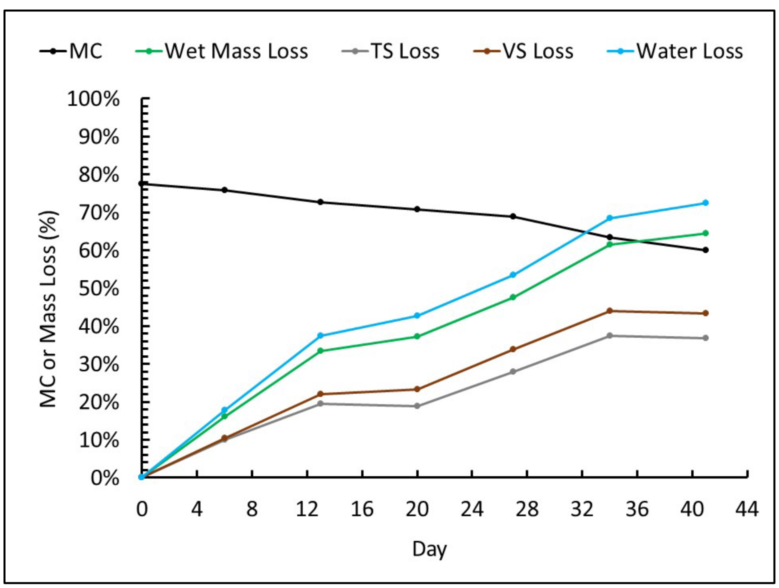


Figure 10. Changes of moisture content, mass of compost, and volatile solids in compost pile 1 (manure fines only).

Characteristics of compost produced during summer are shown in Table 8. Moisture content decreased from 68.5% to 48.7% and from 68.5% to 60.6% for fine particles only and fine particles plus centrifuge solids, respectively. The C/N ratio decreased from 31.1 to 15.0 and from 31% to 16%, respectively. The concentrations of most of elements increased after composting.

Table 8. Characteristics of compost produced during summer.

			Centrifuge Only	**Fine-Only**	**Fine-Only**	**Centrifuge + Fine**
Parameters	**Abbrev**	**Units**	**Day 0**	**Day 0**	**Day 41**	**Day 41**
Moisture	MC	%	50.2	68.5	48.7	60.6
Total Solids	TS	%	49.8	31.5	51.3	39.4
pH	pH	pH	8.3	7.7	8.3	8.2
Electrical Conductivity	EC	mmhos/cm	2.59	4.20	3.32	10.20
Boron	B	mg/L	240	89.1	184	155
Zinc	Zn	mg/L	113	77.5	109	107
Iron	Fe	mg/L	4190	1300	3140	2370
Manganese	Mn	mg/L	143	78.9	127	120
Copper	Cu	mg/L	22.3	16.4	20.6	23.5
Organic Matter	OM	%	38.9	80.9	48	62.2
Potassium	K	%	0.310	0.310	0.37	0.410
Total Phosphorus	TP	%	0.300	0.170	0.25	0.230
Sodium	Na	%	0.120	0.140	0.15	0.170
Calcium	Ca	%	1.80	0.900	1.5	1.30
Magnesium	Mg	%	0.500	0.300	0.4	0.400
Sulfur	S	%	0.310	0.260	0.33	0.350
Total Nitrogen	TN	%	1.67	1.5	1.77	2.19
Soluble Salts	Salt-Sol	mg/L	1660	2690	2120	6550
C:N Ratio	C:N	Ratio	13:1	31:1	15:1	16:1
Heavy Metals						
Chromium	Cr	ppm	--	--	5.73	5.89

Cadmium	Cd	ppm	--	--	0.000	0.000
Arsenic	As	ppm	--	--	0.000	2.330
Lead	Pb	ppm	--	--	1.34	1.65
Nickel	Ni	ppm	--	--	5.43	5.48

Figures 11 and 12 show temperature profiles for compost windrows that were carried out during the winter of 2021. Four windrows were setup: (1) Pile 2 and 4 were composed of fine and centrifuge solids mixed at a ratio of 60:40; and (2) Piles 1, and 3 was composed of fine manure solids only. During the first week, a maximum temperature of about 56℃ could be measured in the second pile at the fourth sensor location. Unlike the experiments conducted during the spring and summer, the temperatures at almost of the locations reached about 60°C directly prior the piles turning during the third and fourth weeks. The temperature exceeded 60°C for a short time directly before piles turning in the fifth and sixth weeks. Relatively similar temperature profiles were also measured in most of the sensor locations in the windrow of the manure fines only (Figure 12). However, the temperature at a few locations in the piles exceeded 70°C during the fifth and sixth weeks.

