NEWTRIENT EVALUATION SUMMARY

CONSERVATION INNOVATION GRANT (CIG):

Agrilab Technologies Inc. Compost Aeration and Heat Recovery (CAHR) Technology

Dairy Manure Treatment Innovations – Enhancing Water Quality and Sustainability

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Publications

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BACKGROUND

In the field of dairy sustainability, technology has played a crucial role in tackling environmental challenges. One innovation gaining traction is the utilization of the Compost Aeration and Heat Recovery (CAHR) system. This technology holds the promise of transforming the composting process, with the potential to lower expenses and minimize its environmental footprint.

An early adopter of this technology is Vermont Natural Ag Products, Inc. (VNAP), a subsidiary of Foster Brothers Farm, Inc., located in Middlebury, Vermont. With a rich history dating back to 1941, Foster Brothers Farm has evolved into a fifth-generation family operation spanning over 2,000 acres of crops. The dairy has a herd of more than 630 cows, of which more than 370 are milking. Their commitment to sustainable farming practices culminated in the installation of the CAHR system, developed by Agrilab Technologies Inc.

As the agricultural landscape faces escalating challenges due to global population growth and increased livestock rearing, the efficient management of organic waste streams has become paramount. Manure, biomass, food scraps, and straw, among other organic waste materials, hold immense value as compost feedstocks. However, traditional composting methods are resource-intensive and time-consuming.

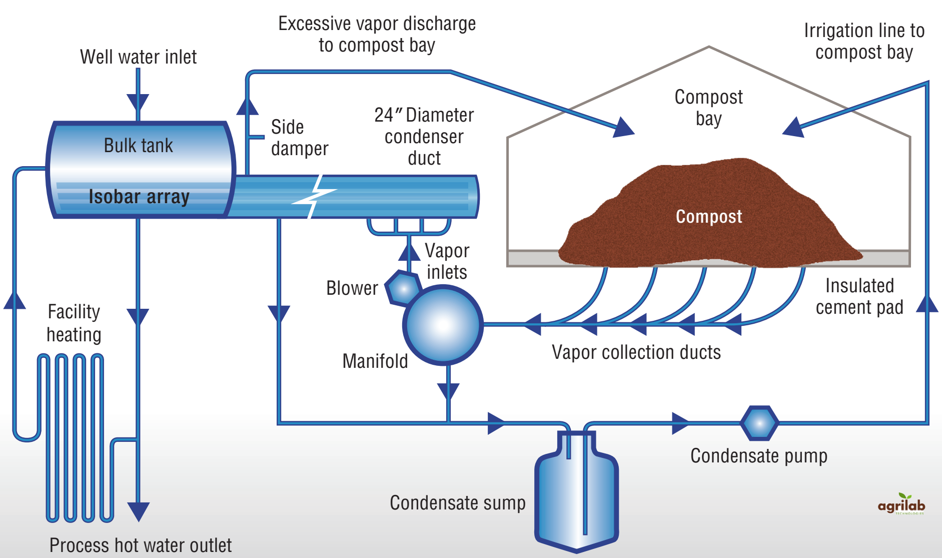
To address these issues, the Foster family, in collaboration with Agrilab Technologies Inc., implemented the CAHR system at VNAP, the largest composting facility in the state of Vermont. The central objective of this study was to evaluate the CAHR system's performance, particularly in comparison to conventional windrow manure composting practices, where aeration is primarily achieved through manual turning.

INTRODUCTION

Starting in 2016 and continuing through 2017, VNAP collaborated with Agrilab Technologies to implement two CAHR systems. This initiative aimed to expedite composting, reduce costs, and harness thermal energy generated during decomposition. The captured heat serves various purposes, including facility heating, pre-heating wash water, drying products before screening and distribution, and enabling year-round composting operations.

The fundamental design of the CAHR system includes compost windrows positioned on a paved pad with a longitudinally oriented shallow trench. This trench contains perforated HDPE piping nestled in wood chips, connecting to insulated HDPE piping leading to a shipping container equipped with an aeration blower (fan), sensors (temperature, oxygen and flow), controls, actuated duct gate valves and a heat exchanger. The system utilizes both positive and negative aeration mechanisms, achieved through aeration blowers. Positive aeration involves the introduction of fresh air into the system, while negative aeration involves the removal of stale air. Recirculation of hot vapor between windrows is an additional capability to jump start the process, particularly in cold weather conditions. These mechanisms enhance the heat transfer process, allowing efficient transfer of heat to the water within the heat exchanger. This recovered heat is employed for radiant floor heating in the bagging building and pre-drying finished compost, concurrently promoting quicker maturation, and reduced turning requirements, thus curtailing diesel, labor, and equipment maintenance costs.

