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Mabee Waste Solution Final Project Report

Mary Hippensteel
Trinity University

Armando Rodriguez
Trinity University

Matthew Willis
Trinity University

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Mary Hippensteel, Armando Rodriguez, and Matthew Willis

Team Adviser: Eliseo Iglesias

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1. Executive Summary

Food waste is typically sent to landfills, where it decomposes and releases methane into the environment, causing a serious pollution issue. Mabee Dining Hall's previous solution to this problem, the Earth Tub Composting Tank, became inoperative after 11 years of service. The team was tasked with developing an alternative solution. Based on the constraints imposed by the location and the project sponsor's stipulations, such as low odor emission and ease of use, the team decided that the solution would consist of an in-vessel composting system. The container, a 6-gallon HDPE tank, is set up in a horizontal configuration suspended by two A-frames and an internal rod with aeration spikes. These aeration spikes prevent the process from going anaerobic and thus minimizing the odor produced in the composting process.

During the development of the prototype, the team conducted a series of empirical tests to determine, (1) the ideal amount and type of bulking agents that would allow the pre-consumer food waste to compost within a four to six week time frame, and (2) to identify the degree to which aeration affects overall composting time and the odor produced by the pile. All tests were performed under a controlled environment in two fume hoods provided by Dr. Hunsicker-Wang and Dr. Uddin. The results suggested that, among the tested food waste to bulking agents, the most effective ratio with regards to fastest composting time and least odor production is 4:1:2 (food waste:hay:wood shavings). Additionally, the aeration test demonstrated that when the pile is properly aerated, the smell of the compost pile is negligible.

Throughout the duration of the project, the team was able to suggest a composting method based on the limiting factors of Trinity University campus, recommend the type and amount of bulking agents that would satisfy ideal conditions of the composting process, create a CAD drawing and an instruction manual, and construct a physical prototype. However, due to delays caused by COVID-19 and the winter storm, several aspects of the project had to be modified. As a result, the team developed a smaller-scale prototype than initially stipulated, and did not get to test it after its completion. However, several recommendations and improvements have been determined using the empirical tests presented in this report.

During the empirical tests, the team failed to obtain suitable compost within the predicted four to six week time frame. The reason for this could be that the sizes of the piles were small (3.5 total pounds of food waste and bulking agents), which affects the ability of the microbes to retain heat. To accommodate this realization, the team added insulation around the pails mid-test. However, the team suspects that too much time had already passed and the majority of the microbes had died. Thus, one of the team's proposals is that the Composting Time Test and the Aeration Test be repeated with insulation added on day one to ensure that the piles are able to complete the composting process without heat loss. Additionally, testing the actual prototype to analyze the results and make the pertaining modifications would be an important improvement.

2. Introduction

The purpose of this project is to design and implement a management system for the pre-consumer food waste produced by Mabee Dining Hall. Typically, this waste is sent to landfills, and common landfills have shown to produce methane which is a greenhouse gas [1]. The goal of this project is to repurpose the waste into compost for a sustainable and environmentally-friendly disposal alternative to the landfill. Previously, a commercial composting system was used. The previous system was inefficient, did not control odors, and required more than 1-2 hours of labor per day. The manufacturer discontinued the composter, and this system was decommissioned from Trinity in Fall 2019 because the equipment was no longer repairable.

This year, the focus of the team was to research different methods of composting and perform multiple experiments to evaluate the efficacy of each method. The overall project objective is to provide an understanding of the composting process as a foundation to next year's design team. The team is required to identify a composting method that is suitable for the waste that Trinity generates. The solution must not exceed two man-hours of labor per day. The team also needs to provide the following recommendations: a list of foods that should be neglected in compost piles, the types of bulking agents to use, and the particle size of waste and bulking agents. The final deliverables include the physical prototype, a drawing package consisting of the CAD model of the prototype, and an instruction manual for the operation of the prototype.

The composting method chosen by the team was limited to the constraints of the project. The budget for the project was $1200, and the operational cost of the prototype must be manageable for Trinity (i.e., the continuous purchase of bulking agents). The prototype must be located on-campus and fit on the outdoor loading dock of Mabee Dining Hall. The composter should not emit odors; odor control is mandatory due to the proximity of the dining hall and student dormitories. For similar reasons, the system must not attract pests.

In order to run a composting site, the Senate Bill 1340, 72nd Legislature *The Texas Omnibus Recycling Law of 1991*, as well as the Senate Bill 1051, 73rd Legislature, which ensures to maintain human health, safety, and environmental protection, must be followed. These regulations ensure that nuisances such as air emissions, odors, pathogens, or other contaminants do not get exposed.

The team empirically tested the time it takes for the food waste to compost to determine if the turnaround time lies within the estimated four to six week range. The team also tested the overall effectiveness of the bulking agents by comparing different bulking agents. In addition, the team also tested different aeration frequencies to see the effects on the compost timeline and odor. Throughout these rounds of testing, the pH, moisture content, and temperature were measured to ensure that the compost was maintaining ideal conditions for the measured parameters. The ideal temperature range of compost is between 50-113ºF at the beginning of the process where the mesophilic bacteria dominate [2]. In the second phase of the process, the ideal temperature rises between 113-158ºF as the thermophilic bacteria take over and complete the

composting process [2]. The ideal level for the pH of the compost is 7.0 [3]. The ideal moisture content is between 40-60%, and the ideal C:N ratio is 25-30:1 [4].

The project was originally designed to be completely built and operated in a single year with the current design team; however, more research and empirical testing was required to have a successful product than was originally planned. Due to this, the project sponsor wanted the current team to focus on gathering research and data. Therefore, the project scope changed since the beginning of the year. Through the empirical tests, the team has identified the superior bulking agents and their respective ratio to food waste, the optimum aeration frequency, suggested particle size range, and categories of food waste to avoid in composting. Rather than building a full-size composter for Mabee Dining Hall, the team built a scaled-down system to replicate the tests from this year. This prototype will be available for next year's team to use for testing.

3. Overview of Final Design

3.1. Description of Proposed Design

The team's design is an in-vessel composting system consisting of one 6-gallon HDPE plastic drum. Previously, the team had planned to use a two-tank rotation system so that there would always be an available tank for composting. However, due to the change in the project scope, the team developed a reduced version of the initial design. The tank's material was chosen due to its high temperature resistance and UV-resistance. Composting temperatures can be as high as 158°F [2], which requires a temperature-resistant material, such as HDPE. The tank will be located outdoors, thus UV-resistance was essential to prevent outside factors from interfering with the process. Additionally, the team decided to cover the drum with a foil bubble insulation sheet in order to retain the heat produced by the microorganisms in the composting process.

Initially, the compost pile was aimed to be bigger and therefore self-insulating. However, since the target food waste capacity requirement was reduced from up to 100 pounds per day to 2 pounds, the insulation sheets were necessary. As shown in Fig. 1, the drum has a horizontal configuration suspended by two A-frames, a 1-inch diameter internal PVC rod with ½-inch PVC spikes to facilitate the aeration process, and one inlet/outlet door. An engineering drawing indicating all respective dimensions and various perspectives of the design can be found in the last page of the report for further details. The initial design was a vertical configuration, aerated by using an automatic aeration unit, composed of an auger located at the center of the tank and driven by a motor. This change was implemented as a more practical solution to the aeration requisite, since it reduces costs in electrical consumption and maintenance. In addition to aiding in the aeration process, the internal rod serves as the support to which the A-frames are attached, providing stability to the device. The prototype includes a slide bolt, which prevents the tank from rotating when the container must be loaded.

Figure 1. Pictures of the team's prototype, which consists of a 6-gallon HDPE drum surrounded by insulation and supported by two A-frames.

3.2. Subsystems

3.2.1. Sorting

The sorting of pre-consumer food waste is conducted by the Mabee Dining Hall staff. They place the pre-processed food waste into a bin separate from any of the regular output that Mabee Dining Hall produces, like plastic waste or post-consumer food waste. On top of separating the food waste, the Mabee staff also separate the meat trimmings and byproducts that are produced from the cooking process. This is removed from the rest of the Dining Hall output because meat in the system can cause the compost to spoil and produce foul odors.

3.2.2. Pre-Processing

Before the sorted food waste is placed into the composter, its particle size will be reduced. The target particle size of the food waste is between an eighth of an inch and two inches, since any size smaller or larger will be counter-productive to the microbial activity and composting speed [3]. Additionally, bulking agents will be introduced at a ratio of 4:2:1 (food waste:hay:wood shavings) with the purpose of maintaining optimum values of moisture content and C:N ratio, which range from 40-60% and from 25-35:1, respectively.

3.2.3. Composting Process

Once the food waste and bulking agents are inserted into the tank, the team estimates that the final compost will be ready after a 4-6 week period, assuming that the ideal conditions are preserved. The user will know that the compost has completed its curing process through a visual and physical test. The compost should have the consistency of a damp sponge, meaning that when the contents are squeezed, it compresses, but slowly returns to original size. As for the visual test, the operator should not see any food particles in the compost. If there are visible food contents, the process is not done.

