Improved Food Waste Processing Through Water Removal in a University Dining Hall

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Abstract - **Elon University has committed to composting food waste, however currently this process requires biweekly visits from CompostNow: a company that takes compost from the community and turns it into fertilizer. Reducing the weight of the waste will result in fewer trips and therefore a reduction in carbon emissions for the composting process; according to U.N. Food and Agriculture Organization, every pound of food thrown away equates to 3.8 pounds of greenhouse gas emissions. The current process being used by Elon University requires compost to be stored in individual cans which hold 200 pounds each. Our analysis of the current composting process reveals potential for savings in cost and emissions. Since compost is comprised of 40-60% water, due to its high-water content, liquid removal from the compost would result in a more efficient process. Therefore, our team proposes a way to reduce the amount of water in compost which will in turn result in a reduction of costs for Elon University. Through observational visits, we established a process flow model of Lakeside dining hall. This included both pre-consumer and post-consumer waste. This model was used to identify potential sizes and locations for compaction as well as to specify our user needs. We additionally performed research into state-of-the-art compaction units as well as user preferences. Regulations and standards for liquid leachate disposal were also reviewed for potential effects on operations. Process flow information was used to specify and design a solution to reduce the weight of compostable food waste. We anticipate that the successful incorporation of this compaction technology into Elon University dining operations will result in decreased cost and carbon emissions associated with composting.**

Index Terms – composting, waste, process optimization, compaction.

INTRODUCTION

Globally, roughly one-third of food produced for human consumption is wasted, an amount of which could feed approximately three billion people [1]. Because the amount of food produced cannot be reversed, one of the most effective ways to make use of food waste is composting [6]. According to the US Environmental Protection Agency, composting is the fifth tier of the EPA Food Recovery Hierarchy, ranking second to last in the most preferred methods of food waste. The benefits associated with composting include but are not limited to reducing methane emissions, reducing the need for chemical fertilizers, aiding reforestation, remediating soils contaminated by hazardous waste, and enhancing water retention in soils. of the biggest problems our engineering team is trying to solve is a way to make composting more attractive. Composting is a time-consuming and often expensive process. Our engineering team wants to tap into finding solutions to food waste by coming up with ways to make composting efficient, affordable, and feasible for average, residential/ university-based users. Our designs will aim to eliminate the negatives that come with compacting and dehydrating the compost as well as leachate, an unpleasant byproduct of composting. Our team aims to find ways to safely store and eliminate the smell of leachate or find alternative uses for it while implementing a composting system to better handle compostable food waste.

The current state of composting is promising but not sufficient. Composting is not only environmentally beneficial, but it is also good for creating jobs. For example, composting operations in Maryland provide more jobs than the state's three trash incinerators combined. There are also new markets that have emerged for compost-based products which means that there is an opportunity for more composting operations. In the United States, regulations have been placed to encourage or require the diversion of source-separated organics. Additionally, over 20 states have enacted bans on the disposal of yard trimmings in landfills. California's waste diversion goal has been effective for creating local organic diversion programs that target yard trimmings and food scraps. California has the highest composting tonnage (5.9 million tons), followed by Florida (1.5 million tons), Washington (1.2 million tons), and New York (1.0 million tons) [6]. Based on the statistics, it seems as though only major cities are taking composting initiatives. Problems associated with composting include increasing household and waste management companies' workload on food wastes collection and sorting. Furthermore, composting facilities cannot generate revenue as they struggle to find end-users for compost-based products. Additionally, odor is an unpleasant byproduct of composting that makes composting less attractive.

By designing an easier, more affordable, and more efficient way to compost alongside Wastequip, a waste handling and disposal equipment manufacturer based in Charlotte, North Carolina, our engineering team hopes to make more people want to compost. Composting will help achieve environmental sustainability because compost will reduce the use of chemical fertilizers and divert organic waste from landfills. Currently, landfills have become the third largest source of methane emission [5]. Researchers have proposed diverting food waste from landfills because it can significantly reduce methane emissions. Not only will composting reduce the number of materials that end up in landfills, but composting is an effective way to recycle organic material by converting them into beneficial products.

The increase in composting predicted by the implementation of the proposed project will ultimately create an efficient way for people to make use of food waste. An increase in composting greatly benefits society in various ways, including the reduction of landfill mass, in-house odor due to trash, and the possible use of food waste as a form of energy. Through further research into current models and the design and prototyping of new bin designs, it is the goal of this project to increase efficiency and reduce the cost of university composting practices. The potential user base of the proposed project are the university campuses and potentially restaurants. Many organizations have tried to compost using a method called co-composting, relying on controlled aerobics, or the natural degradation of organic materials. The disadvantage of this system is that it is inefficient and incompetent. The by-products of aerobic composting include CH_4, N_2O, and NH_3 which are very harmful to the environment [3]. Our project purpose is to attempt to solve these problems at a residential level. The creation of a composting bin with an included filter, grinder, or compactor (the final product will depend on prototyping) can reduce and potentially eliminate the odor from composting and trapping the by-product of composting from being released into the air. Impacts our project will have is more people composting, a reduction in waste, a reduction in the need for chemical fertilizers, and a more pleasant smell.