FIGURE 1: FLOW DIAGRAM OF A CAHR SYSTEM



The CAHR system consists of four pipe zones with holes. It operates in three ways:

Removing Moisture: One zone removes vapor, passes it through a heat exchanger, and releases it outside.

Introducing Fresh Air: Another zone draws in fresh air from the surroundings, helping to keep the system well-ventilated.

Recirculating Vapor: In a different setup, vapor is taken from one zone, heated in the heat exchanger, and directed into another zone. This not only warms the receiving zone but also encourages the growth of helpful microbes in compost piles, making the composting process faster.

METHODOLOGY

The methodology for evaluating the composting systems involved a systematic approach to sampling, testing, and recording. The study focused on two composting treatments: a Compost Aeration and Heat Recovery (CAHR)-treated windrow and a conventionally treated windrow without aeration except for manual, periodic turning. Sampling occurred over a thirteen-week period for both CAHR and conventionally treated compost windows. Initial regular sampling of CAHR compost continued for thirteen weeks at which time it was determined that the CAHR-treated compost was ready for market, and it was then pulled for processing. Sampling continued once a week for the conventionally treated (TRAD) compost for an additional four weeks, at which point the TRAD windrow was also pulled for processing. In total, 43 TRAD compost samples and 39 CAHR compost samples were collected. Sampling points were established using a three-dimensional coordinate system based on windrow dimensions, with eight randomized points generating 5-gallon samples composited to create 40-gallon samples for analysis. Temperature readings were recorded at various depths, with TRAD windrows showing temperature stratification and CAHR windrows maintaining consistent temperatures throughout. Bulk density estimates were determined weekly using the "partial fill and drop" method. The study compared two compost windrows, TRAD and CAHR, with identical initial feedstock compositions, consisting of sawdust, dairy manure, dairy bed pack, chicken manure, and wood ash in specified ratios.

DISCUSSION OF RESULTS

Key Benefits of CAHR

The CAHR system evaluation showed significant capability to provide farmers with several valuable benefits, including enhanced efficiency, nutrient-rich compost, positive environmental outcomes, and a practical heat recovery solution.

Performance: The CAHR system successfully accelerated the composting process, achieving compost maturity in a mere 13 weeks, compared to the 17 weeks required by conventional methods. Additionally, the CAHR system consistently maintained nutrient levels comparable to those obtained through traditional composting methods. Therefore, not only does CAHR save time, but it also delivers compost with nutrient-rich qualities essential for soil health. Finally, CAHR's heat recovery feature, demonstrates its effectiveness in capturing thermal energy, which can be harnessed for various on-farm applications such as heating buildings, drying finished compost, preheating water for washing, and more.

Cost Savings: While the initial assessment primarily focused on the operational costs incurred during compost production, it appeared the CAHR treatment may not be the most cost-effective option. In both energy consumption and financial expenditure, the study revealed that traditional composting methods are more cost-effective than utilizing the CAHR system, primarily due to the significant usage of the aeration blower fan. However, a more comprehensive evaluation, accounting for factors such as time, space, energy efficiency, and cost savings, revealed the CAHR system's potential for substantial financial benefits. Notably, the reduced reliance on #2 heating oil for the bagging building and compost drying translated into significant energy and heating cost reductions. Furthermore, the streamlined operation of the managed aeration system not only required less labor but also averted the necessity for expanding the VNAP facility to accommodate additional traditional windrows. As a result, the CAHR system demonstrated its capacity to generate considerable operational and infrastructure cost savings (Foster, et al., 2018).

The CAHR system has the potential to produce a competitive product in a shorter time frame.

Nutrient Comparison and Mass Balance Analysis: When comparing nutrient content by dry weight basis (Table 1), it was observed that the conventionally treated compost (TRAD) exhibited slightly higher N-P-K content compared to the compost produced using the CAHR system. However, considering the shorter composting duration of CAHR, these results are promising, indicating that the CAHR system has the potential to produce a competitive product in a shorter time frame.