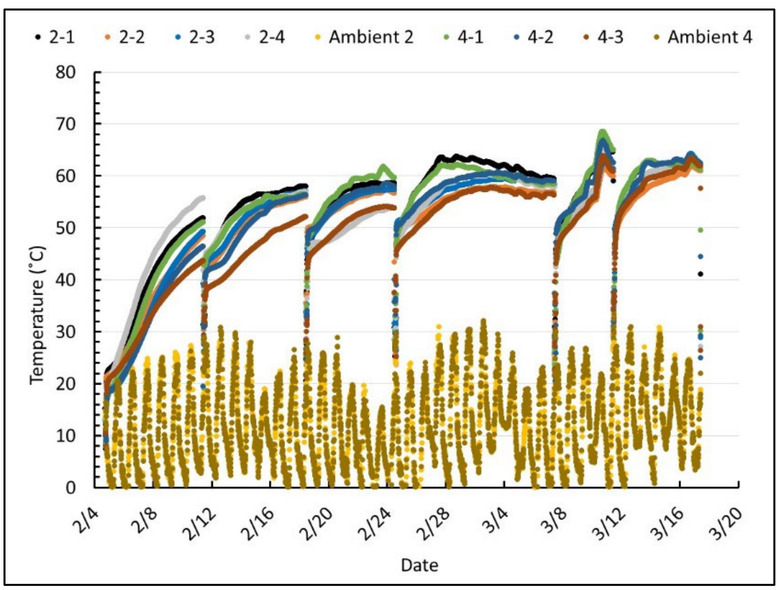


Figure 11. Compost Piles 2 and 4: manure fines and centrifuge solids (60:40) temperature profile during the Winter 2021 season.

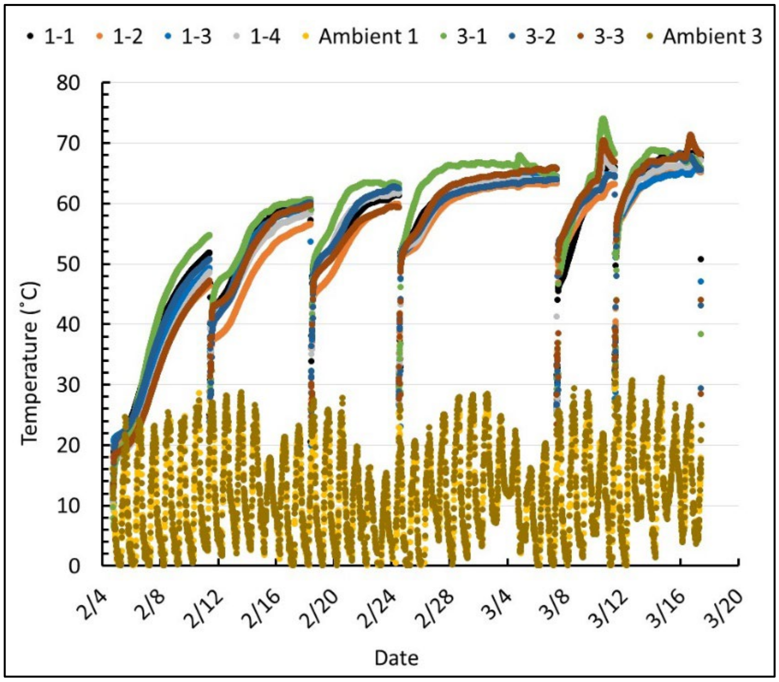


Figure 12. Compost Piles 1 and 3: Manure fines-only temperature profile during the winter season.

After 41 days of composting, the changes in moisture content, mass of compost and volatile solids in both windrows are shown in Figures 13 and 14. For manure fines + centrifuge solids, moisture content decreased from 70.4% to 58.0%. The losses of wet mass, total solids, volatile solids, and moisture mass were 48.8%, 27.2%, 47.5 and 57.8%, respectively. For manure fines only, moisture content decreased from 76.5% to 68.9%. The losses of wet mass, total solids, volatile solids, and moisture mass were 55.9%, 41.8%, 54.6% and 60.3%, respectively.

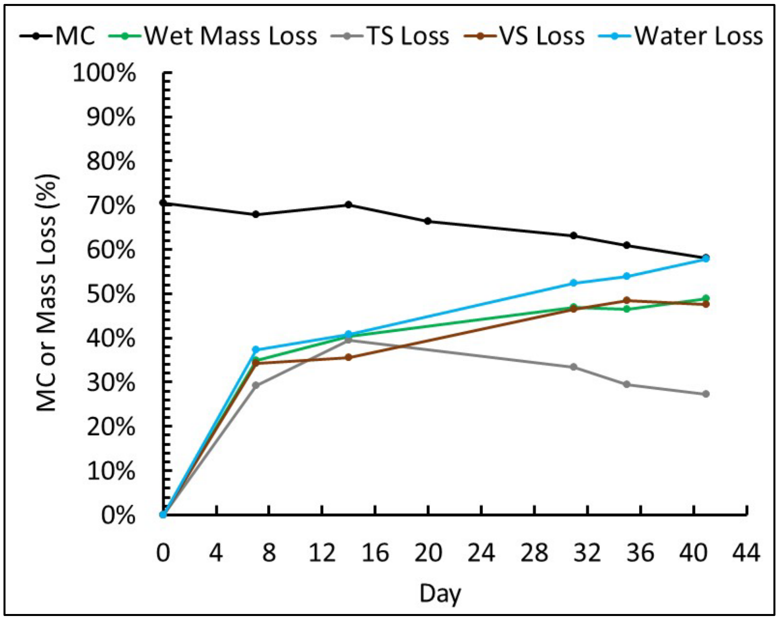


Figure 13. Changes of moisture content, mass of compost, and volatile solids in compost piles 2 and 4 (manure fines + centrifuge solids).