The first objective associated with the proposed project is to design and evaluate the use of composting bins on university campuses. The design of the bin will focus on usage on a university campus composting scale. By implementing efficient composting bins on university campuses, we hope to increase efficiency and cut the cost of the current rate of food waste composting process. Various prototypes of these bins rely on different forms of filtering or waste-size reduction. By including designs with compactors or grinders, it is believed that the rate of composting will increase composting rates as it will need to be emptied less frequently. With the implementation of these composting bins, it is a goal of this project to test its effectiveness on Elon University campus.

An additional objective of the project is to determine the most efficient way to deter any odors from bins. Through the design process, various forms of composting methods will be tested. Possible design ideas include the use of filters and possible drainage systems. Through the use of a charcoal filter, it is possible to increase the retention rate of any odors expelled by the food waste within the bin. Possible drainage system implementation relies on the decision of whether the bins will be stored indoors or outdoors. If outdoors, it is possible to include a system that expels any leachate from the bin before the buildup of odors.

METHODS AND MATERIALS

Specification of our compost water-removal solution required analysis of the process flow of a typical dining hall. For our analysis, we selected Lakeside Dining hall at Elon University: the largest dining hall on campus. Through interviewing the dining hall staff, executive chef, as well as the Director of Sustainability, as well as observing operations, we developed a process flow map of the Lakeside dining hall.

This process flow map allowed us to determine not only potential locations for intervention, but to roughly estimate how much waste would be generated – a necessary component of our design. Compostable food waste was important not only to on-campus staff interested in waste reduction and composting; but also to the executive chef, who tracks food waste generated.

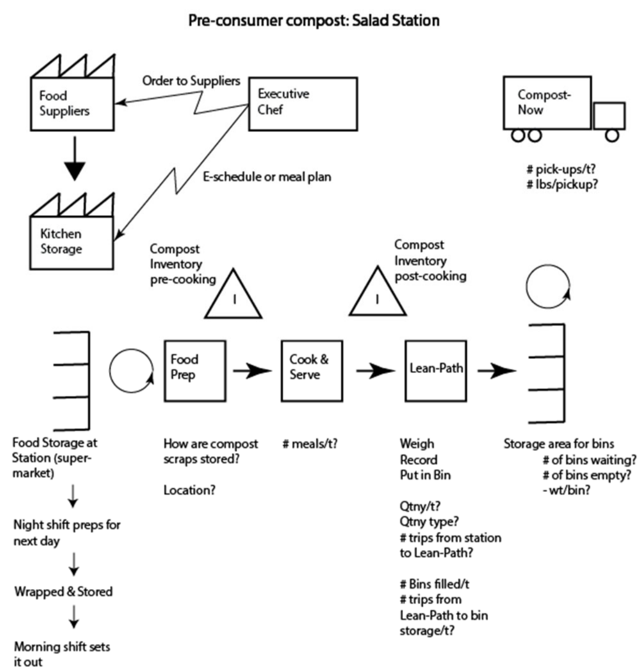

FIGURE I
PROCESS FLOW MAP OF LAKESIDE DINING HALL. THIS PROCESS FLOW MAP WAS USED TO UNDERSTAND HOW WASTE WAS PROCESSED THROUGH THE DINING HALL AND TO UNDERSTAND POTENTIAL LOCATIONS FOR OUR INTERVENTION.

The rough process flow is as follows: the executive chef orders food from the food suppliers based on a meal plan or electronic scheduling. Food arrives from the suppliers and is stored in the kitchen storage area. Stations take food from main kitchen storage to prepare for mealtime: the night shift prepares for the next day. Food prepared by the night shift is wrapped and stored for the morning shift.

The morning shift sets out food prepared the night before and continues to do further processing on the food in preparation for meals. Food is continuously cooked and served during mealtimes. Post processing waste, including scraps and trimmings, is weighed and identified using a LeanPath device, which records weight and type of food waste. This food waste is then stored in multiple plastic bins for pickup through a compost waste processing service. One advantage of this service is that it is able to accept both plant based and meat based material for composting. This means that waste does not require further separation after processing through the LeanPath. Each bin has a weight limit of two hundred pounds due to restrictions set by the composting company. Additionally, while we inquired about contamination with plastic and other non-compostable materials, this was determined to be a fairly minor issue.