TABLE 1: DRY WEIGHT BASIS COMPOST TEST PARAMETERS, FIRST AND LAST DAYS OF STUDY

DRY WEIGHT BASIS		TRAD		CAHR	
Test Parameter	Units	Initial value on 8/24/2021	Final value on 12/15/2021	Initial value on 8/24/2021	Final value on 11/19/2021
Total N	%	1.42	2.62	1.44	2.55
Total *Kjeldahl* N	%	1.45	2.49	1.32	1.99
Nitrate + Nitrite N	%	below detection	0.13	0.12	0.56
Nitrate + Nitrite N	% of TN	below detection	4.96	8.33	21.96
Phosphorus	%	0.42	1.00	0.54	0.87
WEP	mg P /kg	885	869	1,083	841
P as WEP	% of TP	21	9	20	9
Potassium	%	1.18	2.46	1.25	2.29
N-P-K	%	1.42 - 0.42 - 1.18	2.62 - 1.00 - 2.46	1.44 - 0.54 - 1.25	2.55 - 0.87 - 2.29
Total Organic C	%	45.28	40.5	46.79	44.38
C:N Ratio	–	31.2	15.5	32.5	17.4
N:P Ratio	–	3.38	2.62	2.67	2.93
pH	–	8.1	7.8	8.3	7.5
Fecal Coliforms	MPN/g dry	2	10	2	4,430

Note that total *Kjeldahl* N appears greater than total N however, statistically, the values are the same.

On an as-is basis (Table 2), the CAHR system outperformed the conventionally treated compost (TRAD), showcasing higher N-P-K values. This suggests that CAHR has the capability to yield a nutritionally superior product when it still has moisture present, which could be advantageous for specific applications.

TABLE 2: AS-IS COMPOST TEST PARAMETERS, FIRST AND LAST DAYS OF STUDY

AS-IS BASIS		TRAD		CAHR	
Test Parameter	**Units**	**Initial value on 8/24/2021**	**Final value on 12/15/2021**	**Initial value on 8/24/2021**	**Final value on 11/19/2021**
Moisture Content	%	64.73	70.53	64.22	63.85
Total N	%	0.50	0.77	0.52	0.92
Total *Kjeldah*l N	%	0.51	0.73	0.47	0.72
Nitrate + Nitrite N	%	below detection	0.04	0.05	0.20
Nitrate + Nitrite N	% of TN	N/A	5.19	9.62	21.74
Phosphorus	%	0.15	0.29	0.19	0.31
WEP	mg P/kg	312	256	387	304
P as WEP	% of TP	21.16	10.34	21.05	9.68
Potassium	%	0.42	0.72	0.45	0.83
N-P-K	%	0.50 - 0.15 - 0.42	0.77 - 0.29 - 0.72	0.52 - 0.19 - 0.45	0.92 - 0.31 - 0.83
Total Organic C	%	15.97	11.94	16.74	16.04
C:N Ratio	–	31.2	15.5	32.5	17.4
N:P Ratio	–	3.33	2.66	2.74	2.97
pH	–	8.1	7.8	8.3	7.5

The mass balance analysis (Table 3) revealed values above 100% for many parameters, potentially due to measurement errors rather than nutrient input. Nevertheless, some trends emerged. The conventional treatment experienced nitrogen losses, likely through denitrification, nitrate leaching, and ammonia volatilization. On the other hand, the CAHR system retained more carbon, possibly due to its shorter composting duration. Additionally, CAHR showed stable phosphorus retention, which could be influenced by microbial activity and the maintenance of aerobic conditions throughout the composting process. These findings shed light on nutrient dynamics within each treatment and highlight the potential advantages of the CAHR system in terms of nutrient composition and retention.