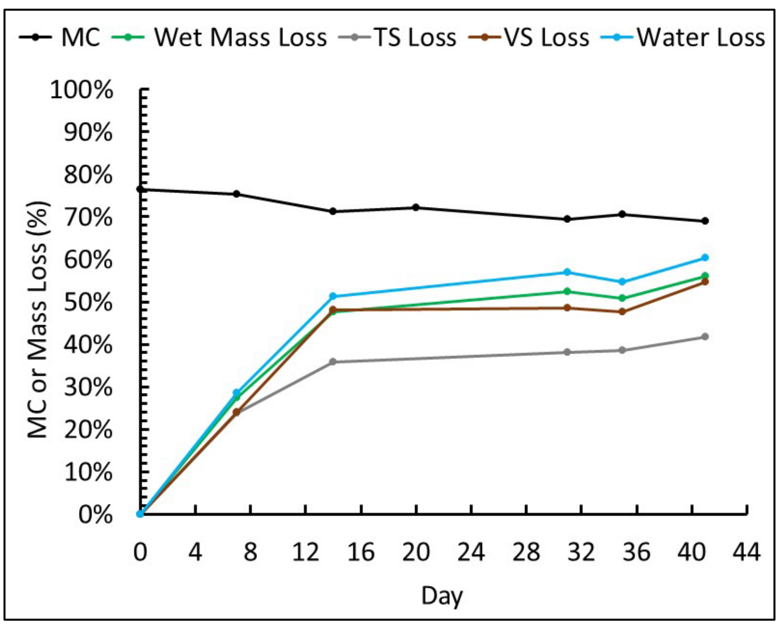


Figure 14. Changes of moisture content, mass of compost, and volatile solids in compost piles 1 and 3 (manure fines only).

Characteristics of compost produced during winter are shown in Table 9. Moisture content decreased from 64.2% to 52.2% and from 64.4% to 50.5% for fine particles only and fine particles plus centrifuge solids, respectively. The VS/TS also reduced from 83.6% to 65.1%, and from 65.4% to 45.9%, respectively. The C/N ratio decreased from 23.1:1 to

21.1:1 and from 21.1:1 to 14.0:1, respectively. The concentrations of most elements increased after composting.

Table 9. Characteristics of compost produced during winter.

			Cent-Only	Fine-Only	Fine+Cent	Fine-Only	Fine+Cent
Parameters	**Abbrev**	**Units**	**Day 0**	**Day 0**	**Day 0**	**Day 41**	**Day 41**
Moisture	MC	%	63.8	64.2	64.4	52.2	50.5
Total Solids	TS	%	36.2	35.8	35.6	47.8	49.5
Moisture	MC	%	58.4	76.1	71.2	70.3	59.8
Total Solids	TS	%	41.6	23.9	28.8	29.7	40.2
Fixed Solids	FS	%	24.7	3.9	10.0	10.4	21.8
Volatile Solids	VS	%	16.9	20.0	18.8	19.3	18.5
Volatile/Total Solids	VS/TS	%	40.6	83.6	65.4	65.1	45.9
pH	pH	pH	8.3	8.2	8.2	8.3	8.4
Electrical Conductivity	EC	mmhos/cm	3.47	3.62	2.6	1.67	1.39
Boron	B	mg/L	225	123	151	123	197
Zinc	Zn	mg/L	81.9	84.5	92.3	111	116
Iron	Fe	mg/L	3880	1920	2660	1870	3430
Manganese	Mn	mg/L	133	98.4	113	99.8	127
Copper	Cu	mg/L	21.2	21.7	18.3	19.6	25.7
Organic Matter	OM	%	35.8	73.1	66.0	73.5	41.3
Potassium	K	%	0.320	0.330	0.310	0.360	0.380
Total Phosphorus	TP	%	0.230	0.220	0.220	0.250	0.280

Sodium	Na	%	0.140	0.170	0.130	0.180	0.170
Calcium	Ca	%	1.60	1.10	1.40	1.20	1.70
Magnesium	Mg	%	0.500	0.300	0.400	0.400	0.500
Sulfur	S	%	0.230	0.260	0.270	0.360	0.330
Total Nitrogen	TN	%	1.68	1.79	1.76	2.03	1.67
Soluble Salts	Salt-Sol	mg/L	2220	2320	1660	1070	892
C:N Ratio	C:N	Ratio	12:1	23:1	21:1	21:1	14:1
Heavy Metals							
Chromium	Cr	ppm	--	--	--	4.02	4.67
Cadmium	Cd	ppm	--	--	--	0.000	0.000
Arsenic	As	ppm	--	--	--	0.031	0.000
Lead	Pb	ppm	--	--	--	0.914	1.04
Nickel	Ni	ppm	--	--	--	4.62	4.98

Economic Analysis

An excel sheet model was developed for evaluating the economics of pellets production. The parameters used for economic analysis are shown in Table 10. We have also used an estimation of the operational costs to preliminarily determine the expected total cost of the production of the pelletized compost products from dairy manure. Actual operational costs will be collected after operating the pelletizing system.

