FORCE YEAR 7 RESEARCH PROJECT

FOOD WASTE AND YARD TRASH COMPOSTING

FINAL REPORT

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SECTION 1.0
INTRODUCTION

Goals and Objectives

This research and demonstration project (Project) was designed to address various barriers inhibiting development of viable composting operations in Florida. The goal is to encourage composting of yard trash and commercial organics in Florida by documenting sound operational practices, evaluating costs and benefits, and assessing potential environmental impacts. It is one of many activities supported by the Florida Organics Recycling Center for Excellence (FORCE) that encourage change in the current status quo and advancement of the Florida composting community.

The Project entailed the following activities:

- Pilot scale composting source-separated Food Waste (FW) and Yard Trash (YT)
- Testing of two different low technology composting methods
- Testing of two different YT / FW mix ratios
- Assessment of potential environmental impacts (leachate and odor) during active composting
- Laboratory analysis of materials at various stages of the composting process
- Assessment of operational requirements (site and facility, equipment and labor, and materials handling)
- Cost / benefit assessment

It is hoped that this practical information will help governments and private enterprises to integrate source-separated FW into cost-effective and environmentally-sound composting facilities in Florida.

Compost Regulatory Environment

The Florida Department of Environmental Protection (FDEP) is currently considering revisions to the Chapter 62-709 composting rules that will enable registration facilities to handle certain types of source-separated FW in addition to YT (a regulatory practice that is common in many other states). The key is to ensure that such facilities are comparable to YT facilities currently operating under Florida's facility registration process with regard to environment and public health impact. Some of the key changes being considered by FDEP include:

- Allow registration facilities to handle source-separated organic materials.
- Exempt registration facilities that handle only source-separated pre-consumer vegetative waste and yard trash from disinfection requirements, i.e. compliance with process to further reduce pathogen (PFRP) standards (55ºC for 15 days and 5 turnings) and pathogen reduction standards (<1,000 MPN/g fecal coliform).

It is hoped that the results of this Project will assist FDEP in its efforts to promote a streamlined regulatory process for facilities that meet certain standards when composting YT and source-separated organics.

Project Summary

This Project composted YT and post-consumer FW at the Reedy Creek composting facility in Orlando using simple low-technology composting methods, i.e. outdoor unaerated windrows turned with a front end loader. The Project evaluated two different mix ratios (4:1 versus 3:1 YT:FW) and two different turning methods (standard turning to meet FDEP disinfection standards versus minimal turning).

FW and YT are well matched feedstocks for composting; the FW provides moisture and nitrogen, while the YT provides porosity and carbon. However, Florida composting regulations have historically presented a barrier to low technology FW and YT composting because a full-scale solid waste facility permit is required to do so.

This Project demonstrated that adding FW to YT significantly enhances and accelerates the composting process. Second, it demonstrated that both composting methods can meet the FDEP pathogen reduction standard of <1,000 most probable number per gram (MPN/g) of fecal coliform. Third, it produced compost that met FDEP Class A classification standards for unrestricted distribution and use.

The Project produced mature, high quality compost in approximately four months. In comparison, it can take as much as a year or more to produce such a product from YT alone in Florida. Therefore, Florida YT composting sites that incorporate FW can realize several benefits. First, FW tipping fees provide an additional source of revenue to improve viability of the Florida composting industry. Second, the FW speeds up the composting process making it possible to process more material in the same amount of space previously used for YT only. Other community-wide benefits include avoided disposal costs and negative impacts associated with FW that would otherwise be disposed. FW accounts for approximately 5% of Florida's municipal waste (more than 1.5 million tons per year). Diverting it from landfill disposal will save space in landfills and extend their life expectancy. FW is a major source of greenhouse gas emissions from landfills due to the methane that it produces, which can be avoided by composting. With regard to waste-to-energy facilities, FW's high moisture content negatively impacts fuel value and energy recovery.

The Project also included a cost-benefit assessment of adding FW composting to an existing registered YT facility. It generated important information regarding operational procedures and costs, and a spreadsheet template for modeling operational requirements and estimating potential revenues and expenses. The assessment determined that the addition of a simple FW composting operation handling approximately 12 tons per day of FW could generate sufficient revenue from tip fees and compost sales to cover expenses, making it a self-sustaining cost center.

Acknowledgements

The Project was coordinated and conducted by Kessler Consulting, Inc. (KCI) on behalf of Sumter County and FORCE. KCI wishes to expressly thank the following parties for their generous help on the Project.

- The Reedy Creek Improvement Authority generously provided numerous in-kind services: the site, feedstocks, equipment and personnel necessary to conduct the Project.
- FDEP staff in Tallahassee and the Southwest and Central District offices provided crucial help with permitting and approvals that made the Project possible.
- HarvestQuest International, which was conducting a separate composting study at Reedy Creek, provided logistical support and help with monitoring.

SECTION 2.0
METHODOLOGY & RESULTS

Composting Methods and Mix Ratios

The Project evaluated two different composting methods. The first is the traditional unaerated turned windrow method used by many facilities. It is the least costly of the three common composting technologies – the others being aerated static pile and in-vessel composting. The second is a modified windrow method that reduces the number of turnings while still maintaining thermophillic conditions. Each is described more specifically here:

- Method 1 (PFRP): Managed to meet the FDEP time, temperature and turning standards in force at the time this Project was conducted for disinfection for unaerated windrows: 15 consecutive days at 55ºC (131ºF) with 4 turnings.[*]
- Method 2 – (Minimal Turning): Turned by bucket loader based on time and temperature feedback (turning if temperature falls below 40ºC, and turning no more frequently than once weekly).

These methods were chosen for several reasons, the primary one being that they have been shown to be the most cost-effective way to control the composting process and environmental impacts, and produce high quality compost. Method 1 is the most common composting method utilized for YT. Method 2 is based, in part, on the principal that hot windrows tend to passively aerate themselves drawing fresh air at the base and releasing hot air out the top, thereby reducing how often windrows need to be turned to keep them aerobic. Method 2 has the potential to reduce operational expenditures because windrows are turned fewer times.

The Project was also designed to evaluate different composting recipes – or volumetric mix ratios of yard trash (YT) and food waste (FW). The ratios evaluated were 3:1 and 4:1, the derivation of which is described in the following paragraphs.

The composting recipe needs to balance three major factors: moisture content, carbon-to-nitrogen (C:N) ratio, and porosity. Source-separated FW tends to be wet and highly putrescible, while YT tends to be dry and takes a long time to decompose. When composted together, FW is

[*] Chapter 62-709 regulations at the time of this Project were based on a definition of disinfection that required 4 turnings. Draft revisions currently being considered by FDEP would increase this to 5 turnings to conform with federal PFRP standards.

seen as a source of moisture and nitrogen while the YT is seen as the source of carbon, dryness, and porosity. In other words, the YT is the bulking agent for making it possible to compost the FW safely. Optimal conditions for composting are generally as follows:

- Moisture content 40% - 60%
- C:N ratio 20:1 – 40:1
- Porosity sufficient pore space to facilitate air flow through the material, which can be assessed in terms of bulk density of 600 – 800 pounds per cubic yard

Obtaining the proper blend of feedstocks is critical to good composting. There are many different kinds of FW with a wide range of characteristics and can be categorized by source and content as follows:

- Pre-consumer FW – Materials generated during the manufacturing and preparation process and discarded prior to retail sale, such as food processing, wholesale and retail market residuals (e.g. overripe, damaged, or otherwise rejected material) and institutional kitchen culls.
- Post-consumer FW – Materials generated after retail sale for consumption, such as restaurant plate scrapings and residential food scraps.
- Vegetative FW – Materials such as vegetable, fruits, condiments, and baked goods that do not contain animal by-products.
- Animal by-products – Materials that are animal in origin, including meat, fat, dairy, and eggs.

Likewise, YT can have a wide range of characteristics such as particle size, moisture content, and available carbon.

This Project used source-separated FW and YT from Reedy Creek Improvement Authority's existing waste collection operations. FW was post-consumer material collected from hotel and restaurants at Disney World, which included prep waste, plate scrapings, discarded beverages, cooking oils, and grease. Processed YT was obtained from Reedy Creek's large stockpile of material resulting from landscape maintenance work on Disney properties. Based on research and previous experience, these materials were assumed to have the following key characteristics:

- Food waste: 85% moisture content, 10:1 C:N ratio, 1600 lb/cy
- Yard trash: 30% moisture content, 50:1 C:N ratio, 450 lb/cy

Using these data, KCI developed mix recipes to achieve optimal conditions for composting as summarized in Table 1. It can be seen that this was a small-scale project handling a total of approximately 85 tons of material.