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TABLE 3: MASS BALANCE FOR MAJOR COMPOST NUTRIENTS

MASS BALANCE		TRAD			CAHR		
Test Parameter	Units	Initial value on 8/24/2021	Final value on 12/15/2021	Retention (%)	Initial value on 8/24/2021	Final value on 11/19/2021	Retention (%)
Bulk Density	lb/CY	910	1,106	**N/A**	869	967	**N/A**
Windrow Volume	CY	480	234	**49**	549	320	**58**
Nitrogen	kg	991	903	**91**	1,125	1,291	**115**
Phosphorus	kg	297	340	**114**	411	435	**106**
Potassium	kg	833	845	**101**	973	1,165	**120**
Total Organic Carbon	kg	31,665	14,009	**44**	36,206	22,514	**62**

Environmental Footprint: The CAHR system not only offers accelerated composting and cost-efficiency, but also has shown significant environmental benefits. Recent research by Wang et al. in 2021 reinforces the effectiveness of intermittent aeration, a key component of CAHR, in mitigating air emissions. Intermittent aeration reduces ammonia (NH_3) and greenhouse gas (GHG) emissions while limiting carbon and nitrogen losses during composting. Aeration rates play a pivotal role in nitrogen transformation and gaseous emissions, and CAHR's regulated aeration system excels in this regard, preventing the release of methane (CH_4), nitrous oxide (N_2O), and NH_3 volatilization due to anaerobic conditions.

Additionally, the CAHR system has demonstrated its ability to contribute to enhanced water quality. Aerated composting, as employed by CAHR, reduces the risk of nitrogen loss through nitrate-leaching and lessens the likelihood of phosphorus runoff by enhancing phosphorous retention during storage and land application. The resulting lighter and more nutrient-dense compost simplifies transportation and handling, minimizes over-application, and ensures better nutrient distribution. Finally, its renewable thermal energy capture reduces operational costs and energy consumption, reinforcing its overall cost-efficiency and sustainability.

Evaluation Key Issues and Challenges

During the study, several key operational issues were identified and addressed as outlined below.

Temperature Stratification: A key measure of efficiency for a forced aeration system lies in its ability to maintain target temperature ranges throughout the compost pile. In the case of the conventionally treated compost (TRAD), an issue of temperature stratification emerged early on. This phenomenon was likely attributable to relatively low average oxygen levels at varying depths beneath the windrow surface. In contrast, the CAHR treatment exhibited no significant temperature stratification, as expected, signifying uniform temperature distribution throughout the compost pile.

Compost Temperature and Moisture Content: Composting efficiency is contingent on various process conditions, including temperature, oxygen levels, pH, and moisture content. In the case of CAHR-treated compost, it maintained notably higher internal temperatures compared to the conventional treatment. This discrepancy was partly attributed to the fact that compost batches had been mixed a few days prior to the commencement of sampling, causing initial compost temperatures to surpass ambient levels. The combination of elevated temperatures and continuous aeration resulted in consistently drier compost material for the CAHR treatment. Consequently, VNAP staff increased their monitoring efforts to ensure that temperatures didn't escalate excessively, and moisture levels remained within an acceptable range. It's worth emphasizing that while diligent monitoring can harness the advantages of higher temperatures and constant aeration, ultimately reducing composting duration, it also mitigates the risk of over-drying, which can affect the compost's quality and performance.

Pathogen Growth: Interestingly, fecal coliform levels exhibited an unexpected increase during the study, particularly in the CAHR system, which maintained consistently higher temperatures and had the potential for pathogen reduction. However, it's important to note that the fecal coliform data were only available for the initial and final samples of each treatment, making it challenging to establish definitive trends. The observed rise in fecal coliform data could have stemmed from various sources, such as elevated bird activity at VNAP, localized pockets of high coliform levels that happened to be randomly sampled, or the possibility of pathogen growth between the time the frozen samples were shipped from the University of Vermont (UVM) and when they were eventually analyzed in the laboratory.

IMPLICATIONS

The CAHR system's ability to expedite composting while maintaining nutrient quality offers farmers an opportunity to enhance operational efficiency. The notable reduction in nitrogen and phosphorus losses and improved nutrient management underscore CAHR's environmental sustainability, urging further research to quantify long-term water quality improvements. While initial operational costs are higher, future research should explore comprehensive economic models to reveal the long-term cost savings potential. Investigating scalability, adaptation, and system performance across diverse farm contexts will be essential for realizing CAHR's broader applicability, practicality, and potential for advancing sustainable agricultural practices.

For additional information on the vendor, environmental impacts, financial implications, and CAHR technology visit the Agrilab CAHR Vendor Snapshot on the **Newtrient website**.

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Newtrient's mission is to reduce the environmental footprint of dairy while making it economically viable to do so.

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