The capital cost of a system with a throughput of 1.0 ton/ hour was obtained from a vendor. The annualized costs included the capital, installation, building and manual maintenance costs. The production costs were estimated based on 260 working days per year and one to three shifts per day. The model was used to estimate the production cost of producing pelletized manure compost under one and two shifts. Two scenarios were carried out. The first scenario was based on the rated capacity of the system (1 ton per hour) and the second scenario was 0.42 ton per hour, which is the capacity of the system with the unrated feeding system. As can be seen in Table 10, the production costs of pellets under the full capacity for one and two shifts were $42, and $35 per ton, respectively. These values are pronouncedly lower than the costs that could be achieved using the current system with having a larger feeding system. Our preliminary results showed that the total costs for producing pelletized dairy manure range from $35-$105 per ton depending on the labor costs and the number of hours of operating the pelletizing system every day. This estimation may be changed once we get the actual costs of operation when the system is fully operational.

Table 10. Estimated costs of pellets production

Parameter	**Pellet mill throughput one ton/hour**		**Pellet mill throughput 0.42 ton/hour**	
	One shift	**Two shifts**	**One shift**	**Two shifts**
Number of working (hours per day)	8	16	8	16
Operational cost per year	$ 62,638	$ 125,276	$ 62,638	$ 125,276
Total yearly cost	$ 90,603	$ 153,241	$ 90,603	$ 153,241
Pellets Production (ton/year)	2,364	4,727	2,364	4,727
Cost per ton of pellets	$ 42	$ 35	$ 105	$ 88

Life Cycle Analysis

The project emissions are approximately half of the emissions of the baseline (Table 11) with savings of 6,357 tonnes of CO_{2e} per year and 0.2 tonnes of CO_{2e} per tonne of manure solids treated. The project emission reductions are mostly due to a significant decrease of manure VS sent to the lagoons and a decrease in the number of trips needed for solids export.

Table 11. GHG emission results of the LCA.

	Total GHG Emissions (tonne CO_{2e}/yr)	**Total GHG Emissions (tonne CO_{2e}/tonne TS)**
Baseline	15,404	0.5
After project implementation	9,047	0.3
Project savings	6,357	0.2

OUTREACH ACTIVTIES AND OUTCOMES

One field day was successfully conducted with wide dissemination of research and demonstration results. The research results were also presented at several conferences, including ASABE International Meetings, Sustainable Dairy Summit, and the California Bioresources Alliance Symposium.

Field day

A field day was successfully conducted on March 30th, 2023. Over 50 people attended the event. Attendees included dairy and almond farmers, compost producers, researchers, and representatives from the California Department of Food and Agriculture and California Dairy Research Foundation. Pictures are shown at the end of the report.

Oral Presentations

1. Edalati, H.; Nielsen, I.; Chio, A.; El-Mashad, H.; and Zhang, R. (2024) Demonstration of a Full-Scale Pellet Mill on a California Dairy. ASABE 2024 International Meeting Tuesday, July 30th, 2024
2. Edalati, H.; Chio, A.; Nielsen, I.; Chen, Y.; Barzee, T.; El-Mashad, H.; and Zhang, R. (2023). Evaluation of an Advanced, Multistage Separator System with Centrifuge on a California Dairy for the Purpose of Generating Manure Solids for Compost Production. ASABE 2023 International Meeting Tuesday, July 11th, 2023
3. Edalati, A.; Chen, Y.; Chio, A.; El-Mashad, H.; Barzee, T.; Nielsen, I.; Khalsa, S.; Pandey, P.; Brown, P.; and Zhang, R. (2022). Evaluation of An Advanced System for Manure Solids Separation for Compost Production on Dairies

Poster presentations

4. The poster titled, “Production and Application of Loose and Pelletized Compost from Dairy Manure and Almond Waste as Soil Amendment on CA Almond Orchards” received the first place prize at the graduate student level in the poster competition. 02/14/2024: 2024 American Society of Agricultural and Biological Engineers California/Nevada (ASABE CA/NV) Section Annual Meeting in Tulare, CA.
5. The same poster was also presented at the 2024 California Dairy Sustainability Summit at UC Davis. 03/26/2024: 2024 California Dairy Sustainability Summit in Davis, CA.

Summarize the practices showcased and outreach events accomplished during the project term. Add rows as needed.