To summarize, the Project conducted four separate tests:

- FORCE 1: Mix 1 / Method 1
- FORCE 2: Mix 1 / Method 2
- FORCE 3: Mix 2 / Method 1
- FORCE 4: Mix 2 / Method 2

Table 1: Mix Recipes

	Cubic Yards	Tons	Dry Tons	Water	C:N Ratio
Mix 1					
FW	30	24.00	3.60	20.40	11:1
YT	90	20.25	14.18	6.08	50:1
Total	120	44.25	17.78	26.48	30:1
Moisture	60%				
Mix 2					
FW	24	19.20	2.88	16.32	11:1
YT	96	21.60	15.12	6.48	50:1
Total	120	40.80	18.00	22.80	33:1
Moisture	56%				

One windrow was constructed for each test. The experimental design made it possible to assess what impacts, if any, each test would have on the compost process, operations and product quality. This design was intended to assess the following:

- The 3:1 mix ratio would have higher moisture content, greater bulk density and lower C:N ratio. The question was whether this would lead to anaerobic conditions and odor problems.
- With regard to the 4:1 mix ratio, there was the question whether the FW would provide sufficient moisture and nitrogen to sustain thermophillic conditions (temperature >40 ºC).
- Composting Method 1 conformed to FDEP regulatory standards for disinfection in place at the time of the Project and was expected to reduce fecal coliform levels to <1,000 MPN/g.
- The questions were (1) whether Method 2 (minimal turning) achieves pathogen reduction standards for disinfection and (2) whether Method 2 would cause anaerobic conditions and odor problems.

Materials Receiving and Mixing

FW was received and mixed with YT in concrete bunkers at the facility's composting building. Before receiving any FW, Reedy Creek staff laid out a thick bed of YT in the bunker and built up a berm of YT across the mouth of the bunker. FW was then discharged onto the YT bed in the bunker, which helped to absorb free liquid and prevent it from flowing out of the mixing area. More YT was immediately added to achieve the proper volumetric ratio and the materials thoroughly mixed by bucket loader. The photos on the following page document the receiving and mixing process.

Reedy Creek collects source-separated post-consumer FW in dedicated side-loader collection trucks. It consists of discards from food preparation, food service, and plate scrapings. In terms of the draft definitions currently being considered by the FDEP for the Chapter 62-709 composting rules, the Project's FW was a mixture of "Vegetative Waste" and "Animal By-products" – because it included plate-scrapings, the FW was not "pre-consumer." Reedy Creek works closely with FW generators to educate them about proper source-separation procedures, nevertheless, the FW did contain small amounts of non-compostable contaminants, most notably cutlery, small service ware, individual plastic service packets, plastic straws, etc. The FW had high moisture due to discarded beverages and other liquids, and appeared to contain a significant amount of cooking oil and grease.

Food Waste Discharged onto Bed of Yard Trash

Food Waste Held in Place by Berm

Mixing in Concrete Bunker

Raw Mixture of Food Waste & Yard Trash

Windrow Construction

Reedy Creek staff built the four windrows on the facility's concrete outdoor curing and storage pad. Reedy Creek equipment operators are experienced at building compost piles and were careful to not compact materials and maximize porosity and aeration. Each windrow was capped with a 1-foot thick layer of YT in order to suppress odors and hide visible FW both of which attract vectors (birds, rodents, and flies). As summarized in Table 2 the Project composted a total of an estimated 348 cubic yards of materials.

Table 2: Windrow Dimensions and Volume – Start of Active Composting

	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Base Width	*feet*	15	15	16	16
Top Width	*feet*	2	2	2	2
Height	*feet*	6	6	6.5	6.5
Length	*feet*	40	40	45	45
Volume	*cubic yards*	76	76	98	98

Note: measurements and volumes are approximate

KCI collected composite samples from each windrow on the day of construction and shipped them for off-site lab analysis. Samples were sent to two different labs:

- Woods End Laboratories in Maine specializes in analytical services for the composting industry.
- TestAmerica is a NELAP certified lab as required by FORCE's Scientific Advisory Committee (SAC) protocol.

Photos on the following page depict windrow construction and sample collection.

Windrow Construction

Cleaning up Aisle

Sample Collection

Completed Windrows with Cap

Table 3 summarizes the raw mixture analyses performed by each lab. Variations in sample results are to be expected due to the heterogeneous nature of the mixture.

Table 3: Summary of Lab Analyses – Raw Mixture

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Woods End					
Density	*Lbs/cy*	810	837	864	891
Moisture	*%*	51.8	54.2	51.1	49.4
Oversize & Inert Material	*% > ¼ inch*	8.7	12.4	5	16.3
pH	*pH Units*	4	4.6	4.1	4.5
Carbon:Nitrogen	*w:w*	36.7	28.2	31.9	38.9
Solvita Maturity Index		1.9	1.9	1.9	1.9
Fecal Coliform	*MPN/g*	5,000,000	720,000	2,600,000	2,600,000
Salmonella	*MPN/4g*	<.54	<.57	13.15	12.7
TestAmerica					
Moisture	*%*	55.2	55.1	50.3	52.4
pH	*pH Units*	4.2	4.3	4.2	4.2
Fecal Coliform	*MPN/g*	35,700	35,700	>32,200	>33,600

Note: these data are for the raw mixture of food waste and yard trash prior to composting.

Moisture and C:N Ratio: Lab analyses verified that the raw mixture met proper conditions for composting:

- Woods End
  - 3:1 mix = 53% moisture and 32:1 C:N ratio
  - 4:1 mix = 50% moisture and 35:1 C:N ratio
- TestAmerica
  - 3:1 mix = 55% moisture
  - 4:1 mix = 51% moisture

These results conform with expectations that the 3:1 mixture would have slightly higher moisture and lower C:N than the 4:1 mixture.

Pathogens: TestAmerica pathogen analysis of the raw mixture found fecal coliform in levels ranging from >32,200 to 35,700 MPN/g total solids, while Woods End reported significantly higher levels (720,000 to 5,000,000 MPN/g). Woods End is a nationally prominent laboratory with over 25 years devoted to compost analysis. According to lab personnel from Woods End who interpreted the results, these levels of fecal coliform are somewhat common in compost testing and can even be expected in YT alone. Similarly, a wide range of fecal coliform results is not uncommon, and can be attributed to a number of factors such as; The raw mixture is highly heterogeneous, and individual samples taken from the same composite sample can result in significantly different results. Lab personnel also stated that different labs frequently observe results differing by 150-fold even for parallel samples, given differences in how samples are handled and errors in lab procedures. The lab indicated that one out of every three fecal pathogen tests result in extremely high numbers. Woods End also suggested that the length of the transportation process could also lead to rapid growth of fecal bacteria. Woods End is located in Maine and took approximately 24 hours to ship samples, while the lab results from Test America's Orlando office, which were immediately tested after sampling, came back significantly lower. Therefore, for the reasons stated above it was determined that the Woods End fecal coliform level for this sample did not reflect an accurate amount present in the raw compost mix, while the Test America results did.

Density: Woods End measured the sample density using a methodology that simulates a windrow depth of four feet. It found that the 3:1 and 4:1 mix averaged 824 and 878 pounds per cubic yard (lbs/cy), respectively.

pH: Analyses by both labs for pH confirmed that the raw mixture was acidic (pH 4.0 – 4.6), which is typical of this type of feedstock blend.

Oversize and Inert Material: Woods End determined the amount of material larger than ¼ inch – this includes oversize materials such as wood chips as well as physical contaminants such as plastic, glass, and metal. FORCE 3 had the lowest percentage of oversize and inert materials (5%) and FORCE 4 had the highest (16.3%).

Solvita Maturity Index: The raw mixture was also subjected to Woods End maturity tests which entail analysis of CO_2 and NH_3 generated by the samples and then characterization on its Solvita Maturity Index scale. All four samples ranked 1.9 on the scale, which is characterized as raw, fresh, very active compost.

In summary the characteristics of the raw materials were consistent with what would be expected for compost material containing post-consumer FW and YT.

Active Composting

The four test windrows remained in active composting for approximately 50 days. Each day Reedy Creek staff recorded temperature at three points in each pile at two depths – one foot and three feet. A front-end loader was used for windrow turning according to the two different protocols.

Composting Protocols

- *FORCE 1 & FORCE 3 – PFRP Trials:* These two windrows were managed to meet the FDEP disinfection standards enforced at the time of this Project for time, temperature and turning for unaerated windrow composting: 15 consecutive days at 55ºC (131ºF) with 4 turnings. Once that was achieved the windrows were managed in the same manner as the Minimal Turning Trials.

- *FORCE 2 & FORCE 4 – Minimal Turning Trials:* These two windrows were turned based on the following time and temperature protocol. As long as the average temperature remained above 40ºC, the windrow was not turned. If average temperature fell below 40ºC, the windrow was turned, but no more than once every seven days.

Temperature charts for each windrow are provided in Attachment B. FORCE 1 and 3 met FDEP process standards for disinfection. FORCE 2 and 4 windrow temperatures quickly rose to above 55°C, remained there for approximately 20 days and remained above 40°C for almost the entire active composting phase.