The tank should be rotated once every week to oxygenate the compost, which prevents the biological processes from turning anaerobic. In order to verify that the composting process is progressing correctly, temperature, pH level, and moisture content should be monitored at least once per week. The team prepared an Excel spreadsheet that can aid the user in determining the amount and type of bulking agent needed to be added into the compost pile in order to produce the ideal C:N ratio and moisture levels.

3.2.4. Distribution

After 4-6 weeks at ideal composting conditions, the compost will be ready to be taken out of the composter. The operators will be responsible for removing the compost from the drum. They will take the product and distribute it to various gardens and locations around campus.

3.3. Construction

The first step in building the prototype was making alterations to the 6-gallon drum that the team used as the container for the compost. The team modified three 6-gallon HDPE drums to create a single drum. The top of all of the drums had a handle and a threaded cap, which was undesirable for the usage of this project because a PVC pipe needed to go through the center of both ends of the drum. The team used a precision saw to cut off the lid of drum #1 and a bottom of drum #2. The bottom of drum #2 was plastic welded onto the body of drum #1 to make an enclosed drum. Additionally, a 2-inch strip of drum #3 was cut out using the precision saw. This strip served as excess material to use for the welding process. Figure 2 shows how the bottom of drum #2 was placed on drum #1 with the plastic strip around the container to prepare for welding.

Figure 2. Set-up of HDPE drum to be plastic welded.

Prior to enclosing the drum, the team used a 20'' Palmgren drill press to drill 1.5-inch holes through both ends of the composter so that a PVC pipe (described below) could go all the way through it.

The drum features a 6 inch by 8 inch rectangular cutout on the side of the drum to serve as the inlet/outlet of the composter. This opening was covered by an overlapping 8 inch by 10 inch lid (cut out from an additional drum) to provide enough overlap for water-proofing purposes. To attach the overlapping lid, the team used two 1-inch door hinges. A post hasp lock was used to lock the door so that it would not open when the unit was being rotated.

Next, the team built A-frames that secure the composter off the ground. To build these A-frames, the team started with four pieces of plywood cut to a size of 23.25 inches. To cut the wood into the proper shape needed for an A-frame, the team used a vertical bandsaw. The team joined each side of the A-frame using a Dewalt biscuit joiner along with 2 wood biscuits for each A-frame. The team used wood glue to adhere the wood biscuits together. The top of each A-frame has a 1 ¼ inch two-hole strap that is used to hold the PVC pipe to it. The A-frame also has two pieces of wood along the bottom to add stability as seen in Fig. 4.

The third step of the prototype that the team built was the PVC pipe that would go through the composter and hold it between the A-frames. The team used a 1-inch diameter piece of PVC and cut it to its proper length using a miter saw. The team also drilled ten ¾-inch holes through the PVC and placed five ½ inch diameter PVC spikes through the holes to act as the aeration unit for the prototype. The spikes were attached to the rod with PVC primer and PVC cement. Silicone adhesive sealant was used on the spikes to prevent water and/or organic matter from getting into the spikes.

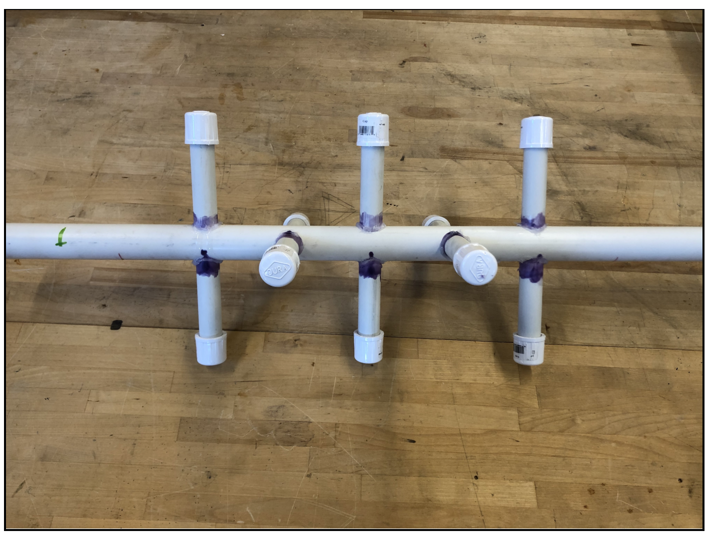

Figure 3. Internal mechanism for the aeration of the compost pile.

Finally, the team added insulation around the composter to prevent heat loss to the surroundings.

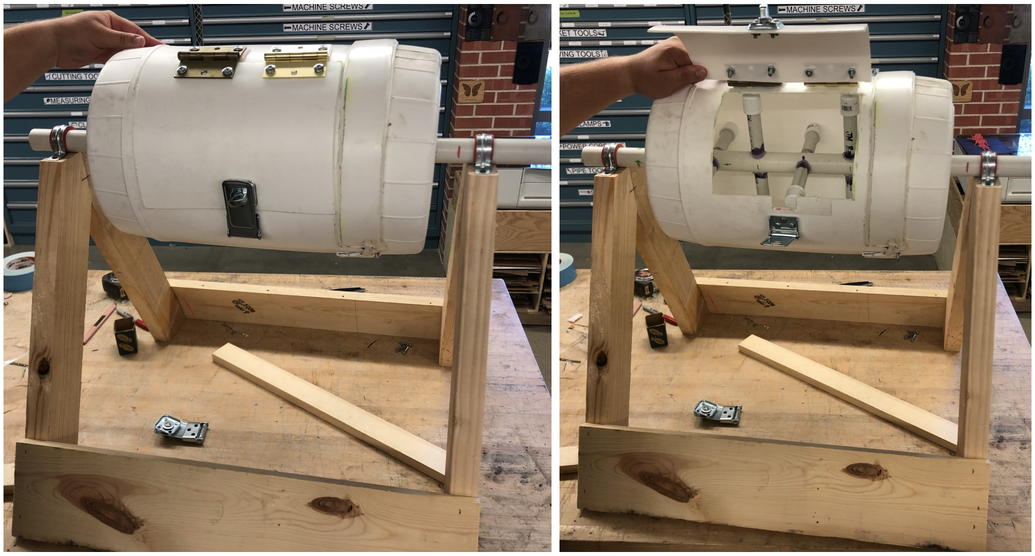

Figure 4. The team's prototype (prior to insulation), consisting of the 6-gallon HDPE drum, aeration mechanism, and two A-frames for support.

4. Design Evaluation

This section will address the effectiveness of the team meeting the design requirements and constraints.

4.1. Bulking Agents

The team needed to evaluate different types of bulking agents to make a recommendation for the optimal additives to the food waste.

4.1.1. Associated Tests

Using a waste report from 2019, the team analytically evaluated the moisture content and the carbon-to-nitrogen ratio (C:N) of Mabee's food waste. The team also measured the moisture content of a sample of waste from Mabee Dining Hall to confirm the results found in the analytical calculation (i.e. a 90% moisture content for vegetables) were accurate. The moisture content tests used an oven and a microwave. The analytical calculations used the equations shown in Appendix A.

After the moisture content and C:N ratios were calculated, the team conducted the Composting Time Test to evaluate different bulking agents and the overall curing time of the compost empirically. Six 5-gallon pails were used for this experiment. Pails 1-3 tested a 1:1 (food waste:wood shavings) ratio, and pails 4-6 tested a 4:2:1 (food waste:hay:wood shavings) ratio. The temperature, pH, and moisture content of each pail was recorded every day. To take measurements of the temperature, a thermometer was used. The moisture content and pH were measured using a Sonkir probe.

4.1.2. Test Results

The results for analytical calculations concluded that to maintain ideal conditions for the moisture content and the C:N ratio, two bulking agents should be used.

The results of the Composting Time Test are shown in Table 1 and Figures 5-7.

Table 1. Average values of the temperature, pH, and moisture content readings of the compost piles in the Composting Time Test (3/23-4/29).