Event Type	Date	Practice Showcased	Location (County)	No. Attended	No. Farmers or Ranchers Attended
Field day	3/30/2023	Mechanical separator and centrifuge for solids removal, composting of manure solids, and a pelletization system to produce pelletized manure from manure compost.	Merced	50	34

Pre- and Post event surveys

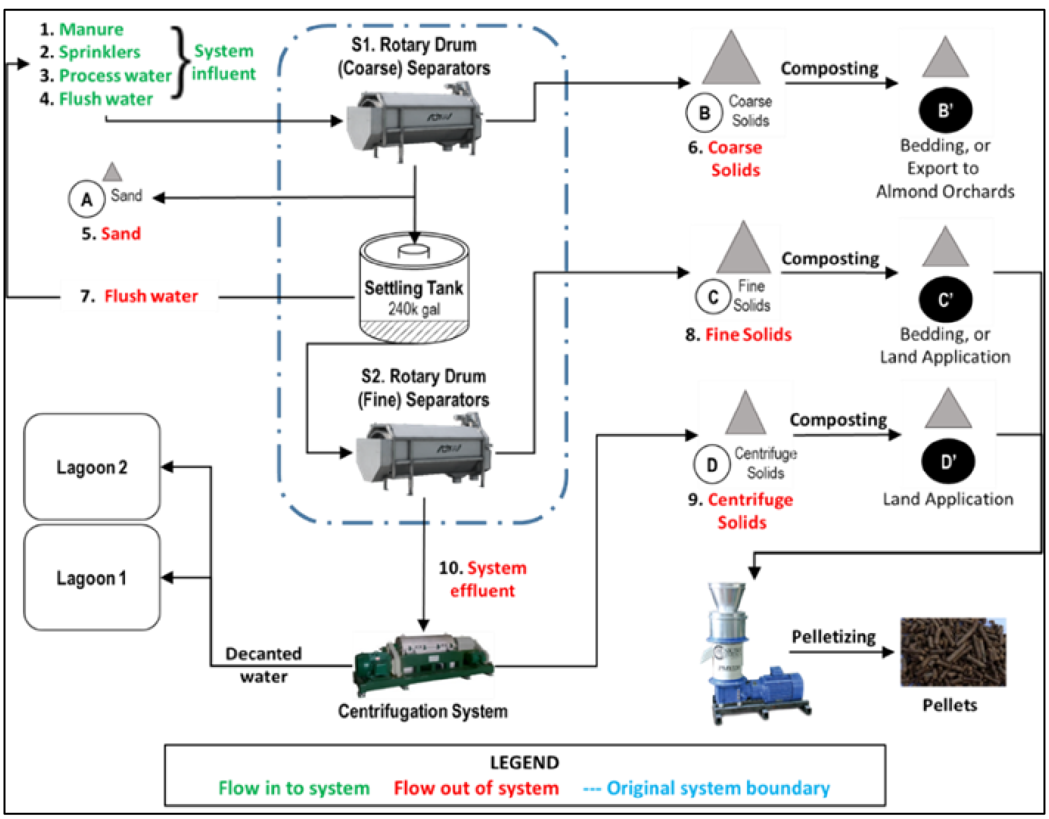
The results of the pre- and post-event surveys indicated that:

1. Some attendees indicated that they attended the events to learn about production of manure compost, benefits of compost, production of manure compost, application of compost on orchards, and pelletization of manure compost.
2. Some attendees are willing to use the compost products that were described in the events. While a few other attendees indicated that they needed more information prior to using the products.

PROJECT PICTURES OR PRODUCTS

Pictures of the project site, system, and composting:

Manure management system on the dairy before installing the centrifuge.