Water Addition

By the end of one month of active composting, all the windrows needed additional water. Weather during this time was dry, hot and sunny. On December 4th the four windrows were spread out, watered with a high volume hose, and then reformed. The water addition coincided with windrow turning on Days 36 and 37 (see charts in Attachment B).

It was expected that FORCE 1 and 3 would need water because of frequent turning and incorporating the insulating blanket of YT into the mix. However, the degree to which FORCE 2 and 4 had dried out was not expected, because they had not been turned and were capped with a blanket of YT. Several factors may have contributed to this (see discussion regarding Moisture on page 18).

Leachate

Based on prior experience, properly constructed compost piles rarely produce free running liquid (leachate) because the materials have significant water holding capacity. However, the potential does exist for windrows to generate leachate after major precipitation. Therefore, windrows were inspected by KCI twice weekly to see if leachate was emanating from them (composting took place on a concrete pad). During the first week of active composting, KCI found only trace amounts emanating from the base of the windrows. Quantities were too small to be readily collected for analysis. After this initial week, no leachate was observed.

Temperature Monitoring

Windrow Turning

Windrow Turning

Turned Windrow

Odor

Odor emanating from the trial windrows was assessed utilizing Draeger tubes for two major sources of composting odor – ammonia (NH_3) and hydrogen sulfide (H_2S). KCI performed the measurements using a "chimney" of duct pipe that was acclimated so that air inside it was representative of convective air emanating from the windrow. Draeger tube samples were then drawn from a sampling port on the side of the chimney. Samples were taken at three times: immediately after pile construction, after one week of active composting (and immediately after pile-turning in the case of the PFRP trials), and on quiescent piles after 30 days of active composting. The results of the Drager samples are provided in Table 4. The only time either compound was detected was on Day 8 for FORCE 1.

Table 4: Ammonia and Hydrogen Sulfide Sampling Results

Day of Active Composting	FORCE 1		FORCE 2		FORCE 3		FORCE 4	
	NH_3	H_2S	NH_3	H_2S	NH_3	H_2S	NH_3	H_2S
Day 1	ND	ND	ND	ND	ND	ND	ND	ND
Day 8	10	ND	ND	ND	ND	ND	ND	ND
Day 48	ND	ND	ND	ND	ND	ND	ND	ND

Note: "ND" = not detected. Detection limits = 2.5 ppm for NH_3 and 2 ppm for H_2S.
Results in parts per million (ppm).

The presence of either compound in compost emissions is indicative of certain conditions. Ammonia is indicative of aerobic conditions and volatilization of nitrogen in the compost pile due to pH that is neutral to alkaline. Its odor detection threshold for humans is in the range of 5 to 20 ppm. Because it is lighter than air, NH_3 disperse easily and is therefore less of a problem for off-site odor problems at composting facilities compared to other compounds.

Hydrogen sulfide and the broader family of reduced sulfur compounds for which H_2S is an indicator are caused primarily by anaerobic conditions, which can be caused by various factors including low porosity, too much water, and low C:N ratio. The odor detection threshold for H_2S is very low – in the range of 0.5 ppb; and because it is denser than air it does not disperse readily and tends to "hug the ground." Reduced sulfur compounds are commonly associated with off-site odor problems at a compost facility.

The absence of detectable NH_3 emissions in all but one of the tests is consistent with the low pH of the raw mixture. The absence of detectable H_2S indicates that aerobic conditions were being maintained in all four windrows.

The Project also performed qualitative odor assessments. Twice weekly KCI staff visited the Project site to inspect the windrows, check composting progress, and assess odors. Three aspects of odors were assessed:

- Intensity: slight, moderate, strong, very strong
- Character: description of the odor (e.g rotten egg, garbage, ammonia, earthy)
- Tone: very offensive, offensive, neutral, pleasant, very pleasant

Odor was assessed separately for each windrow at the same time that temperature data was being collected. Odors were moderate to strong during the first two weeks of active composting. The PFRP method windrows, FORCE 1 and 3, produced more intense odors than FORCE 2 and 4, which is likely due to the fact that the piles were being turned frequently. All four windrows generated odors that were characterized as garbage- and grease-like, which is most probably attributable to the type of food waste used in this Project. The absence of rotten egg and other reduced sulfur compounds odors indicate that aerobic conditions were being maintained in the windrows. Odors diminished quickly and after 2 weeks the windrows were not producing any detectable odor when standing in their vicinity.

Compost Analyses – End of Active Composting

After approximately 50 days of active composting, KCI collected composite samples from each windrow for lab analysis. Results are summarized in Tables 5 and 6 and in the following paragraphs (see Attachment A for detailed results). All four windrows met FDEP standards for heavy metals, pathogens, organic matter and foreign matter for Class A compost for unrestricted distribution and usage.

Table 5: Summary of Lab Analysis – End of Active Composting (Woods End)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Density	*Lbs/cy*	459	432	432	486
Moisture	*%*	14.1	16.2	23.3	20.9
Oversize & Inert Material	*% > ¼ inch*	48.1	46.7	45.4	40.7
pH	*pH Units*	6.1	6.5	6.8	6.8
Organic Matter	*%*	75.7	75	53.6	55.9
Conductivity	*dS/m*	4.0	4.1	3.1	3.7
Carbon:Nitrogen	*w:w*	29.4	34.3	25.6	24.6
Total Nitrogen	*%*	1.4	1.2	1.1	1.2
Solvita Maturity Index		1.9	1.9	1.9	1.9

Note: Data reported on "as is basis" for samples as received; "nd" means not detected.

Pathogens

One objective of the Project was to determine whether a less intensive composting method (FORCE 2 and 4) would meet FDEP disinfection standards with regard to pathogen levels, specifically: fecal coliform <1,000 MPN/g dw. Based on the results in Table 6, both composting methods met FDEP disinfection standards.

Table 6: Lab Analysis – End of Active Composting (TestAmerica)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Moisture	*%*	14	15.8	26.4	17.8
Total Kjeldahl Nitrogen (TKN)	*mg/kg dw*	11,900	7,270	13,300	14,400
Dissolved Phosphorus	*mg/kg dw*	175	236	146	161
Total Potassium	*% dw*	0.2	0.1	0.4	0.6
Organic Matter	*%*	76.1	81.5	64	59.5
Specific Oxygen Uptake Rate	*mg/hr/gm dw*	0.3	0.4	0.4	0.3
Conductivity	*dS/m*	2.0	2.0	1.6	1.7
pH	*pH units*	6.1	6.5	7.2	7.0
Foreign Matter	*%*	0.7	0.8	0.5	2.0
Arsenic	*mg/kg dw*	1.1	1.1	1.2	1.1
Cadmium	*mg/kg dw*	0.2	0.2	0.3	0.2
Chromium	*mg/kg dw*	0.6	0.6	0.7	0.8
Copper	*mg/kg dw*	2.3	0.9	2.9	3.0
Lead	*mg/kg dw*	Not reported	1.8	2.6	2.2
Mercury	*mg/kg dw*	0.03	0.04	0.04	0.04
Nickel	*mg/kg dw*	0.6	0.6	0.7	0.6
Selenium	*mg/kg dw*	2.3	3.5	4.6	3.6
Zinc	*mg/kg dw*	9.9	10.0	12.9	21.6
Fecal Coliform	*MPN/g TS*	<288	<301	<292	<255

Moisture

Lab analyses confirmed that all four windrows became dry regardless of turning schedule. Moisture content ranged from 14% to 26%, which is well below the optimal range for composting. Water was added to the windrows once on Day 35, however this was not sufficient to maintain adequate moisture levels. An unexpected finding was that the Minimal Turning method employed for FORCE 2 and 4 had no discernable impact on retaining moisture. Based on these results, KCI made several conclusions.

- *The capping layer lowered moisture content* – each of the windrows was capped with a 1-foot thick layer of YW in order to minimize odors and attraction of scavenger birds. The capping layer was subsequently incorporated into windrows when they were turned. The drying effect of this material was not taken into account when developing the initial mix ratios.

- *Initial moisture content could be greater* – The initial raw mixture samples had moisture content in the range of 50% and C:N ratios of 28:1 to 39:1. A wetter raw mixture would be possible by increasing the amount of food waste (e.g. less than 3:1 YT:FW mix ratio). Based on characteristics of the Project feedstocks, a 2:1 mix ratio would have had moisture content in the range of 60% and C:N ratio of approximately 25:1. Such a mix would compost well, although there may be elevated chances for odor. This, prior to considering the effect of a capping layer, which would increase C:N and reduce moisture.

- *Fats and oils may have suppressed water holding capacity* – The FW used in the Project may have contained significant amounts of liquid fats and oils, which would have made the raw mixture appear wetter than it actually was in terms of water content. Fats and oils may have also tended to coat YW particles and impeded their ability to absorb and retain water during the composting process.