Pail	Temperature [℉]	pH [-]	Moisture Level [%]
1	72.0	7.7	29
2	72.1	7.6	30
3	71.8	7.7	32
4	75.7	7.5	64
5	76.1	7.6	65
6	75.9	7.5	63

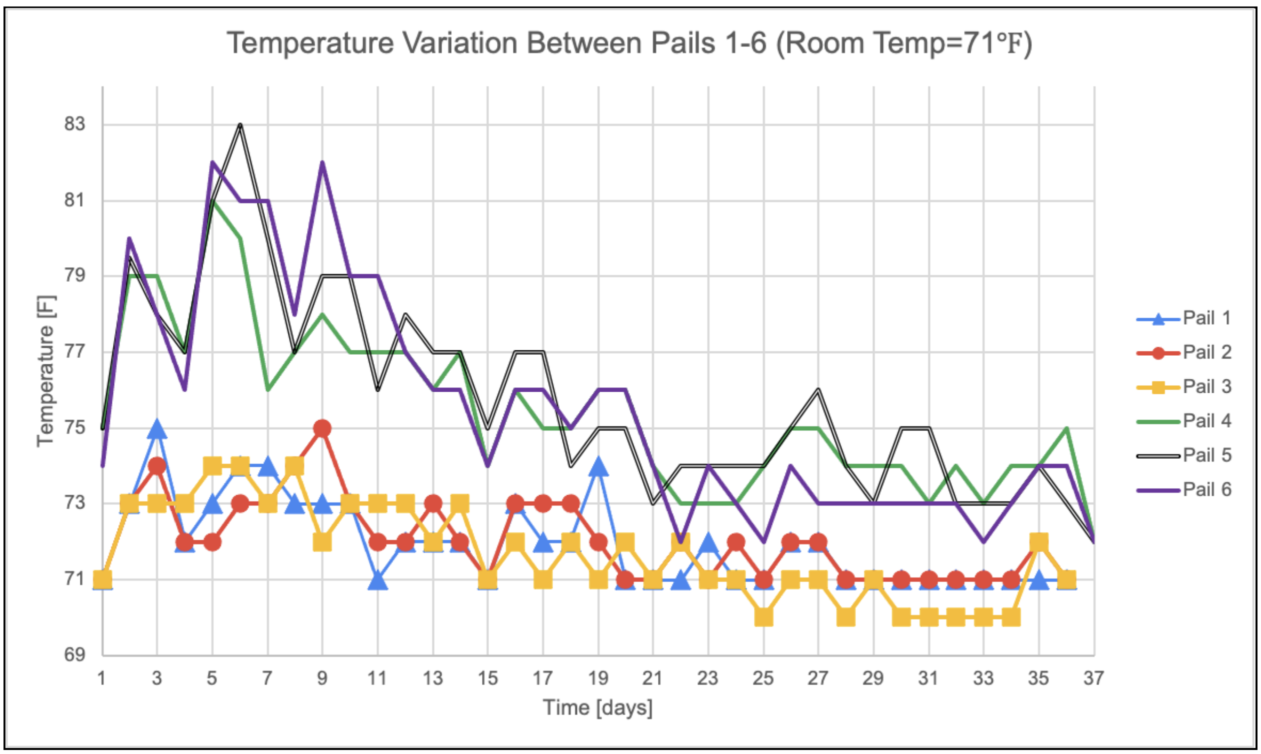

Figure 5. Temperature variation between the pails throughout the duration of the Composting Time Test.

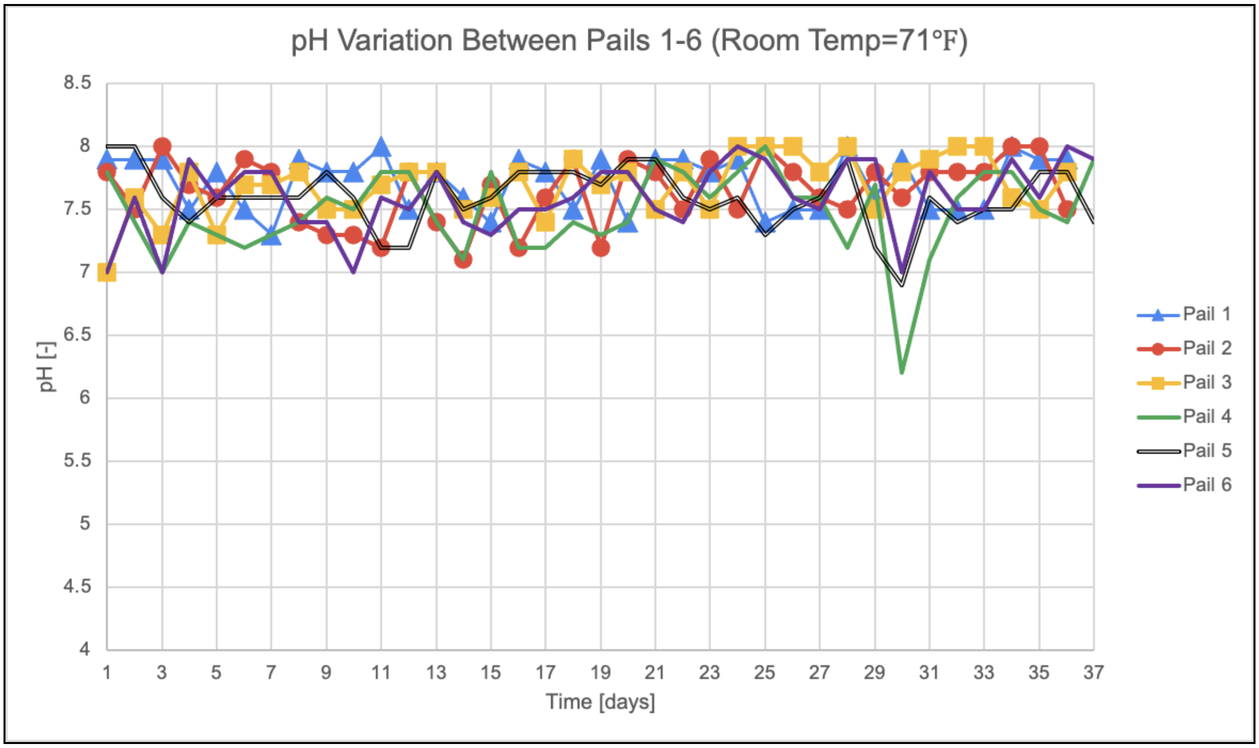

Figure 6. Comparison of the pH values between pails 1-6 throughout the duration of the Composting Time Test.

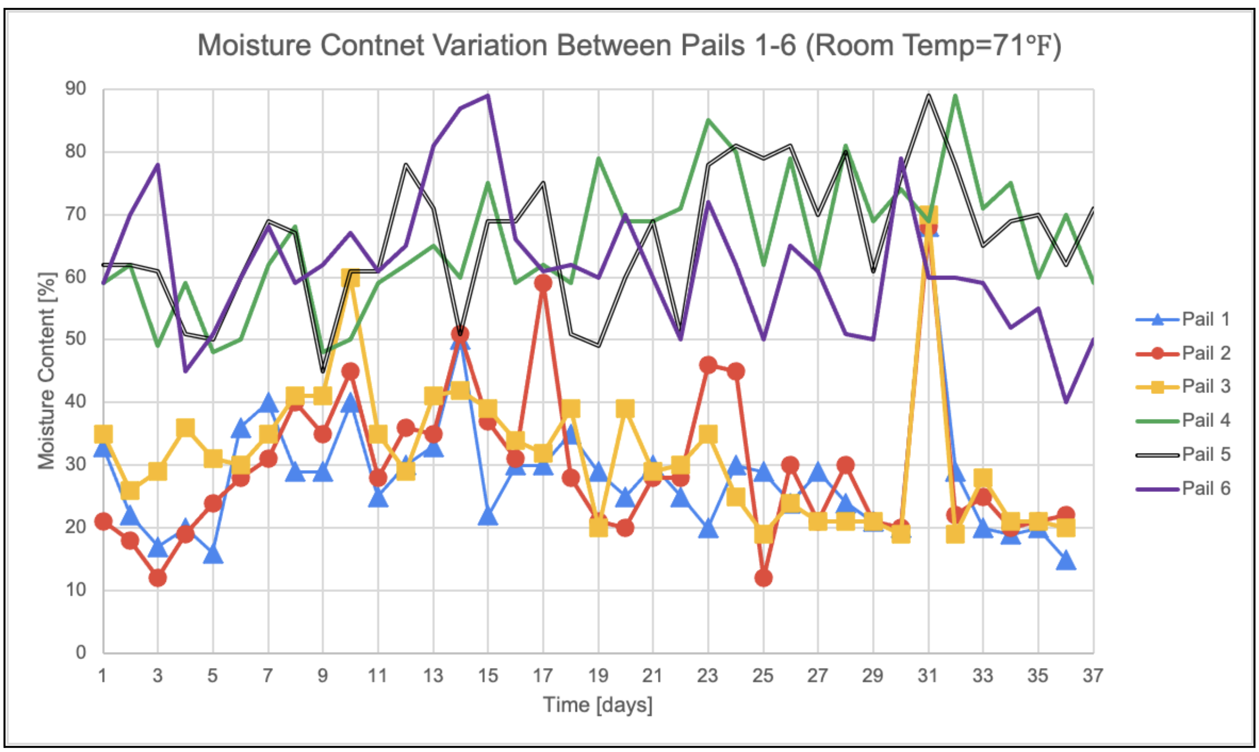

Figure 7. Comparison of the moisture content between pails 1-6 throughout the duration of the Composting Time Test.