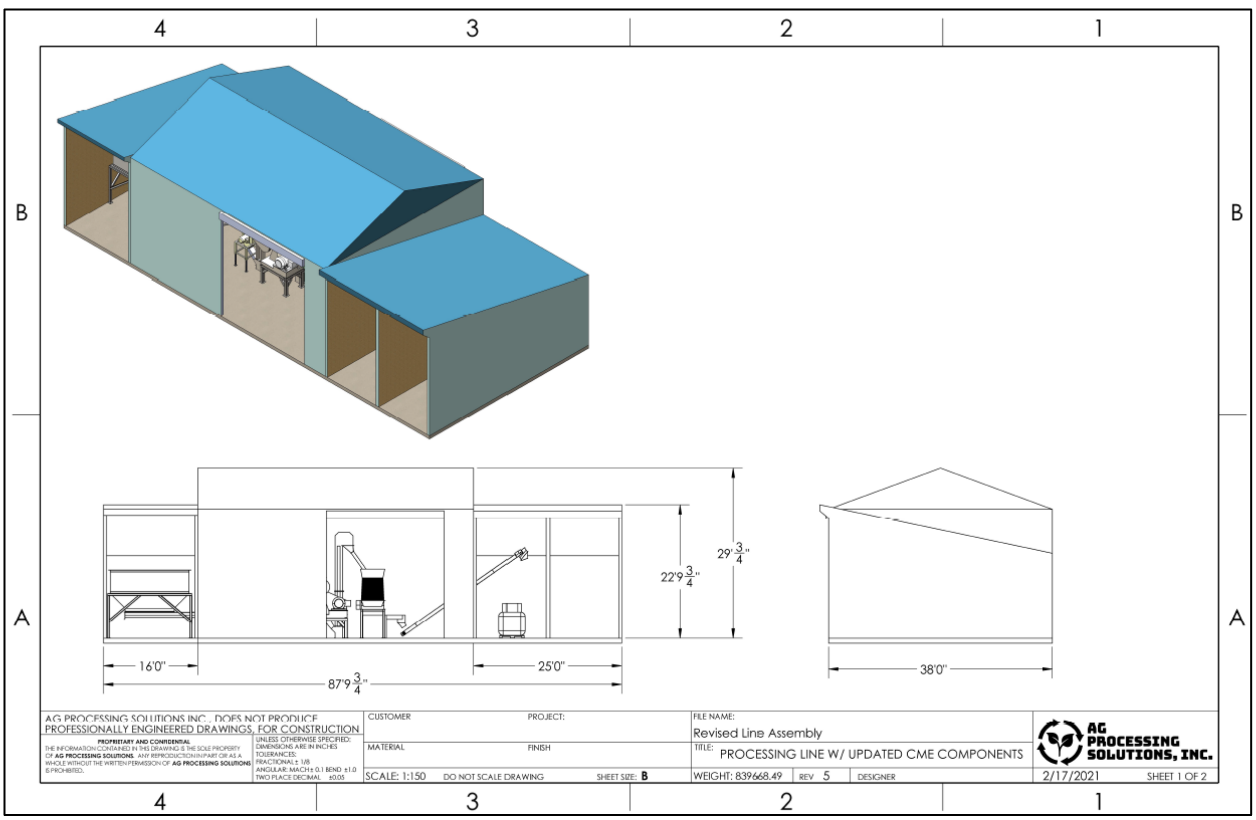


Advanced solid-liquid separation system under study in this project.

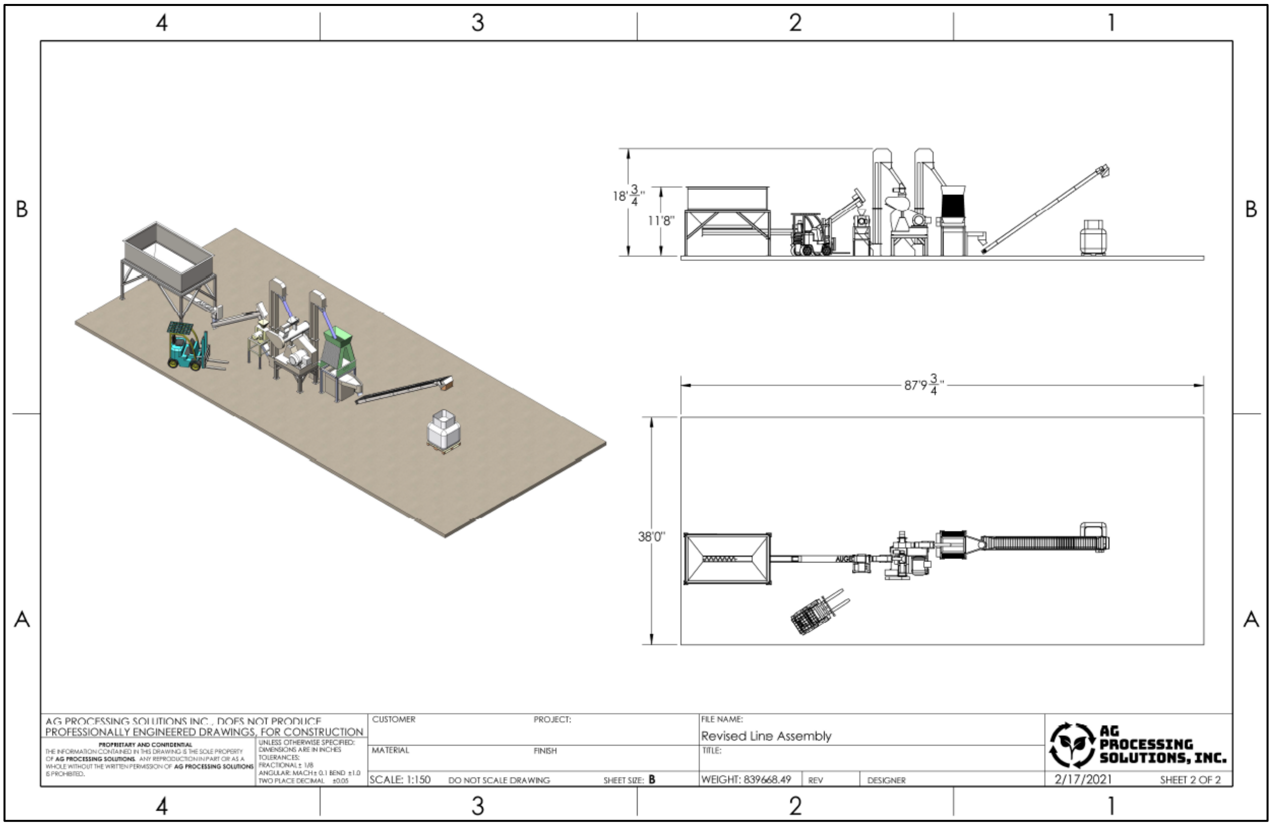
Aerial picture of centrifuge system including concrete pads, centrifuge, auger, and feed tank (left); close up of centrifuge and concrete riser pillars (right).