- *Small windrows dried out more rapidly that full-scale operations* – Larger windrows have a lower surface to volume ratio than smaller windrows; which reduces the potential for moisture loss. Even FORCE 2 and 4, which were only turned once during active composting, dried out significantly. In addition to other measures identified above, it is possible that larger windrow dimensions would help to conserve moisture.

Specific Oxygen Uptake Rate (SOUR)

This analysis is used to determine the level of oxygen consumption, or respiration, in a material. It is a measure of the decomposition potential or putrescence of a material, and is used as a regulatory standard for the potential for attracting vectors (birds, rodents, and flies) that may spread disease. To comply with 40 CFR 503 vector attraction reduction requirements, SOUR must be less than 1.5 mg/hr/gm dry weight. Analysis performed by TestAmerica found the SOUR in all sample to be well below the 503 standards, ranging from 0.25 to 0.42 mg/hr/gm dry weight.

Solvita Maturity Index

Maturity is a measure of whether a compost material is ready for application and use. Woods End's Solvita Maturity Index combines measurements of CO_2 respiration and NH_3 volatilization. Results for the analysis of the Project samples at the end of active composting indicated that all four windrows had an index rating of 1.87, which is characterized as very active, raw compost that is not suitable for end use. KCI had originally expected the compost at this stage to have a higher Solvita Index. Lower than anticipated maturity results may have been caused by several factors. First, the lack of adequate moisture during active composting would have suppressed biological decomposition – although the windrows easily met time and temperature standards for pathogen reduction, there was still significant amounts of degradable material remaining after the approximately 50 days of active composting. Secondly, the FW/YT mixture handled in the Project may have required more than 50 days of active composting even it had had optimal moisture content due to the high oil and grease content.

Other Physical Parameters

Lab results for several other physical parameters are discussed in the following bullet points:

- *Density* – Woods End found that samples had densities in the range of 16 to 18 lbs/cf (432 to 486 lbs/cy). This is low compared to typical compost and is due to the low moisture content discussed above.

- *Oversize and Inert Materials* – Woods End determined how much of the sample material is greater than ¼ inch in size, and found this range from 41% to 48%. Materials retained on a ¼ inch screen would typically include wood chips, contaminants and other large particles.

- *Foreign Matter* – TestAmerica measured the amount of foreign matter present in the samples and levels to be very low, ranging from 0.5 to 2.0% on a weight basis, which meets FDEP Class A compost standards

Heavy Metals

Table 7 shows that all for windrows met state and federal heavy metal standards for unrestricted distribution and use of compost. The FDEP Chapter 62-709 currently regulates the content of five heavy metals in compost: cadmium (Cd), copper (Cu), Lead (Pb), nickel (Ni), and zinc (Zn). FDEP Chapter 62-640 (Domestic Wastewater Residuals) conforms to the US EPA biosolids standards for heavy metals.

Table 7: Regulatory Heavy Metals Standards for Unrestricted Distribution of Compost

Analysis Parameter	Units	Range FORCE 1 - 4	FAC 62-709 Code 1	FAC 62-640	US EPA Part 503
Arsenic (As)	*mg/kg dw*	1.1 – 1.2	na	41	41
Cadmium (Cd)	*mg/kg dw*	0.2 – 0..3	15	39	39
Chromium (Cr)	*mg/kg dw*	0.6 – 0.8	na	1,200	1,200
Copper (Cu)	*mg/kg dw*	0.9 – 2.9	450	1,500	1,500
Lead (Pb)	*mg/kg dw*	1.8– 2.6	500	300	300
Mercury (Hg)	*mg/kg dw*	0.03 – 0.04	na	17	17
Nickel (Ni)	*mg/kg dw*	0.6 – 0.7	50	420	420
Selenium (Se)	*mg/kg dw*	2.3 – 4.6	na	100	100
Zinc (Zn)	*mg/kg dw*	9.9 – 21.6	900	2,800	2,800

Notes: “na” means not applicable.

Analysis of samples from the Project found levels of heavy metals far below all regulatory standards.

Other Chemical Parameters

Results for various chemical parameters are summarized in the following bullet points.

- *pH* – As the composting progresses, pH typically moves from acidic towards basic (pH 7). This was observed in the samples analyzed for the Project. The pH of compost samples at the end of active composting ranged from 6.1 to 6.8 and 6.1 to 7.2 as measured by Woods End and TestAmerica, respectively. Compost pH should be slightly acidic to slightly alkaline for most end uses.

- *Conductivity* – Conductivity is a means for measuring salinity in compost in terms of the electrical conductivity – higher conductivity indicates a higher level of soluble salts. The samples had levels ranging from 3.1 to 4.0 dS/m (Woods End saturated paste method) 1.6 to 2.0 dS/m (TestAmerica aqueous solution method). Conductivity in the ranges of 2 to 5 dS/m saturated paste (1 to 2 dS/m aqueous solution) is interpreted as moderate salinity, which would require the compost to be mixed with other materials for most uses (e.g. blended with soil). Moderate salinity is typical for post-consumer FW like that used in this Project. Compost produced from pre-consumer vegetative FW typically has lower salinity that does not restrict its usage.

Curing and Post-Processing

After approximately 50 days of active composting, Reedy Creek staff spread out the four windrows, added water using a high volume hose, and formed them into curing piles. Temperatures were monitored twice weekly at three points in each pile at two depths – one foot and three feet. Piles were turned twice by bucket loader on Day 21 and 37 of the curing phase. Materials were kept in curing piles for 70 days, after which Reedy Creek staff screened the finished compost using a 3/8-inch trommel screen.

Temperature and Turning

Temperature and turning records for each curing pile are provided in Figure 5 through 8 in Attachment B. Over the course of curing temperatures followed expected trends: an overall downward trend from thermophilic range (> 40°C) into mesophilic range (10°C – 40°C) with temperatures rising after turning introduces fresh air into the piles.

After 70 days in curing the piles were still registering mesophilic temperatures in the range of 28°C to 35°C (82°F to 95°F), slightly above ambient conditions and indicating some degree of remaining biological activity. Under normal operating conditions KCI would have continued to cure the compost for another 20 days (total of 90 days curing). Nevertheless it was necessary to complete the Project in order to meet reporting deadlines for FORCE.

Compost Analyses – End of Curing

Samples of screened compost were sent to Woods End to be analyzed for parameters commonly considered for compost distribution and use in the composting industries (see Table 8). Results indicate that compost from all four trials were of very high quality. The following bullet points summarize major parameters of interest for regulatory compliance and market utilization.

Table 8: Lab Analysis – Screened Finished Compost (Woods End)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Density	*Lbs/ft*	21	21	28	25
Moisture	*%*	20.6	26.8	25.6	24.6
Oversize & Inert Material	*% > ¼ inch*	<0.1	<0.1	<0.1	<0.1
Organic Matter	*%*	55.4	56.7	35.4	33.3
pH	*pH Units*	7.9	8.0	8.3	8.2
Conductivity	*dS/m*	5	4.9	3.1	5.1
CO2 Respiration	*(mg/gVS/day)*	3.1	1.2	0.7	0.7
Solvita Maturity Index	*unitless*	3.7	5.8	7.7	7.8
Total Nitrogen	*%*	1.7	1.5	0.8	1.0
Phosphorus (P)	*%*	0.4	0.2	0.1	0.2
Potassium (K)	*%*	0.4	0.4	0.2	0.2
Fecal Coliform	*MPN/g*	99	<2	<2	<2

Note: Data reported on "as is basis" for samples as received; "nd" means not detected.

- *Density & Moisture Content* – Finished compost samples had density ranging from 21 to 28 lbs/cf (567 to 756 lbs/cy) and moisture content from 21% to 28%.

- *Oversize & Inert Material* – The finished compost had no visible contaminants and a very consistent fine texture; over 99.9% of the samples passed through a ¼ inch screen.

- *Organic Matter* – Organic matter content was significantly higher in the 3:1 mix ratio materials (FORCE 1 and 2), averaging 56% versus 34% for the 4:1 mix ratio piles.

- *pH* – All four samples had neutral to slightly alkaline pH.

- *Conductivity* – Samples of finished compost had conductivity in the range of 3.1 to 5.0 dS/m using the saturated paste method. According to Woods End interpretive material, the samples are characterized as having medium salinity. Such compost should be mixed with other materials (such as blended topsoil or soil amendment) for most uses; the compost would have limited use as a direct substitute for soil.

- *Stability (CO_2 respiration)* – FORCE 1 had significantly higher respiration (3.1 mg CO_2/g volatile solids/day) compared to the other 3 trials (0.7 – 1.2 mg CO_2/g volatile solids/day). The FORCE 1 sample was characterized as moderately stable, while the other three were highly stable. KCI did not discern any difference in the actual stockpiles of finished compost, so the difference found in FORCE 1 may have been due to sampling variability.