4.1.3. Evaluation

As shown in Table 1, pails 4-6 had higher values for each of the measured parameters in comparison to pails 1-3. Temperature is the first significant measurement, and the variation is shown in Fig. 5. Pails 1-3 averaged a temperature of 72ºF, which was only one degree above the room temperature of the testing site. The compost piles with wood shavings and hay, pails 4-6, averaged to be approximately 76ºF. The higher temperatures in pails 4-6 suggest that the compost piles approached the thermophilic composting stage faster than pails 1-3, which is an indication of an overall quicker composting process. However, the thermophilic stage was never reached and therefore the composting process was not complete. This could be due to the small size of the compost piles, prohibiting the retention of heat. To accommodate this observation, the team added insulation around the pails on day 24. As shown in Fig. 5, the temperature of pails 4-6 increased slightly after the insulation was added and leveled to a temperature of 73.5ºF, rather than continuing to decrease (which was the trend prior to the insulation).

Microorganisms in compost breakdown organic matter best at a pH between 5.5-8 [5]. The pH level, shown in Table 1 and Fig. 6, of all compost piles was between 7.0 and 8.0 which is in the ideal range. The pH values suggest that the piles are neutral and not too acidic; this is due to the fact the team excluded acidic foods (e.g., pineapple) in the compost piles, since acidic conditions can inhibit undesirable bacterial growth and produce foul odors [6].

Moisture content plays an important role in hydrating bacteria, allowing microbes to break down the organic material. The moisture level for pails 1-3 were significantly lower than pails 4-6. This can be attributed to the increased amount of bulking agents in the first set of pails compared to the latter. The larger quantity of bulking agents in pails 1-3 is the reason why their recorded moisture levels were lower. The lower moisture level in pails 1-3 may be the reason the temperature did not rise. The slow rise in temperature causes the composting process to take longer, and the relatively slow compost time could lead to a faulty compost or a longer cure time than desired.

The team suspects that most of the microorganisms died prior to adding insulation, which is why the piles never reached the thermophilic composting stage. However, since pails 4-6 were able to reach higher temperatures, the team recommends that wood shavings and hay should be used as the bulking agents for the prototype. The wood shavings provide a high carbon content, whereas hay has a high nitrogen content. Using just one of these bulking agents would produce a C:N ratio that is outside of ideal limits. The team suggests that the next team repeats this test with insulation on the pails from the beginning of the test through completion.

4.2. Limiting Hours of Labor

The team needed to make sure that the operator did not have to spend more than two hours per day managing the composting system.

4.2.1. Associated Tests

The Aeration Test evaluated different frequencies of aeration. For this test, three different time intervals of aerating the piles were used to determine if the time of aeration had an effect on the compost. The three intervals were: twice a week, once a week, and once biweekly. The

objective of this test was to determine the minimum amount of time the operator needs to aerate the pile to prevent the compost from turning anaerobic. Six 5-gallon pails were used for this test; each aeration frequency was repeated with two piles. Table 2 describes the aeration timelines for each pail.

Table 2. Description of the aeration frequencies for each of the pails in the Aeration Test.

Pails	Aeration Frequency
1, 2	Twice a week
3, 4	Once a week
5, 6	Once biweekly

The pH, moisture content, and temperature of all pails was recorded twice a week. The same instruments used to track the temperature, moisture content, and pH for the Composting Time Test were also used for this test. The acceptable criteria for this test was that the piles maintained aerobic composting and that the time required for operation is less than two hours a day.

The piles were mixed by hand with a wooden stick. This was decided because the team could deliberately break apart any clumps of material.

4.2.2. Test Results

Taking measurements of all metrics of interest for the compost piles takes a total of 25 minutes, with the breakdown of the time for each measurement shown in Table 3. Table 4 shows the difference between the amount of time needed for each aeration test.

Table 3. Total time required for measuring all compost parameters.

Measurement	Time Required [minutes]
pH	10
Moisture Content	10
Temperature	5
Aeration	2
Total	**27**

Table 4. Time taken by each aeration test.

Aeration Frequency	Time Required per 2 Weeks [minutes]
Twice a Week	108
Once a Week	54
Once Twice a Week	27

Table 5 displays the results of all measured parameters in the Aeration Test.

Table 5. Average values of the temperature, pH, and moisture level measurements for the duration of the Aeration Test (4 weeks).

Amount of times Aerated	Pail	Temperature [°F]	pH [-]	Moisture Level [%]
2 per week	1	79.5	7.2	64
	2	80.0	7.2	64
1 per week	3	81.2	7.4	59
	4	81.3	7.1	55
1 per 2 weeks	5	80.3	7.5	58
	6	81.3	7.4	47

Figures 8-10 show the measured moisture content, temperatures, and pH values, respectively, of all the pails in the Aeration Test.

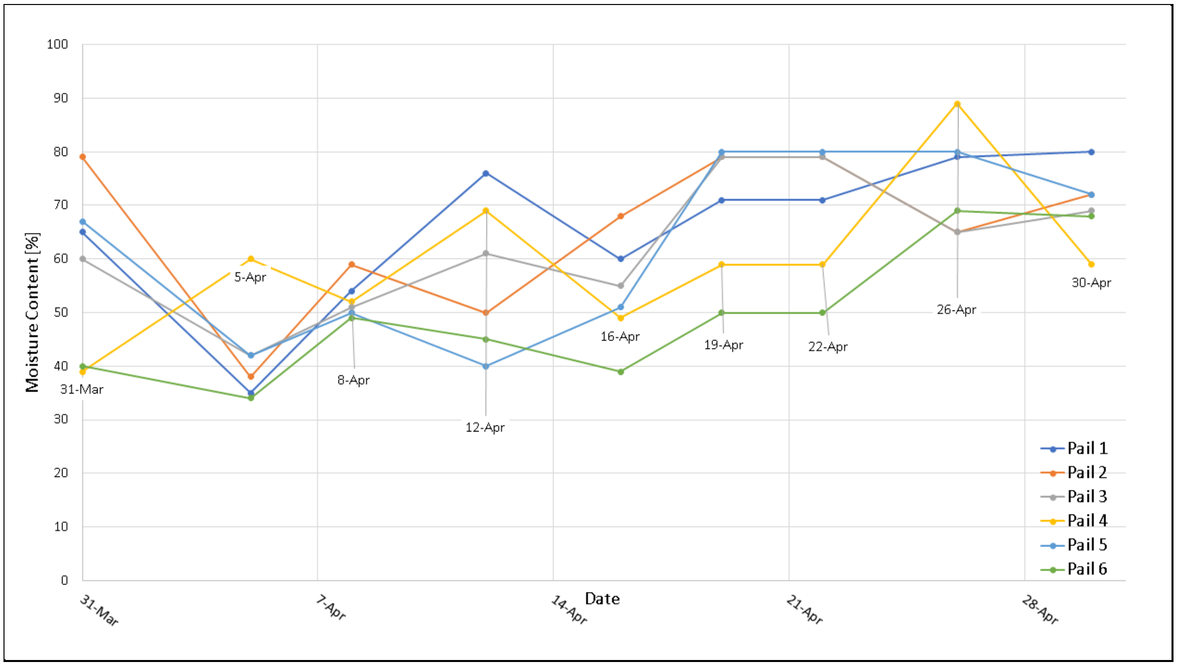

Figure 8. Comparison of the moisture contents for each aeration frequency test in the Aeration Test.

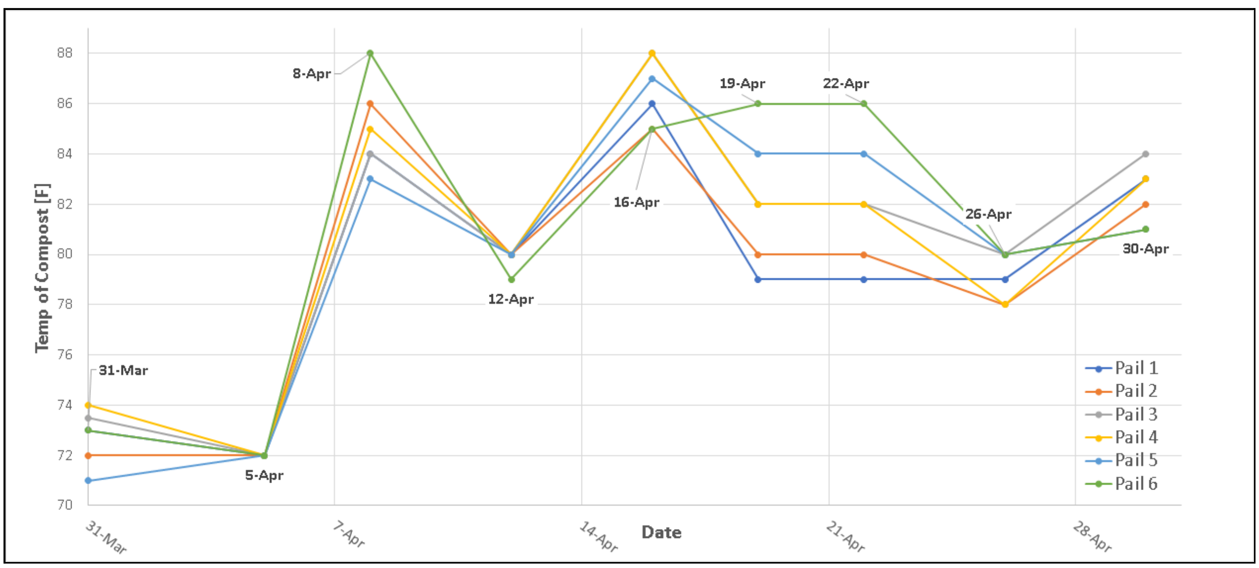

Figure 9. Comparison of the temperatures for each aeration frequency test in the Aeration Test.