Back view of centrifuge (left) and effluent solids auger from the centrifuge (right).

Electrical centrifuge control panel (left) and metal feed tank and concrete pad for the centrifuge (right).



Pelletizer builder plans from Ag Processing Solutions, Inc.

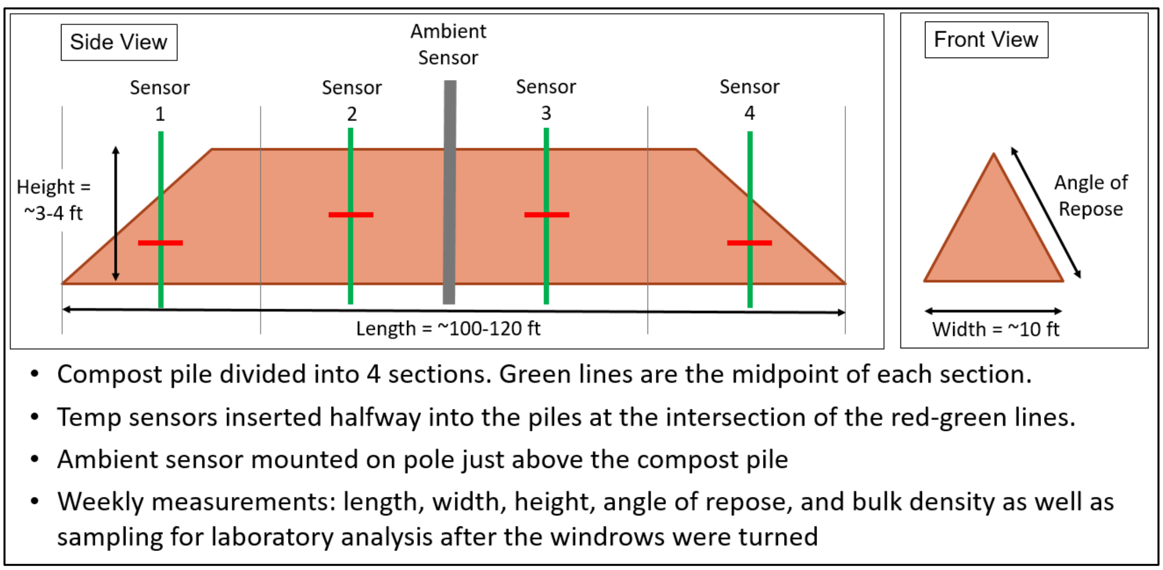


Pelletizing line assembly and equipment plans from Ag Processing Solutions, Inc.

Constructing compost windrows: Top left and bottom photo taken for Healthy Soils Project but used to depict construction of compost piles. Top right photo shows centrifuge solids being dumped for windrow construction.

Turning and aerating the compost windrow on Week 0 (left) and Week 4 (right).

Close up of turning and aerating the compost windrow.



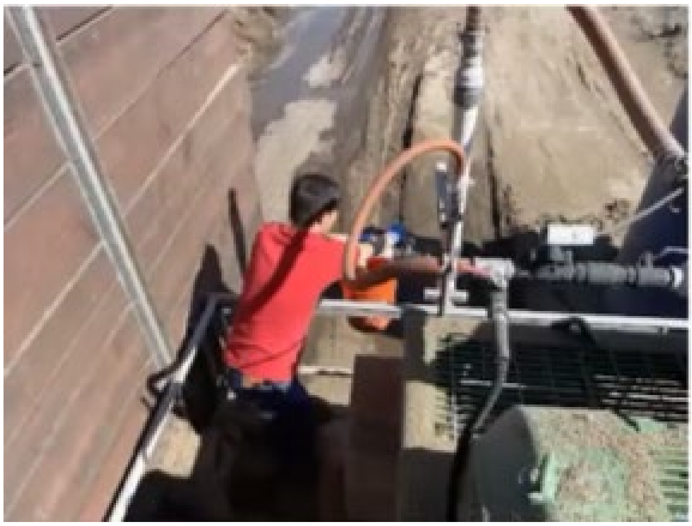
Side and front view diagram of the windrows, a depiction of temperature sensor placement, and an explanation of weekly measurements taken on the farm.

Components of the pelletizer system on the farm. Pictures include the hoppers, stands, compost surge bin, and augers for the pelletizer system in the warehouse in Wisconsin.

Pictures during the sampling of the manure separation system:

Sampling the inlet of the rotary drum separator.

Sampling the outlet of the rotary drum separator.