- *Maturity* – Solvita Maturity Index results were comparable to stability – FORCE 1 being less mature than the others – however the results also suggest that the 3:1 mixture (FORCE 1 and 2) had not yet fully matured after 70 days of curing. Solvita maturity 3.7 is characterized as active compost and 5.8 is characterized as curing compost. Maturity levels of 7.7 and 7.8 found in 4:1 mix ratio are characterized as well-aged finished compost.

- *Macro-nutrients* – The macro-nutrients are nitrogen, phosphorus and potassium. Compost is generally considered as a soil amendment with low levels of these nutrients in organic form that is not-leachable and slowly released to plants. Nitrogen content was higher in the 3:1 mix ratio (average 1.6% TKN) versus 4:1 mix ratio (0.9% TKN). Likewise, phosphorus and potassium levels were higher in the 3:1 mix ratio; but they were less than 1% in all samples for both elements.

- *Fecal Coliform* – Levels of fecal coliform were well below the regulatory threshold.

- *Regulatory Classification* – KCI reviewed sample analyses in relation to the current Chapter 62-709 classification standards (see Table 9). Samples from the four tests met the requirements for Class YM and Class A compost for unlimited distribution, with one possible exception – maturity for FORCE 1 (note that FDEP does not specifically define how to measure maturity). Samples from the 4:1 mix ratio (FORCE 3 and 4) were well-matured compost, samples from the 3:1 mix ratio (FORCE 1 and 2) needed additional curing time. It is possible that maintaining higher moisture levels during active composting would have resulted in a more mature compost after the same 70 days of curing.

Disposition of Finished Compost

At the conclusion of the Project, materials were re-incorporated into Reedy Creek's normal operations to ensure compliance with the facility's permit.

Table 9: Comparison to Regulatory Classifications for Compost

Parameter	Class YM	Class A	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Heavy Metals	Code 1	Code 1	Code 1 [1]	Code 1 [1]	Code 1 [1]	Code 1 [1]
Particle Size	Varies	<= 10mm	<0.1% [2]	<0.1% [2]	<0.1% [2]	<0.1% [2]
Organic Matter	Varies	>= 25%	55.4%	56.7%	35.4%	33.3%
Foreign Matter	<=2%	<=2%	<0.1% [2]	<0.1% [2]	<0.1% [2]	<0.1% [2]
Maturity [3]	Mature or semi-mature	Mature	Moderately active; limited use	Curing; ready for some use	Well matured; good for all uses	Well matured; good for all uses

Notes: [1] Code 1 metal compliance was demonstrated in Table 7 previously. [2] Woods End analysis shows >99.9% passing a ¼ inch sieve (6.35 mm). [3] FDEP rules do not specifically define maturity.

Windrow Tear Down

Curing Pile

Screen “Overs”

Screened Compost

Screened Compost from Four Trials

SECTION 3.0
GUIDELINES FOR FOOD WASTE COMPOSTING

Based on the experience and results of the Project, KCI compiled guidelines for composting source-separated food waste (FW) and yard trash (YT). They have been organized in this section by stages of the composting process: feedstock selection, receiving and mixing, active composting, and curing and post-processing.

Feedstock Selection

Start with pre-consumer vegetative FW – While it is important to understand that all types of FW require good composting knowledge and operational control, pre-consumer vegetative material (e.g., fruit and vegetables from grocery stores) presents the best entry point into FW composting. This Project handled post-consumer FW that included meats and grease and had extremely high moisture content; and it needed to be treated to meet disinfection standards to kill human pathogens. Based on the draft revisions to the compost regulations being considered by FDEP, this type of FW can be incorporated into a registered YT facility's operations without needing to meet disinfection standards.

FW and YT have different characteristics depending on the source – Fruit and vegetable waste from a grocery store is substantially different from restaurant FW that includes plate scrapings and beverages. YT moisture content can vary significantly seasonally, as well the C:N ratio depending on the amount of green waste and grass clippings present. The texture or particle size gradation of YT is an important characteristic. A good bulking agent for FW should have a broad range of particle sizes ranging from small particles that will readily absorb water to large pieces that will provide sufficient structure to the pile to ensure porosity.

Test materials prior to composting – to determine key parameters: moisture content, carbon & nitrogen content, bulk density, and contaminants.

Address contaminants – The provider of FW for this Project, Reedy Creek, needs to work consistently with the hotels, restaurants and food services from which it collects source-separated FW for composting. Contaminants are always present in small amounts and Reedy Creek provides feedback regarding persistent issues and special problems.

The types of contaminants in FW will depend on the source – For example, common contaminants in post-consumer FW like that used in the Project will likely be straws, condiment packets (e.g. ketchup) and flatware. Pre-consumer vegetative waste from grocery stores will tend to have different contaminant problems such as plastic film wrap.

Receiving and Mixing

Develop mix recipes based on feedstock parameters – The following are general guidelines:

- 50 – 60% moisture content; because compost will dry out during active composting, higher initial moisture (as high as 65%) is possible if the YT provides sufficient porosity and moisture holding capacity.
- C:N ratio greater than 20:1 in order to comply with regulatory standards.
- Bulk density between 800 and 1,000 lbs/cy as an indicator of sufficient porosity for air flow within the windrow.

Have a readily available stockpile of processed YT – In order to handle incoming FW quickly and minimize potential problems associated with excessive moisture, facilities need to stockpile YT ahead of time to meet bulking agent needs. The YT should be free of contaminants, in particular plastic bags.

Prepare a bed of YT on which to receive FW – As a general rule of thumb the bed should be a volume at least equal to the volume of FW. Given the high moisture content of the FW handled in this Project, the YT bed was also constructed in a three-sided bunker with a raised berm of YT across the front of the bunker. The berm was needed to keep the FW from flowing out of the bunker.

Mix FW with YT immediately after receiving – FW has a high potential for odors and attracting vectors, which can be minimized by mixing. It should be mixed with YT according to the recipe as soon as possible, and in any case within 48 hours of receiving in order to conform with regulations. The mixing method of creating a pile of YT with FW sandwiched in the middle helps to facilitate mixing and environmental control.

Minimize potential for leachate – Leachate may be discharged from the FW during receiving and mixing. The bed of YT is intended to absorb any free liquid. To provide an additional level of protection this Project utilized concrete bunkers.

Mixing FW directly into windrows – While not suitable for the kind of free-flowing FW handled in this Project, it is possible to mix FW directly with YT in windrows. This method is more suitable for solid FW such as fruit, vegetable, and bakery waste that have low leachate potential and that mix readily with YT. For example, a long bed of YT can be laid out as the base of a windrow. Then loads of FW can be discharged onto the bed, additional YT added on top and the windrow mixed and formed in one place.

General housekeeping – Mixing areas should be thoroughly cleaned frequently to avoid the build of odors and attraction of vectors.

Active Composting

Construct windrows to height capacity of turning equipment – Most low technology YT composting facilities utilize front-end loaders for materials handling, including windrow turning. Large machines are generally able to handle windrows up to 8-feet high and 16-feet wide. In any case, height should not exceed 12 feet in order to comply with regulations. Excessive windrow height will lead to compacted materials with minimal pore space and thus high potential to become anaerobic.

Maximize aeration and porosity during windrow construction – The proper way to build a windrow is sometimes referred to as the "lift and cascade" method. Materials should be lifted up and cascaded out of the bucket to form the pile. The loader should never press the material down, bulldoze it into place, or drive on the windrow.

Cover windrows with cap of pure YT – The Project protocol included covering the windrows with a foot-thick layer of pure YT, which served four purposes. First and foremost, it helped limit vectors (birds, animals and insects) which are attracted by visual cues such as FW visible on the surface of the pile. Second, the cap helps to suppress odors which also attract vectors and cause a public nuisance. Third, the YT cap serves as an insulating blanket that enables thermophillic temperatures to extend out to the edge of the underlying FW/YT mixture. Fourth, the cap acts like a dry sponge able to absorb rain and preventing release of leachate.

If necessary, remove YT cap prior to turning – If windrows are being managed to meet FDEP time and temperature requirements, then turning will beginning very soon after windrow construction, and it may be advisable to remove the YT cap before and replace it after turning windrows in order to keep it functioning as a vector and odor barrier. Once the FW has been subjected a few days of thermophillic composting it should no longer pose a vector concern. At this point the cap can be mixed into the windrow.

Add water to YT cap before mixing it into windrows – In order to maintain proper moisture content when incorporating a YT cap into the windrow, water should be applied to the cap to bring it up to proper composting moisture levels.

Monitor windrow temperatures daily – Temperature is an essential indicator of the composting process, and daily temperature monitoring is recommended for any facilities that handle FW. Temperature should be measured at several places on the windrow in order to account for variations in the windrow. It should be monitored at two depths (2-feet and 4-feet depth) in order to comply with regulations.