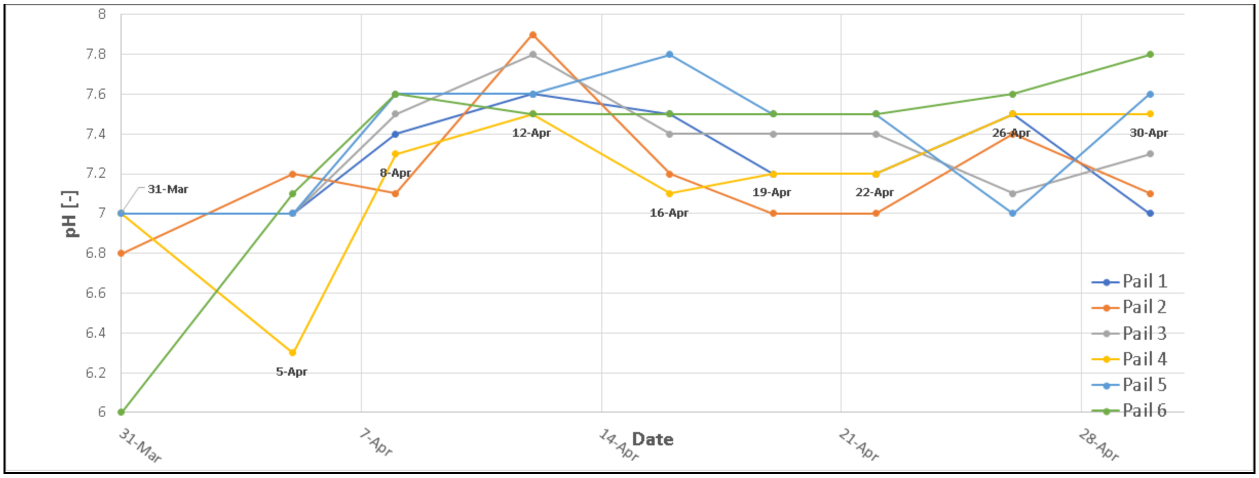

Figure 10. Comparison of the pH levels for each aeration frequency test in the Aeration Test.

4.2.3. Evaluation

Unlike the Composting Time Test, the team measured the data of the compost piles every time they were aerated, instead of everyday. This decision was made because the results from the Composting Time Test showed that there were not often dramatic changes on a day to day basis.

From this test, the team concluded that any of the aeration frequencies would meet the labor time requirement of less than two hours per day. The test that takes the most amount of time to operate is the aeration schedule of twice a week. This test has the operator interacting with the pile twice a week and each interaction would only take about 30 minutes.

Table 5 shows the averages of the pH, moisture content, and the temperature of every pile that was tested. Pails 3-6 had the highest average temperatures, and pails 1-2 had the lowest temperature averages.

While the different pails were fairly close with the temperature averages, the moisture levels of the compost piles have a large difference and really shows one of the tests as untenable. Table 5 shows that the moisture level for pails 1-2 is above the ideal conditions at a moisture level of 64% for each test. Pails 3 and 4 had moisture levels of 59% and 55%, respectively, which are within ideal conditions. These moisture levels are the closest to the mathematical model that the team performed in the first semester. The models that the team calculated had moisture levels, depending on the amount of bulking agents used, around 56-59% which is similar to the pails that were aerated once a week. Although pails 5-6 also had a moisture level that was within the ideal range, the piles did not seem to be consistent; there was a large difference between the two pails.

The pH of the tests were all within an acceptable range. Figure 6 looks like there is a lot of variation between the pH levels but it is important to notice the y-axis and that it only goes between 6 and 8. This shows that the pH was almost always within the range of 7-8 on the pH scale. The only tests that had a number outside of this range was pail 6 with a pH value of 6 and pail 4 with a pH of 6.4. Both of these values are still within an acceptable range for a pH value and were only within the 6-7 range for a single measurement.

The team wants to address that the time for aeration could be subject to change depending on the mass of the compost being used. However, even if the time changes, the pile should not need to be aerated more than twice a week.

4.3. Odor

The team needed to assess whether or not the compost piles produced an odor. The prototype will be located on the loading dock of Mabee Dining Hall, which is near student dormitories. The sponsor specified that the system must not produce an odor due to the fact that the composter will be on Trinity grounds and near to the student population.

4.3.1. Associated Tests

The team monitored odor during the Aeration Test.

4.3.2. Test Results

The odor was subjectively evaluated based on a scale of 1 to 5, where 5 is the worst smell. At the beginning of the Aeration Test, each pail was filled with the same amount of food waste and bulking agents. Initially, the team did not drill holes into the lids of the pails. On day 6, the team drilled holes. Table 5 shows the recorded odors for the respective day of measurements.

Table 5. Observations of odor in the Aeration Test.

Day	Odor
5	5
8	4.5
12	3
16	3
19	1
22	1
26	1
30	1

4.2.3. Evaluation

The team suspects that the odor at the beginning of this test was due to the piles turning anaerobic. Aerobic composting can turn anaerobic if the pile does not allow for air flow, so the piles likely went anaerobic without the air holes on the lids. Anaerobic composting results in a foul odor, but it can be reversed upon aerating the pile until the moisture level is reduced [7]. After the holes were drilled into the pail lids and the piles were aerated, the odor dissipated. When the odor reached a level of 1, the piles smelt earthy like the hay and organic matter.

5. Conclusions

The team had to make modifications to the project plan as the year progressed and certain factors of the project scope were altered. The team's schedule was pushed back due to a winter storm that delayed the start of empirical testing and caused a longer waiting period for equipment to be shipped. As a result, the team did not have time to conduct testing on the prototype. However, the team has satisfied the requirements set forth for the prototype in the most recent project plan. The prototype is intended to be used as a foundation for next year's team; the next team can perform empirical tests inside the prototype and use the design as a reference for the scaled-up version of the project.

The current team has been able to accomplish all of the design and project requirements that were given to them by the project sponsor and advisor. The team has suggested a composting method based on the limiting factors of Trinity University, such as location of the composter and operational cost. The team also made a suggestion on the types of bulking agents that would satisfy the ideal conditions of the composting process. The team has been able to reduce the amount of labor hours per day that were required to operate the previous composter used at Mabee. The team has also made recommendations on the particle size of the compost and the frequency of aeration that the compost requires. Lastly, a CAD drawing and an instruction manual, which were project requirements, were created for the prototype.

The team was not able to fulfill some of the design requirements that were originally set at the beginning of the year, such as building a full-size prototype handling up to 100 pounds of food waste per day. This was unfeasible for the team because of the large amount of research and testing that was required to validate the research. The team has recommended empirical tests for next year's team to perform, which is described in Appendix B. One of the proposals is that the Composting Time Test and the Aeration Test be repeated with insulation around the piles from the start of the test; the insulation should prevent heat loss so that the piles are able to complete the composting process.

To conclude the progress for this year's team, we have maintained contact with the project sponsor throughout the year and have accomplished all the requirements set forth by all parties of the project.

6. Appendices

Appendix A: Moisture Content and C:N Calculations

Equation 1 was used to estimate the input moisture content for the food waste coming from Mabee Dining Hall [8].

$$G = \frac{(Q_1 x M_1)+(Q_2 x M_2)+(Q_3 x M_3)+...}{Q_1+Q_2+Q_3+...} \quad (1)$$

In Equation 1, "G" represents the total moisture content of the food waste produced by Mabee dining hall. Q_n represents the mass of the material n, and M_n represents the moisture content in the material n as a percent.

To determine the amount of bulking agents needed the Eq. 2 was used [8].

$$Q_B = \frac{(GxQ_1)+(GxQ_2)-(M_1xQ_1)-(M_2}{M_B-G} \quad (2)$$

In Equation 2, Q_B represents the mass of bulking agents in pounds needed to bring the compost to an ideal environment. Q_n represents the weight of the food waste in the compost, M_n represents the moisture content of the food waste in the compost, G represents the moisture content goal, and M_B represents the moisture content of the bulking agent.

Equation 3 was used to estimate the C:N ratio of the input food waste stream [9].

$$R = \frac{Q_1(C_1x(100-M_1)+Q_2(C_2x(100-M_2)+...}{Q_1(N_1x(100-M_1)+Q_2(N_2x(100-M_2)+...} \quad (3)$$

In Eq. 3, "R" represents the resultant C:N ratio, "Q_n" represents the mass of the materials, "M_n" represents the moisture content of the material, "C_n" represents the Carbon % composition, and "N_n" represents the Nitrogen % composition.