Sampling the outlet of the centrifuge system.


Sampling the outlet of the centrifuge.

Sampling the flush water.

Construction of metal building for the pelletizing equipment.

Building for housing the pelletizing equipment.

Small Scale Pellet Mill Moisture Testing. Ian and Hossein Pelletizing Manure Compost (left) and screened pellets (right).

Pictures of testing the pellet mill:

Start-up and testing of pelletization system.

Start-up and testing of pelletization system.

Testing of pelletization system.

Pelletized manure created.

Pulley wheel for the Pellet Mill System Feed Auger.


Screen and screening of composted manure on the Dairy Site.

Laying out manure compost in order to condition it to the appropriate moisture content.

Full Scale Pellet Mill Testing at California Dairy Farms - Batch #2 Drier, sandier manure compost.

Full Scale Pellet Mill Testing at California Dairy Farms - (Left) Exterior of the Pellet Mill feed cone and die with pellets sticking out; (Center) Rollers and Die visible from inside the feed cone; (Right) Compressed composted manure removed from the feed cone after plugging of the die.

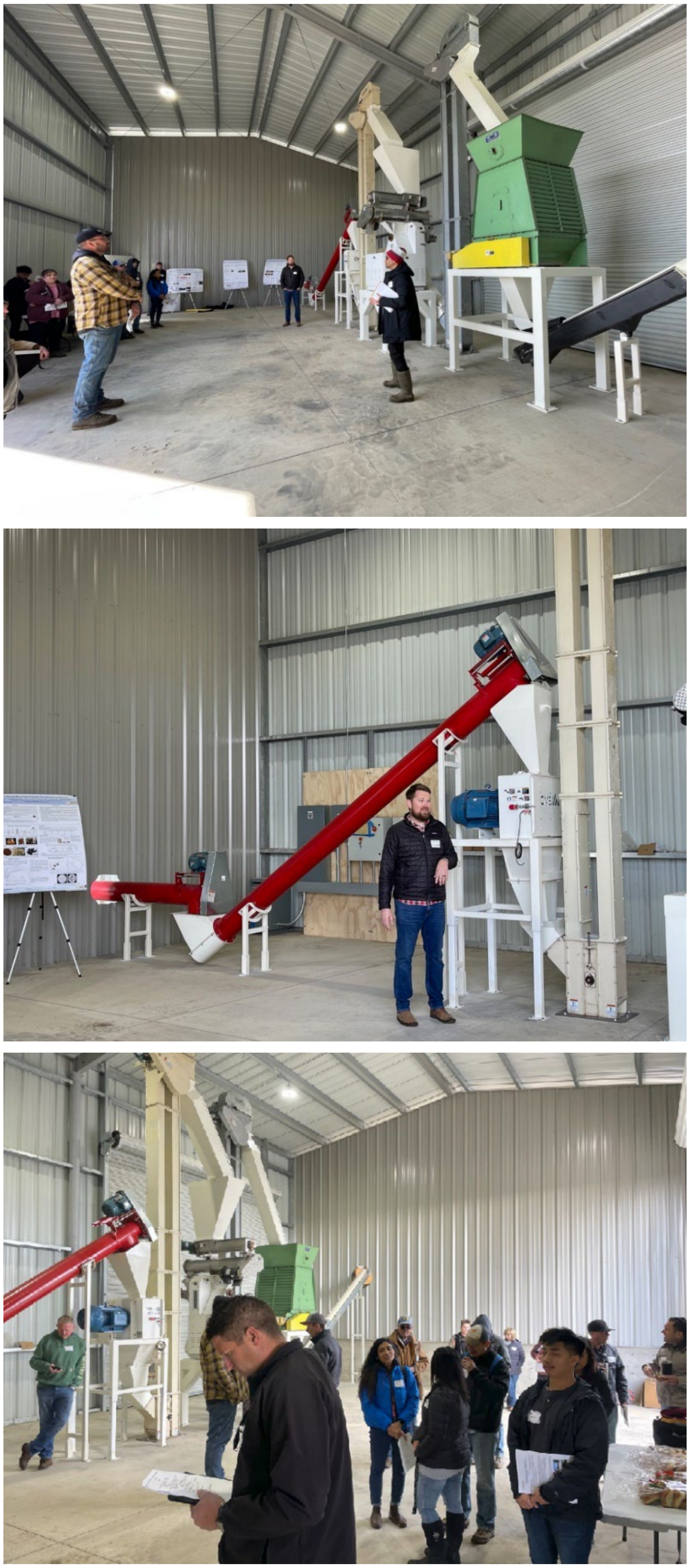
Full Scale Pellet Mill Testing at California Dairy Farms - (Left) Pellets dropping into collection bin; (Center) Macrobin of pellets; (Right) Pellets up close.

Pictures of the Field Day:


Project members and CDFA program Manager introducing the project to the field day attendees.


Attendees of the field day in the front of the building of the pelletization system.

Attendees of the field day in the front of the composting piles.



Some attendees of the field day inside the building of the pelletization system.