Meet disinfection standards – Forthcoming FDEP regulations are expected to revise how disinfection standards apply to FW composting. Facilities that handle only pre-consumer vegetative FW and YT may be exempt from disinfection requirements. In order to meet the FDEP pathogen reduction standards for time and temperature, other facilities must maintain windrows at 55ºC for 15 days during which they are turned 5 times. In addition the compost must have <1,000 MPN/g fecal coliform. Forthcoming FDEP regulations may allow facilities to use other methods, such as the minimal turning method demonstrated in this Project, that do not meet the time and temperature standard as long as they meet additional pathogen testing standards for enteric virus and helminth ova.

Monitor windrow moisture weekly – Moisture content can be readily assessed using the "squeeze method" wherein a handful of material is taken from two feet inside the pile. The material should feel like a damp sponge and it should be possible to squeeze out a few drops of liquid. If no liquid comes out or the material feels dry, the pile needs moisture. If liquid drips readily out of the material, it is too wet.

Add water as necessary – During active composting, windrows will dry out and it is often necessary to add more water. Windrows can become dry due to evaporation caused by dry sunny weather. They also loose moisture in the form of water vapor released with the hot air emanating from the windrow and liberated in large volumes when turning the pile. The best time to add water is when turning piles, by spreading them out adding water and then re-building.

Maximize aeration and porosity when turning windrows – Windrow turning needs to thoroughly mix and re-aerate the material. Windrows should not be simply rolled over but, in the same manner described above, they should be turned using the "lift and cascade" method.

Compost for at least 45 days – Materials should remain in active composting at least as long as it takes for there to be no visible FW remaining. The material should have no odors that resemble garbage or raw waste. Based on the feedstocks and experience in this Project, a minimum of 45 days of active composting should be expected. Active composting is complete when temperatures no longer remain in thermophillic range after being turned.

General housekeeping – Throughout the composting process, the area should be kept orderly and in good operating condition. Aisles between windrows should be kept free of material; the composting surface should be maintained; and windrows should be re-built neatly after turning. Because materials shrink during the composting process, it may be appropriate in some cases to combine two windrows into one in order to maintain windrow dimensions that sustain thermophillic conditions.

Curing and Post-Processing

Construct curing piles to height capacity of equipment – Curing piles are typically taller than compost windrows in order to conserve space. At this point in the composting process biological activity and respiration rate have slowed significantly, therefore aeration and porosity are not as critical. Most facilities using front-end loaders for materials handling can build curing piles up to 10-feet high.

Ensure proper moisture content – Water addition should not be necessary in most cases, however moisture should be assessed once weekly using the "squeeze method." It should feel slightly drier than active compost (as described previously), but it should still be moist. During curing compost should be allowed to dry out somewhat so that it can be screened effectively.

Monitor temperature twice weekly – While temperature continues to be a key to monitoring the composting process, daily temperature monitoring is no longer necessary. Temperatures were recorded twice weekly during this Project, and this provided sufficient information to track composting progress. Temperature should be measured at several places on the curing pile in order to account for variations within the pile. It need only be measured at one depth (for example, 3-feet depth).

Turn curing piles if necessary – It is not necessary to turn curing piles if temperatures remain in the mesophillic range. Turning may be needed when pile temperatures have fallen to ambient conditions, after which the pile should re-heat if biological activity is reinvigorated.

Maximize aeration and porosity when turning – The same "lift and cascade" turning technique should be used to ensure thorough aeration and good porosity in the pile.

Screen finished compost for distribution and use – Trommel screens are most commonly used for compost. A 3/8-inch screen is effective for removing physical contaminants and producing consistent fine-textured compost. The "overs" fraction may be recycled into the composting process again, or marketed as a mulch product depending on market demand and quality (i.e. presence or absence of contaminants).

Finished Compost Testing

Laboratory analysis for regulatory parameter – Compost must be analyzed for specific parameters required by FDEP regulations and to determine its classification for distribution and use. Regulatory testing parameters include: moisture, organic matter, reduction in organic matter, pH, and pathogens. Pathogen testing is not required for compost produced from pre-consumer vegetative waste or yard trash. Heavy metal testing is not required for source-separated organic wastes.

Laboratory analysis for market-related parameters – Compost markets (e.g. landscapers, soil blenders, nurseries and greenhouses, farmers, golf courses, construction contractors, public works and transportation departments, etc.) need additional information regarding compost characteristics. Compost producers should participate in the United States Composting Council (USCC) Seal of Testing Assurance (STA) program that provides specific guidelines for compost testing and labeling. Analytical parameters required by the STA program are: pH, soluble salts (conductivity), macro-nutrients (N-P-K), organic matter, moisture percent, particle size, stability (respirometry), maturity (bioassay), inerts, trace metals, weed seed, and pathogens.

Environmental Control

Odor – Odor problems may be caused by poor mixing, low C:N ratio, insufficient porosity or windrow compaction, and insufficient aeration. Solutions generally entail ensuring optimal conditions in the compost pile with regard to moisture, C:N ratio, mixing, particle size and aeration.

- *Materials receiving and mixing* – First, incoming food residuals must always be rapidly mixed with sufficient bulking agent and formed into the composting pile. Second, if incoming FW already has malodors, one must work with the generator and hauler to either correct the problem or stop accepting FW from this source.

- *Active compost malodor* – If conditions in early stages of active composting are not optimal, odors can be offensive. The fist step is to diagnosis the problem using temperature, moisture and visual information, and then to implement an appropriate solution. One common solution is to increase the ratio of YT in the mix. If FW is not thoroughly mixed into the pile, then it must be remixed and aerated. If sections of the pile are too moist, then it must be remixed and dry bulking agent added if necessary. A pile may also be anaerobic due to compaction, loss of pore space, and insufficient turning. When turning a pile it is important to lift and cascade material to incorporate as much air and pore space as possible. If malodors persist, then one can cover the malodorous section of the pile with a layer of fresh dry YT.

- *Windrow turning odor complaints* – If windrows become anaerobic, breaking into them can release large quantities of offensive odor. If possible, windrow turning should happen when weather conditions are most favorable, e.g. when the prevailing wind is blowing away from residential and public use areas. Windrows should not be turned in early morning when air is still and settled. Turning can also be scheduled for days when outdoor public activity is minimal, e.g. cold days and rainy days.

- *Odor neutralizing spray as a contingency* – Companies such as as Ecosorb, Global Odor Control, HLS, and Hinsilblon offer commercial products that can be applied directly to windrows to minimize offensive odors.

Leachate – Leachate problems are caused by high moisture content. Compost windrows should never generate free liquid on their own. They also have significant extra moisture holding capacity and to absorb rain. Even after a significant rainfall, water draining from the pile should not last for more than a day or two. The first step to solving leachate problems is to "mop up" the leachate and prevent it from leaving the site. This can be done by constructing a small compost filter berm with compost or dry bulking agent. Next it is necessary to thoroughly mix dry bulking agent into the compost pile to bring the moisture content into the acceptable range.

Vectors – Pest problems that can occur include flies, birds, and rodents. The principle cause of pest problems is food residuals that have not been properly mixed into an active compost windrow. The immediate solution is to thoroughly mix and aerate any material attracting pests, ensuring proper mix ratio of food residuals to bulking agent and proper moisture content. With proper conditions, windrow temperatures will rapidly increase and prevent pest problems. Birds and rodents may also be attracted to food waste that is present on the surface of a windrow. If this problem occurs, the material can be covered with a layer (e.g. 1-foot thick) of fresh processed YT or finished compost "overs." The windrow may then be turned after several days to move un-decomposed food residuals toward the core of the pile.

SECTION 4.0
COST & BENEFIT ASSESSMENT

One of the Project's major objectives was to assess the potential costs and benefits of food waste (FW) & yard trash (YT) composting. Such information (along with the technical information in previous Sections) will help Florida's public and private YT facilities incorporate FW into their operations.

Operational Factors

The first step in conducting the cost benefit assessment was to establish specific operational parameters, i.e. the amount of labor and equipment time required to perform composting operations. KCI tracked operational aspects of the Project, namely, site and facility needs, specific materials handling activities, equipment and labor utilization, and quantities of materials handled at each stage of the process (see Table 10).

Table 10: Operational Parameters for FW & YT Composting

Activity	Rate	
Front End Loader & Operator		
Receive & Mix	120	cy/hr
Build Windrow	120	cy/hr
Turn Windrow	400	cy/hr
Move to Cure	150	cy/hr
Turn Curing Pile	400	cy/hr
Compost Screening	50	cy/hr
Load Finished Compost	150	cy/hr
Labor		
Add Water to Windrow	600	cy/hr
Monitor Windrow Temperature	3,000	cy/hr
Add Water to Curing Pile	600	cy/hr
Monitor Curing Temperature	3,000	cy/hr
Sample Finished Compost	3,000	cy/hr
Trommel Screen		
Compost Screening	50	cy/hr

The operational parameters were obtained through time and motion study of Reedy Creek personnel as they performed the various composting activities. For example, KCI tracked how many cubic yards of material were handled and the time it took to complete a task. The data in Table 10 was incorporated into the cost-benefit assessment discussed below.