Appendix B: Composter Prototype Test Data

1. Test Summaries

The Composting Time Test evaluated bulking agents and environmental parameters (moisture content, temperature, and pH). The team compared ratios of food waste to bulking agent(s) and the difference between the combination of bulking agents. The tests consisted of six 5-gallon pails. The first set of three pails tested a ratio of 1:1 (food waste:wood shavings), and the other three pails tested 4:2:1 (food waste:hay:wood shavings).

The piles in the Composting Time test did not produce odors. The pails with the 1:1 ratio did not change in appearance; the pails looked to be primarily wood shavings. The organic matter in the 4:2:1 ratio appeared darker in color (shown in Fig. 11) and decreased in volume (shown in Fig. 12) as time went . The consistency of these piles were slightly damp and had an almost sponge-like consistency where they would compress when squeezed and slowly expand back to their original size.

Figure 11. Pictures showing the difference in color at the beginning (left) and at the end of the composting process (right).

Figure 12. Pictures showing the difference in volume at the beginning (left) and at the end of the composting process (right).

The Aeration Test evaluated moisture content and odor to determine the optimum aeration frequency. This test was conducted with 6 additional 5-gallon pails. Three aeration frequencies (2 pails per test) were tested: twice a week, once a week, once biweekly. The compost piles in developed visible white fungus growth, shown in Fig. 13, which could be an indication of actinomycetes [10]. Some fungi can be detrimental to the compost, however the presence of actinomycetes indicates successful decomposition of fibrous materials [10].

Figure 13. White fungus growth during Aeration Test.

The team recommends that the next team repeats the Composting Time Test and the Aeration Test (with insulation on all 12 pails) at the beginning of the Fall semester. The additional data will help the team understand the composting process and provide insight as to whether or not insulation affects the composting timeline and/or environmental conditions.

In addition to these tests, the next team should evaluate the compatibility of compost with Trinity's soil. For example, after the curing stage of composting is complete, there should be a test conducted to determine if the compost is nutritional to the soil on campus. This test is important because premature compost may contain harmful microorganisms that can damage plants [11]. However, maintaining ideal conditions for the moisture content and C:N ratios of the compost should mitigate the risk of harmful microorganisms.

The raw data for the compost testing can be found here.
The raw data for the aeration testing can be found here.
The raw data for the mathematical modeling can be found here.

Appendix C: Composting Review

The team reviewed five composting methods: in-vessel composting, aerated static pile, vermicomposting, and anaerobic digestion. Composting is the natural process of organic material being decomposed by microorganisms, and it can be classified into two different processes: anaerobic and aerobic [12]. The difference between these processes is whether or not the microorganisms need oxygen to thrive; in aerobic composting, the microorganisms require oxygen.

Anaerobic composting is unique to the other methods found by the team in that it does not require oxygen to take place. Similar to in-vessel and vermicomposting, anaerobic composting requires an enclosed space so that it can keep oxygen out of the composting material. It can take anywhere from 20-30 days for the bacteria produced during this process to break down the organic material and produce compost [12]. One con to anaerobic composting is that it produces biogas which requires trained personnel to be able to be handled due to its explosive nature [12]. Another issue with anaerobic composting is that it requires expensive equipment to operate [12]. Anaerobic composting also tends to produce foul smelling odors and takes much longer to decompose material [12], so the team recommends using an anaerobic process.

The aerobic processes that the team researched include in-vessel composting, vermicomposting, and aerated static pile composting. For in-vessel composting, the materials are fed into an enclosed system and depend on natural occurring bacteria to break down the material. In-vessel composting is a promising choice of composting because it can handle various types of food waste and is relatively faster than other types of composting by a week or two. In-vessel composting needs to be aerated regularly during the composting process to prevent the compost from turning anaerobic. This aeration can be handled either mechanically through a mixer, such as an auger, or with air being blown through the pile with a pipe.

Vermicomposting requires worms to aid in the breakdown of organic matter in contrast to in-vessel composting that relies on microbial activity. Similar to in-vessel composting, vermicomposting requires an enclosed vessel for the process. Red worms are the most common types of worms used for this style of composting [13]. The C:N ratio of vermicomposting needs to be kept with a much higher carbon rating then in-vessel with a C:N ratio of 20:1 while in-vessel can be kept at 35:1 [13]. Another downside to this style of composting is that there are several waste restrictions to this style of composting due to the worms and their natural diet; straying from their natural diet could lead to the worms becoming sick and dying [13]

Aerated static pile composting is the process of stacking organic waste in an open environment. Aerated static composting is a very effective method in regards to labor because very few turns of the composting pile are required. These static piles are also really good at eliminating prolonged odor that can be produced by other methods. Even though some aspects of

aerated static pile composting is useful, it also has many disadvantages. One big issue with the static pile method is that the material can dry out before it has fully broken down and been composted [14], so water must be added to the pile which could increase operational costs. Another issue with the static composting method is that the pile will require a blanket of finished compost or mulch to cover any piles that have just started to get the process started [14].

Table 6 shows the decision matrix for all of the composting processes that the team researched. The main constraints were ease of use (because specialty employees will not be hired to operate the composter), sustainability, and financially feasible (which included the ongoing operational cost). Scalability refers to the ability for the composter to adapt to low-volume and high-volume waste outputs from Mabee Dining Hall (i.e., summer months versus mid-semester). The decision matrix led the team to choose in-vessel composting as the most useful method for Trinity.

Table 6. Decision matrix for composting method.

Category	Weighting factor	In-vessel composting	Vermi-composting	Aerated Static Pile Composting	Anaerobic
Ease of Use	10	6	8	5	3
Sustainable	7	7	3	8	5
Financially feasible	9	5	6	5	1
Odor	5	9	5	3	7
Speed	6	4	3	2	5
Size	4	7	9	1	4
Scalability	7	7	4	7	7
Total Score		**300**	262	231	204

Appendix D: Instruction Manual

Procedures for the operation of the composter prototype:

1. To operate the composter prototype, rotate the barrel so that the black slide bolt is on the top. Take off the silver carabiner and switch the position of the gate lock to the right-side. Secure the position with the carabiner.

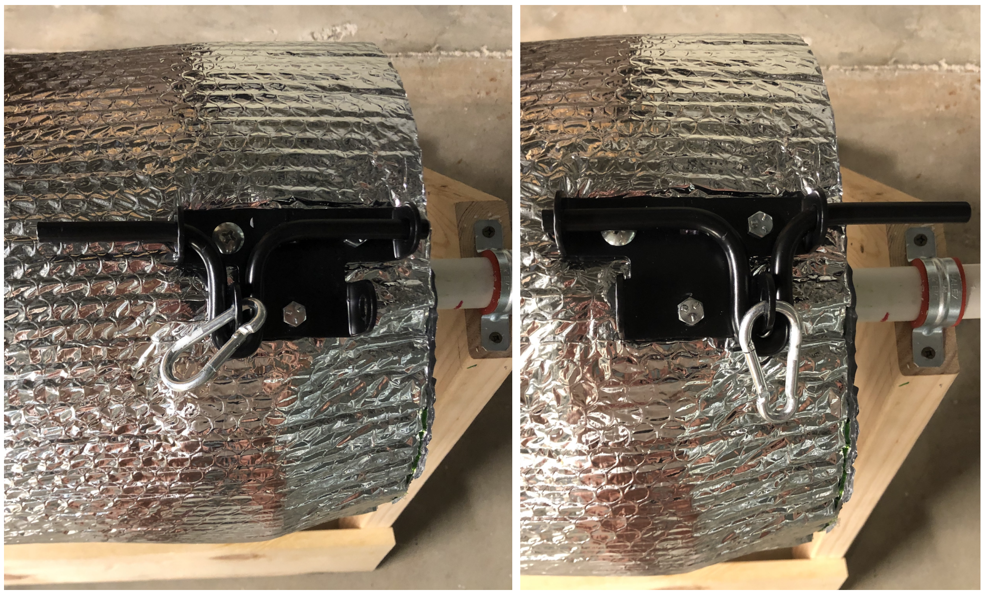

Figure 14. Securing the position of the balck slide bolt.

2. Rotate the barrel so that the bolt is now at the bottom of the composter. Slide the barrel to the right, with the bolt secured between the A-frame. This will prevent the drum from rotating excessively while loading.