Based upon our observations we developed a prototype device to evaluate the relationship between force and water removed. This prototype device was constructed based on two five gallon buckets (Bucket A and Bucket B). Utilizing a power drill, small holes were punctured into the bottom of Bucket A and overlayed with kitchen sink strainers that were repurposed to lay flush against the bottom of the bucket. A piece of solid acrylic was cut down to a radius just smaller than that of the bucket and was attached to a conventional bathroom plunger. Bucket A was then filled with 5 lbs of compost (vegetable and fruit waste) and placed inside Bucket B. Force was applied to the acrylic by pushing downward on the plunger, expelling liquid from the solid compost. Force was measured using a conventional bathroom scale (Etekcity, Amazon.com).

RESULTS

Compostable vegetable waste was obtained from Elon Dining and evaluated in our experimental compactor. In our first trial, we found that applying 200 pounds of force to varying amounts of compost resulted in a range of 12.67 – 29.86% yield of leachate.

Trial	Compost Weight (lb)	Leachate weight (lb)
1	10	1.267
2	11.8	3.524
3	21.8	4.591

TABLE 1

OUR EXPERIMENTAL COMPACTOR WAS USED TO ESTIMATE THE AMOUNT OF LEACHATE THAT WOULD RESULT FROM COMPRESSION OF VEGETABLE SCRAP COMPOST. 200 POUNDS WAS APPLIED TO VARYING AMOUNT OF LEACHATE.

Currently, three different kitchen-scale compactors were identified as being on the market. The first was the Dehydra Compact Food Waste dewaterer, which is currently in use in applications like restaurants. This dewaterer is based on a grinder that feeds to a centrifugal separator. Dewatered waste is collected in a bin through a side port. While this is a roughly continuous process, throughput is limited due to the design. ORWALK makes a FLEX trash compactor that uses hydraulics, pneumatics, or electric to compact waste directly into a container or waste bag. This is an efficient device but is not intended for de-watering. The compaction method did serve as inspiration for our current design, however. Finally, the Gaia food waste dryer is a large batch process dryer that uses heat to evaporate water from compostable waste. However, while this process is highly effective, with almost 92% water removed, this is a time-and-energy intensive batch process, making it inappropriate for relatively large waste streams such as we are encountering in the Elon Dining Hall.

FIGURE 2

PHOTOGRAPH OF RAPID PROTYPE DESIGN #1. UTILIZING BUCKETS AND MESH TO CREATE A DRAINAGE SYSTEM, THE AMOUNT OF FORCE NEEDED TO EXPEL LIQUID FROM THE SOLID COMPOST WAS DETERMINED (SEE TABLE 1).

Discussion

Fundamentally one of the major issues facing Elon Dining is lack of personnel. Therefore, our final device had to require as little manpower as possible. Our final design was based on hydraulics, as pneumatics was determined to be too loud and potentially problematic in terms of installation of air lines into an existing facility.

As part of our design process, we had to determine if leachate required storage or disposal – as the basis of our solution involves decreasing weight of composted waste, separate storage of leachate would obviate any benefit of our process. Leachate may contain dissolved organic compounds, inorganic macro compounds, as well as heavy metals such as copper, lead, cadmium, chromium, and nickel – as well as xenobiotic compounds such as polychlorindated biphenyls. The average biochemical oxygen demand (BOD) for co-composting food waste and yard waste was 6575 ± 294.40 mg/L [4]. Based on our experimental values, our estimate for leachate generation was roughly 500 gallons a week – this is insignificant compared to the amount of sewage generated by the University as a whole. If necessary, reduction of BOD in leachate could involve microalgae, hydrogen peroxide treatment, coagulation-flocculation, membrane bioreactors, or an anaerobic bioreactor [7]. While leachate can sometimes be used as fertilizer in organic cultivation farms because our compost involves meat, our leachate is not appropriate for this process. Due to the small amount of leachate generated, our design involves disposal of leachate directly into sewer.

Our design was based on a combination grinder/compactor (Figure 3). Briefly, food waste is fed into a side-mounted grinder. Ground food waste is fed into a chute in which the food will slide into a grinder comprised of two cylindrical shredders. Ground food will then fall into a bin within the exterior shell of the device. As the bin reached capacity, the compactor will be initialized, compressing all solid food waste within the bin, This will expel the liquid from the water, which will then be drained through a pipe connected to the sewage system.

CONCLUSION

In this paper we present our design for a device intended to separate leachate from compostable waste. Because compostable waste requires transport to a composting facility, reduction in waste weight would require less transport and thereby decrease the carbon footprint of our compositing process.

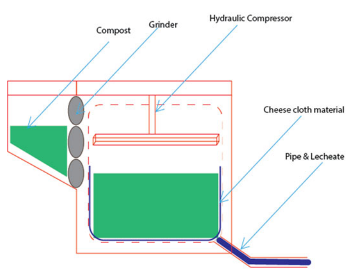

FIGURE 3

DIAGRAM OF COMPACTOR/GRINDER DEVICE. THIS DESIGN WILL BE USED FOR REFERENCE IN FURTHER STEPS OF OUR DESIGN PROCESS.

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