FW & YT Composting Cost-Benefit Assessment

KCI developed a spreadsheet template that enables one to estimate revenue and expenditures for integrating FW composting into an existing YT facility. It addresses the question of whether adding FW composting into an existing YT facility will "support" itself. It assumes that there is readily available supply of processed YT to be used as feedstock and bulking agent for FW composting. It also assumes that existing equipment and personnel are available for the time required for composting activities.

Two financial benefits associated with FW & YT composting are incorporated into the spreadsheet: FW tipping fees and finished compost sales. Indirect costs and benefits associated with FW diversion were not considered, such as improved heating value of waste destined for incineration, conservation of landfill space, reduced landfill leachate, reduced greenhouse gas emissions, increased recycling rate, etc.

The following tables present the results for a FW composting operations based on receiving approximately 12 tons per day (5,000 cubic yards at 1,200 lbs/cy). The assumptions in Table 11 are based on the operating practices recommended in Section 3.0 of this report and use of the PFRP turned windrow composting method. YT is used as a bulking agent for the FW at 3:1 volumetric ratio, but this would be adjusted depending on actual feedstock characteristics.

Materials are composted for 60 days during which time windrows are turned five times, conforming to a disinfection regime required for post-consumer FW and animal by-products. The cubic yards in process are calculated based on the incoming quantities, the residence time in composting, and shrinkage in windrows. Compost is cured for 60 days during which time it is turned once. Unit costs for equipment and labor are set at current industry averages. The tip fee for incoming FW is set at $25. This tip fee should be lower than prevailing disposal charges in order to provide some incentive for FW generators to source-separate material. The price for finished compost is set at $15 per ton which translates to approximately $6 per cubic yard.

Table 11: Cost-Benefit Assumptions

Materials	CY	Lbs/CY	Tons
Food Waste Feedstock	5,000	1,200	3,000
Yard Waste Feedstock	15,000	450	3,375
Windrow Building (w/ cap)	20,000	850	8,500
Active Composting	20,000	850	8,500
Curing	14,000	825	5,775
Post-processing	14,000	825	5,775
Finished Compost	6,000	800	2,400
Performance Factors	Compost	Cure	
Days	60	60	
Avg CY in Process	2,800	2,300	
Turnings	5	1	
Temp Monitor Days/Week	6	2	
Water Additions/Month	1	0	
Sampling for Analysis/Year	0	4	
Unit Costs			
Front End Loader & Operator	$75	per hr	
Trommel Screen	$50	per hr	
Labor	$25	per hr	
Tip Fee for FW	$25	per ton	
Finished Compost Sale Price	$15	per ton	

Table 12 provides information about the specific activities involved in the FW composting process and how many hours it takes to complete them based on the assumptions above. It demonstrates that windrow turning and screening are the most time consuming activities for equipment, while temperature monitoring is the most time consuming activity for labor.

Table 13 provides the estimated revenue and expenses for the operation outlined in the assumptions. Capital costs have been included to construct a mixing area with a reinforced concrete pad and retaining wall, the cost of which has been spread out over eight years at 7%. Front end loader operating costs are the single largest expense item, accounting for over 70% of annual operating costs in this scenario. Clearly, the number of times that windrows are turned has a major impact on expenses. With regard to revenue, the tip fee for incoming FW is the major driver and prevailing disposal fees will impact this source of revenue.

As shown in Table 13, the FW composting operation has an annual net revenue of approximately $2,800, i.e. revenue from tipping fees and compost sales are sufficient to cover the cost of incorporating FW into an existing YT composting facility.

Table 12: FW & YT Composting Activity Profile

Activity	Quantity	Units	Times Performed	Rate		Hours/Yr
Front End Loader & Operator						
Receive & Mix	20,000	cy/yr	1	120	cy/hr	167
Build Windrow	20,000	cy/yr	1	120	cy/hr	167
Turn Windrow	20,000	cy/yr	5	400	cy/hr	250
Move to Cure	14,000	cy/yr	1	150	cy/hr	93
Turn Curing Pile	14,000	cy/yr	1	400	cy/hr	35
Compost Screening	14,000	cy/yr	1	50	cy/hr	280
Load Finished Compost	6,000	cy/yr	1	150	cy/hr	40
Total						1,032
Trommel Screen						
Compost Screening	14,000	cy/yr	1	50	cy/hr	280
Labor						
Add Water to Windrow	2,800	cy	1	600	cy/hr	56
Monitor Windrow Temperature	2,800	cy	313	3,000	cy/hr	292
Add Water to Curing Pile	2,300	cy	0	600	cy/hr	0
Monitor Curing Temperature	2,300	cy	104	3,000	cy/hr	80
Sample Finished Compost	6,000	cy/yr	4	3,000	cy/hr	8
Total						436

Table 13: FW & YT Composting Revenue and Expense Estimate

Item	Quantity	Units	Unit Cost	Total Cost
Capital Cost				
Structures				
Concrete Mix Pad	320	sq ft	$20	$6,400
Concrete Mix Wall (8 ft)	40	ft	$150	$6,000
Engineering & Contingency	10%	of total		$1,240
Total Capital Cost				$13,640
Annual Cost of Capital	Term (yrs)	Rate		
	8	7%		$2,284
Operating Cost				
Labor & Equipment				
Front End Loader & Operator	1,032	hrs/yr	$75	$77,375
Trommel Screen	280	hrs/yr	$50	$14,000
Labor	436	hrs/yr	$25	$10,899
Supplies				
Monitoring Equipment				$350
Lab Analyses	4	times	$700	$2,800
Miscellaneous				$500
Total Operating Cost				$105,924
Total Annual Cost				**$108,208**
Cost per Ton				$17
Revenue				
Food Waste Tip Fee	3,000	Tons	$25	$75,000
Finished Compost Sales	2,400	Tons	$15	$36,000
Total Revenue				**$111,000**
Net Revenue				**$2,792**

Conclusions

In summary, the following conclusions and recommendations can be derived from this cost-benefit assessment.

- The addition of FW composting to an existing YT facility has the potential to generate revenue sufficient to cover its costs.

- FW tip fees are a major driver in determining the feasibility of FW composting. They need to be low enough to provide incentive for FW generators to source-separate, and they need to be high enough to generate revenue to cover operating costs.

- If the characteristics of incoming FW allow the mix ratio to be less than 3:1 (the ratio used in preceding tables) then a higher percentage of the material composted will generate tip fee revenue and improve the economics of FW composting.

- Windrow turning is the most time consuming equipment activities over which an operator has control, so efforts to control cost should first focus on strategies to reduce the number of turnings. For example, the preceding assessment is based on five windrow turnings to meet current FDEP regulatory requirements for composting FW. Yet, the Project demonstrated that a minimal turning technology can produce high quality compost. Draft rules being considered by FDEP may allow facilities to handle pre-consumer vegetative waste without meeting PFRP process standards, and allow those that handle other types of source-separated FW to conduct additional pathogen testing in lieu of PFRP.

- Temperature monitoring is the most time consuming labor activity. While daily monitoring is important during active composting for various reasons, there are potential options to make this activity more efficient. The use of rapid-response digital composting thermometers is one option. A second is the use of permanent thermocouples and a wireless data logger, however this strategy is typically cost-effective only for facilities larger than the one modeled in the preceding tables.

SECTION 5.0
CONCLUSION

The goal of this Project was to encourage composting of food waste (FW) and yard trash (YT) in Florida by conducting a pilot-scale demonstration. Post-consumer FW and YT were composted at the Reedy Creek composting facility using simple low-technology composting methods, i.e. outdoor unaerated windrows turned with a front end loader. The Project evaluated two different mix ratios (4:1 versus 3:1 YT:FW) and two different turning methods (standard turning to meet FDEP disinfection standards versus minimal turning). Major findings of the Project are summarized below.

Composting Method and Compost Quality

Adding FW to YT significantly enhances and accelerates the composting process. The Project produced mature, high quality compost in approximately four months. In comparison, it can take as much as a year or more to produce such a product from YT alone in Florida. Both composting methods met the FDEP pathogen reduction standard of <1,000 most probable number per gram (MPN/g) of fecal coliform. Finished compost met FDEP Class A classification standards for unrestricted distribution and use.

Guideline for Food Waste Composting

The Project identified many guidelines that facilities should incorporate when composting FW and YT in order to ensure environmentally-sound and cost-effective operations as well as high quality product. These guidelines are provided in Section 3.0 of this report and can be used as the starting point for planning and implementing a FW composting operation.