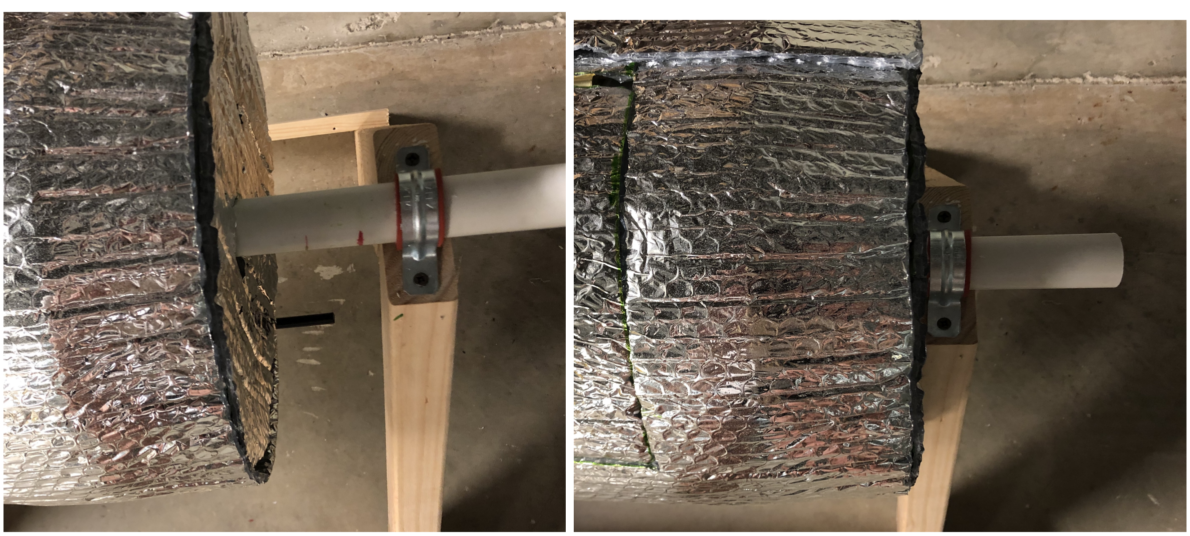

Figure 15. Sliding drum across the PVC pipe to secure the position of the door on the top-side.

Figure 16. Slide bolt secured between the A-frame to prevent excessive rotation of the drum when loading the composter.

3. Unlock the post hasp by turning the lock to a vertical position. Open the door and load the contents (i.e., food waste and bulking agents) into the composter. Shut the door and lock the hasp.

Figure 17. Unlocking the post hasp.

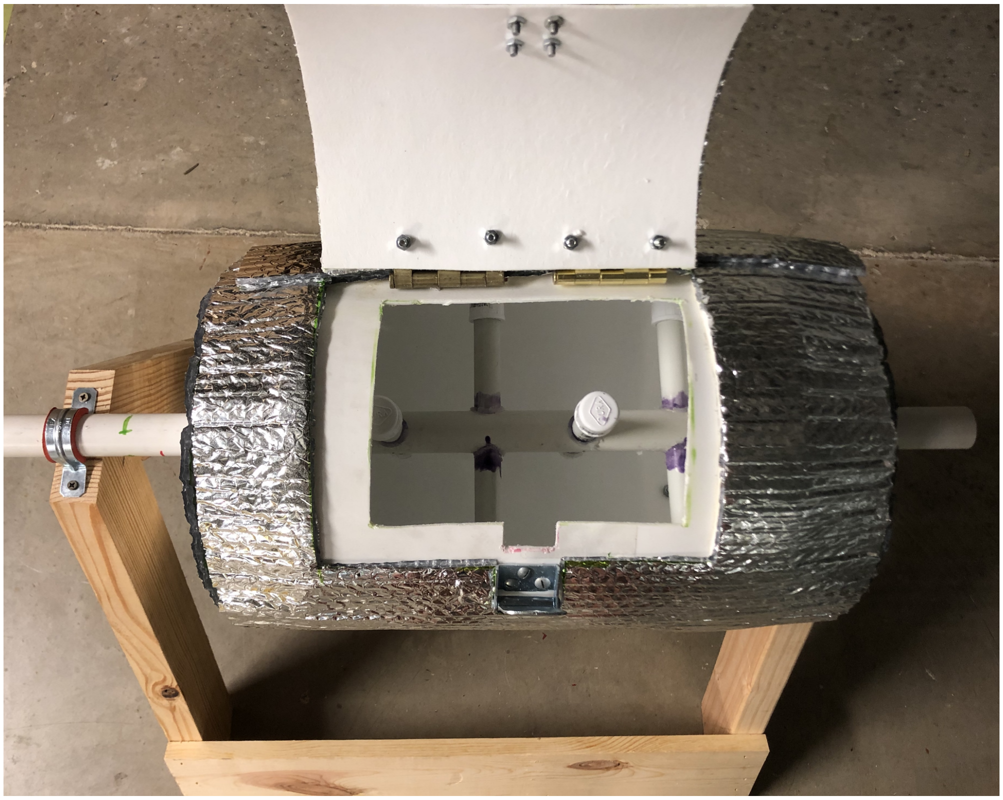

Figure 18. Open door for loading the composter.

4. Slide the barrel across the PVC pipe to the left. Rotate the barrel so that the black slide bolt is on the top again. Switch the position of the black slide bolt to the left-hand-side and secure it with the silver carabiner. This will allow the drum to spin around the PVC pipe.

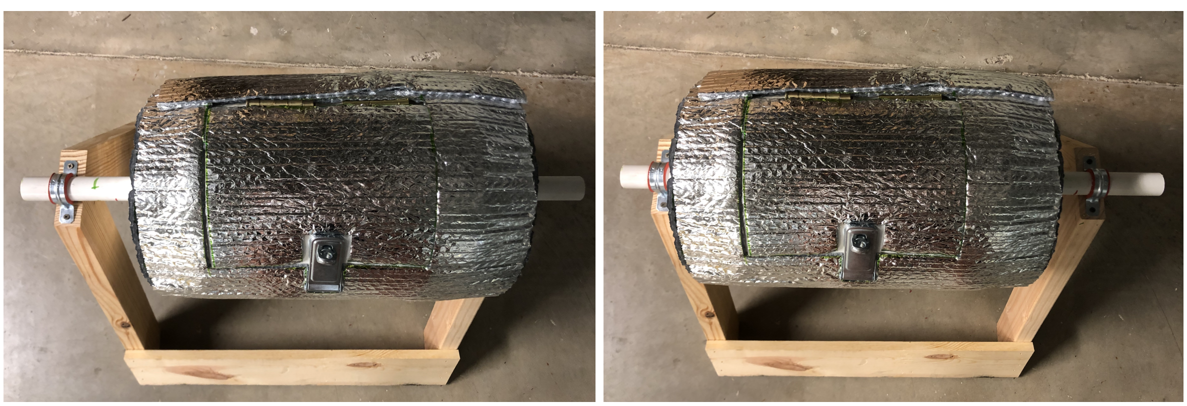

Figure 19. Sliding the drum to the right to allow rotation of the drum.

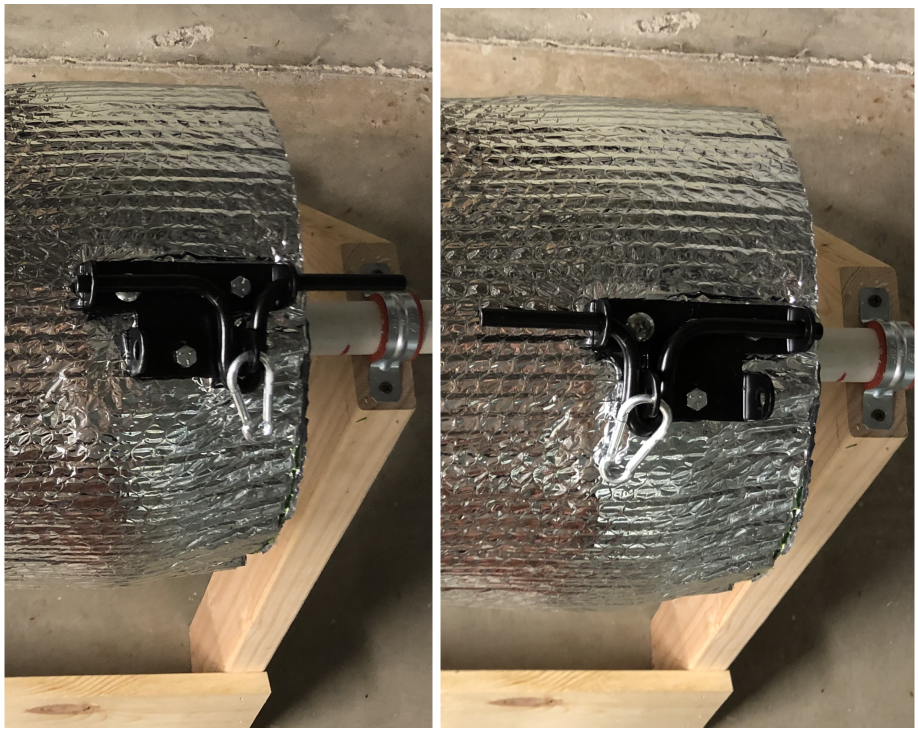

Figure 20. Securing the position of the black slide bolt on the left-hand-side to allow the drum to rotate.

Now that the composter is loaded, here are the instructions for the composting process:

1. Aerate the pile once a week by spinning the drum around the PVC pipe. The spikes inside the composter will break apart large clumps that may form during the composting process. Each time the pile is aerated, measure the temperature, moisture content, and pH of the pile. If the Sonkir probes are used to measure the moisture content and pH, turn the switch on the probe to the appropriate measurement. Insert the probe into the pile and wait 10 minutes for the probe to stabilize. Record the measurement. Slide the switch to the other measurement and wait another 10 minutes before recording the measurement.
2. After 4-6 weeks, the pile should have reached the thermophilic stage (temperatures between 113-158ºF) and cooled back down to mesophilic temperatures (50-113ºF). After this occurs, the compost has cured and will be ready for removal from the composter. To unload the composter, unlock the post hasp on the door by turning the lock to the vertical position. Turn the drum so that the lid is facing the ground. The compost should fall out due to gravity.

Recommendations for the food waste feedstock and bulking agents:

To generate the best compost in the desired timeframe of 4-6 weeks and limit the odor generated, the team recommends including certain food groups while excluding others. Food waste that should be included in the compost are: low acidity fruits (i.e., melons, apples, etc.),

vegetables, breads and other high carbohydrate foods. The following foods should be excluded: coffee grounds, high acidity fruits (i.e., pineapple), meats, and egg shells.

The particle size of food waste should be reduced to about ½ an inch to 1-inch. However, particle sizes that are too small are counter-productive; the particle size must be larger than an ⅛ of an inch.

For the bulking agents, the team recommends the combination of hay and wood shavings. The recommended ratio of food waste to bulking agents is 4:2:1 (food waste:hay:wood shavings).

Appendix E: Bill of Materials

Tables 7 and 8 will showcase the bill of materials for the prototype and the suppliers for all materials, including the materials used in testing.

Table 7. Bill of materials for prototype.

Item	Quantity	Price/Unit [$]	Total Price [$]
6-gallon HDPE drum	4	4.12	16.48
Door hinge	2	2.98	5.96
Post hasp	1	6.18	6.18
2x4 wood	4	2.48	9.92
Wood biscuits	4	0.08	0.32
Foil bubble insulation	1	43.21	43.21
Wood glue	1	2.97	2.97
1-inch diameter PVC	1	4.37	4.37
½-inch diameter PVC	1	2.40	2.40
PVC cap slip	10	0.47	4.70
PVC primer and cement	1	7.97	7.97
Silicone gap filler	1	4.28	4.28
Slide bolt	1	5.45	5.45
Carabiner	1	2.15	2.15
2-hole strap	2	0.65	1.30
Velcro	2	3.47	6.94
Total price to construct 1 prototype:			124.60

Table 8. List of suppliers for materials purchased (including materials used for testing).

Supplier	Materials
Tractor Supply	5-gallon pails, pail lids, pine shavings
Amazon	Sonkir moisture meter and pH probe, thermometer
Walmart	Hay
Barrels for Sale	6-gallon HDPE drums
Lowe's	Foil bubble insulation
Home Depot	PVC pipe, PVC cap slips, lumber, 2-hole straps, door hinge, post hasp, slide bolt, velcro

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Signatures

Project Name: Mabee Waste Solution Team

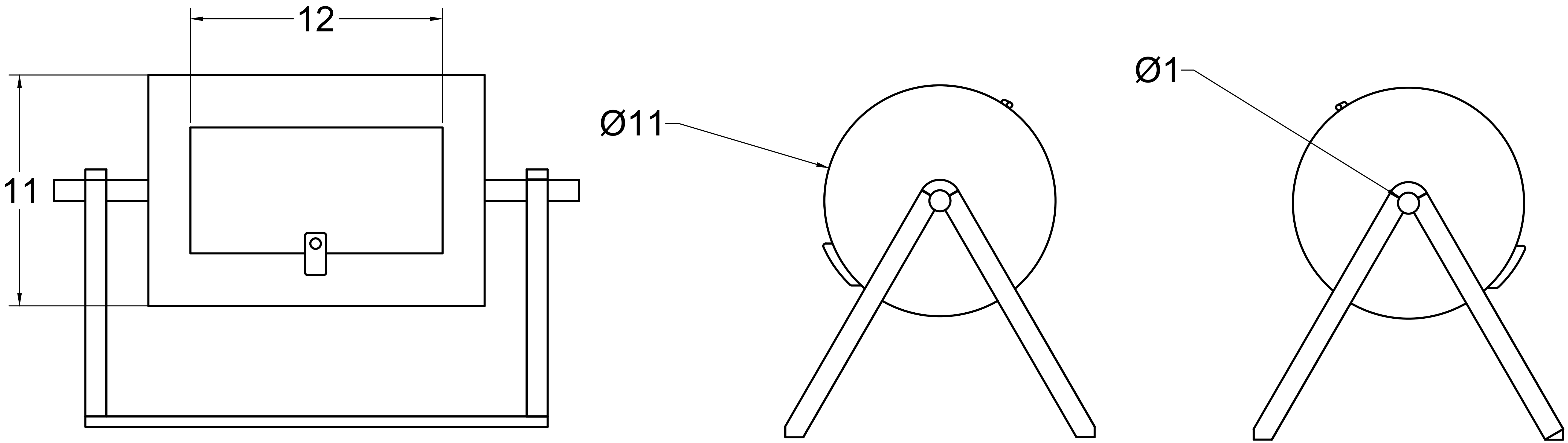
The undersigned have reviewed and approved the final version of this document.

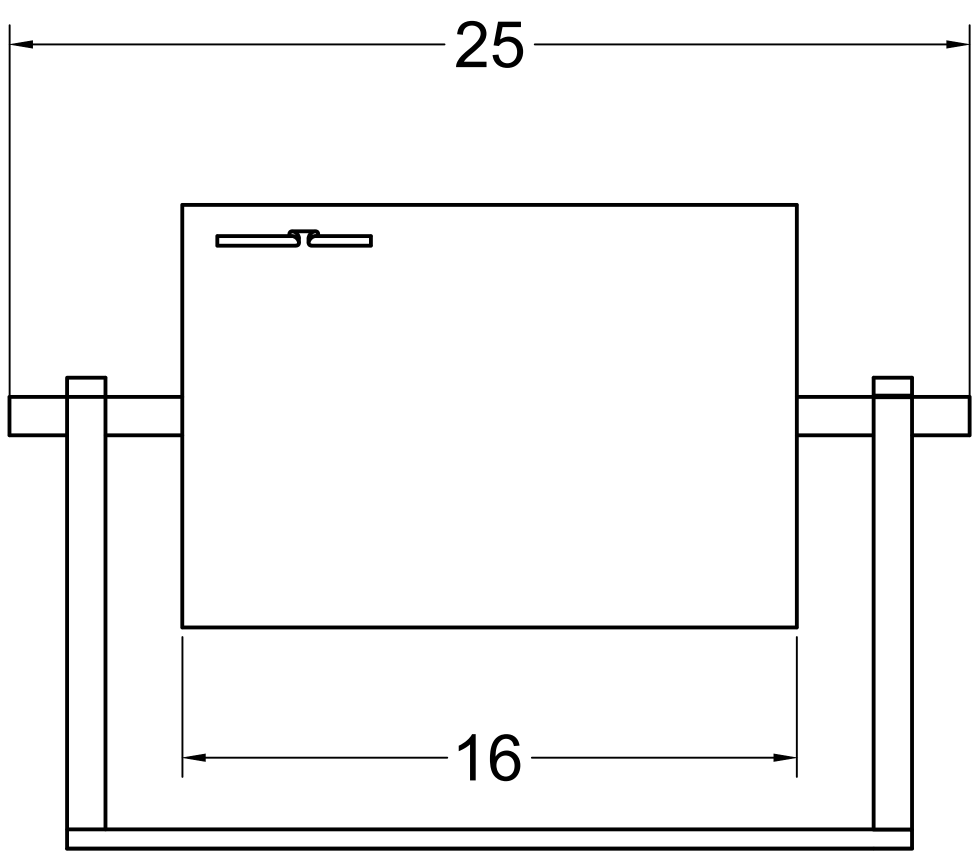
	Date Received	Date Approved
Team Members:		
Mary Hippensteel	5/7/21	Mary Hippensteel
Armando Rodriguez	5/7/21	Armando Rodriguez
Matthew Willis	5/7/21	Matthew Willis
Team Adviser:		
Eliseo Iglesias		5/7/2021

Document Change Control

This section records the revisions to this document.

Version Number	Date of Issue	Brief Description of Change
I	7 May 2021	Initial Version





A 0.3 in thick foil bubble insulation sheet was used to cover the entirety of the tank.

All specified dimensions are in inches.

PROJECT	Mabee Food Waste Solution Team				
TITLE	Compost Tank Prototype				
APPROVED		SIZE B	CODE	DWG NO	REV
CHECKED					
DRAWN	Mabee Waste Solution Team 5/4/2021	SCALE 1:5	WEIGHT	SHEET 1/1	