Costs & Benefits

The cost benefit assessment presented in Section 4.0 demonstrates that it is possible for an existing YT facility to incorporate FW composting and cover the additional costs incurred. Two sources of revenue (tipping fees for incoming FW and sales of finished compost) can be sufficient to cover costs and even produce net revenue.

Other community-wide benefits include avoided disposal costs and negative impacts associated with FW that would otherwise be disposed. Diverting FW from landfill disposal saves space in landfills and extends their life expectancy. FW is a major source of greenhouse gas emissions from landfills due to the methane that it produces, which can be avoided by composting. With regard to waste-to-energy facilities, FW's high moisture content negatively impacts fuel value and energy recovery.

Additional Sources of Information

For those interested in learning more about FW and YT composting, there are many sources of information. The following are excellent "portholes" through which one can access the full breadth of knowledge and information:

- FORCE website (www.floridaforce.org) – This website funded by FDEP provides a wealth of information including a search bibliography, technology database, list of composting training courses, and educational materials.

- JG Press (www.jgpress.com) – JG publishes *Biocycle* magazine – the journal of the composting and organics recycling – and *Compost Science and Utilization* – the peer-reviewed journal of the industry.

- United States Composting Council (www.compostingcouncil.org) – This is the trade association for the composting industry and provides a wide range of information and resources.

ATTACHMENT A
LABORATORY ANALYSIS RESULTS

Table A-1: Lab Analysis – Raw Mixture (Woods End)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Density	*lbs ft*	30	31	32	33
Total Solids	*%*	48.2	45.8	48.9	50.6
Moisture	*%*	51.8	54.2	51.1	49.4
Water Holding Capacity	*%*	73	73	71	71
Oversize & Inert Material	*% > ¼ inch*	8.7	12.4	5	16.3
pH	*%*	4	4.56	4.1	4.53
Free Carbonates	*Rating*	1	1	2	1
Organic Matter	*%*	42.6	40.1	39.9	41.3
Conductivity	*dSm*	4.6	4.4	4.1	4.7
Carbon:Nitrogen	*w:w*	36.7	28.2	31.9	38.9
Total Nitrogen	*%*	0.63	0.77	0.67	0.57
Solvita CO2 Rate		1.87	1.87	1.87	1.87
Solvita NH3 Rate		4.94	5.24	4.79	5
Solvita Maturity Index		1.87	1.87	1.87	1.87

Note: analysis performed on "as is" samples, i.e. not dry weight.

Table A-2: Lab Analysis – Raw Mixture (TestAmerica)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Moisture	*%*	55.2	55.1	50.3	52.4
% Solids	*%*	44.8	44.9	49.7	47.6
Total Fixed Solids	*mg/kg*	50,500	46,100	79,400	352,000
Total Volatile Solids	*mg/kg*	398,000	403,000	434,000	123,000
Fecal Coliform	*MPN/g dry*	35,700	35,700	>32,200	>33,600
pH	*pH Units*	4.2	4.28	4.18	4.22

Table A-3: Lab Analysis – End of Active Composting (TestAmerica)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Moisture	*%*	14	15.8	26.4	17.8
Ammonia Nitrogen	*mg/kg dw*	334	605	598	6.38
Nitrate Nitrogen (14797-65-8)	*mg/kg dw*	2.32	6.65	7.75	3.41
Nitrate Nitrogen (14797-65-0)	*mg/kg dw*	0.639	1.42	0.272	0.122
Total Kjeldahl Nitrogen (TKN)	*mg/kg dw*	11,900	7,270	13,300	14,400
Total Nitrogen	*mg/kg dw*	11,900	7,280	13,300	14,400
Dissolved Phosphorus	*mg/kg dw*	175	236	146	161
Total Potassium	*% dw*	0.202	0.137	0.354	0.633
Dissolved Boron	*mg/kg dw*	3.37	3.44	3.94	3.52
Iron	*mg/kg dw*	112	110	206	142
Calcium	*mg/kg dw*	4,320	1,340	4,650	10,800
Magnesium	*mg/kg dw*	446	262	694	1120
Organic Matter	*%*	76.1	81.5	64	59.5
Total Organic Carbon	*mg/kg*	496,000	487,000	483,000	479,000
Carbon:Nitrogen Ratio	*X:1*	41.7	66.9	36.3	33.3
Specific Oxygen Uptate Rate	*mg/hr/gm dw*	0.251	0.378	0.418	0.331
Conductivity	*uS/cm*	1,960	1990	1580	1710
pH	*Standard units*	6.12	6.52	7.21	7.04
Total Volatile Solids mg/kg	*mg/kg*	761,000	815,000	640,000	595,000
Total Fixed Solids	*mg/kg*	99,600	60,600	95,700	225,000
Foreign Matter	*%*	0.722	0.846	0.489	1.99
Antimony	*mg/kg dw*	2.39	2.38	2.63	2.46
Arsenic	*mg/kg dw*	1.05	1.07	1.18	1.11
Barium	*mg/kg dw*	5.06	9.61	8.98	42.1
Cadmium	*mg/kg dw*	0.234	0.238	0.263	0.246
Chromium	*mg/kg dw*	0.586	0.596	0.658	0.786
Copper	*mg/kg dw*	2.27	0.93	2.92	3
Lead	*mg/kg dw*		1.76	2.55	2.21
Manganese	*mg/kg dw*	14.3	95.9	16.4	33
Mercury	*mg/kg dw*	0.0349	0.0352	0.04	0.0368
Molybdenum	*mg/kg dw*	1.27	0.715	0.79	1.23
Nickel	*mg/kg dw*	0.586	0.596	0.658	0.614
Selenium	*mg/kg dw*	2.27	3.51	4.63	3.61
Silver	*mg/kg dw*	0.586	0.596	0.658	0.614
Thallium	*mg/kg dw*	2.23	2.27	2.5	2.33
Vanadium	*mg/kg dw*	0.586	0.596	0.737	7.37
Zinc	*mg/kg dw*	9.94	10	12.9	21.6
Fecal Coliform	*MPN/gram TS*	<288	<301	<292	<255

Table A-4: Lab Analysis – End of Active Compost (Woods End)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Density	*lbs ft*	17	16	16	18
Total Solids	*%*	85.9	83.8	76.7	79.1
Moisture	*%*	14.1	16.2	23.3	20.9
Water Holding Capacity	*%*	73	73	68	69
Oversize & Inert Material	*% > ¼ inch*	48.1	46.7	45.4	40.7
pH	*%*	6.14	6.45	6.77	6.77
Free Carbonates	*Rating*	1	1	1	2
Organic Matter	*%*	75.7	75	53.6	55.9
Conductivity	*dSm*	4.03	4.13	3.1	3.67
Carbon:Nitrogen	*w:w*	29.4	34.3	25.6	24.6
Total Nitrogen	*%*	1.39	1.18	1.13	1.23
Solvita CO2 Rate		1.87	1.87	1.87	1.87
Solvita NH3 Rate		4.61	4.63	4.77	4.66
Solvita Maturity Index		1.87	1.87	1.87	1.87

Table A-5: Lab Analysis – Finished Compost (Woods End)

Analysis Parameter	Units	FORCE 1	FORCE 2	FORCE 3	FORCE 4
Density	*lbs ft*	21	21	28	25
Total Solids	*%*	79.4	73.2	74.4	75.4
Moisture	*%*	20.6	26.8	25.6	24.6
Water Holding Capacity	*%*	68	70	61	59
Oversize & Inert Material	*% > ¼ inch*	<0.1	<0.1	<0.1	<0.1
pH	*%*	7.92	7.98	8.32	8.19
Free Carbonates	*Rating*	2	1	2	1
Organic Matter	*%*	55.4	56.7	35.4	33.3
Conductivity	*dSm*	5	4.93	3.1	5.08
Carbon:Nitrogen	*w:w*	18	20.6	23	18.4
Total Nitrogen	*%*	1.66	1.49	0.83	0.98
Solvita CO2 Rate		3.73	5.88	7.67	7.79
Solvita NH3 Rate		5	5	5	5
Solvita Maturity Index		3.73	5.77	7.67	7.79
Phosphorus (P)	*%*	0.347	0.211	0.138	0.154
Potassium (K)	*%*	0.395	0.37	0.208	0.204
Sodium (Na)	*%*	0.395	0.356	0.185	0.181
Calcium (Ca)	*%*	3.362	2.327	2.632	1.493
Magnesium (Mg)	*%*	0.119	0.098	0.082	0.075
Iron (Fe)	*ppm*	2050	963	705	1779
Fecal Coliform Bacteria	*MPN/g*	99	<2	<2	<2
CO2 Respiration (mg/gTS/day)		2.25	0.91	0.32	0.33
CO2 Respiration (mg/gVS/day)		3.13	1.15	0.66	0.73

ATTACHMENT B
ACTIVE COMPOSTING AND CURING TEMPERATURE CHARTS

Figure 1: Active Composting Temperature - FORCE 1

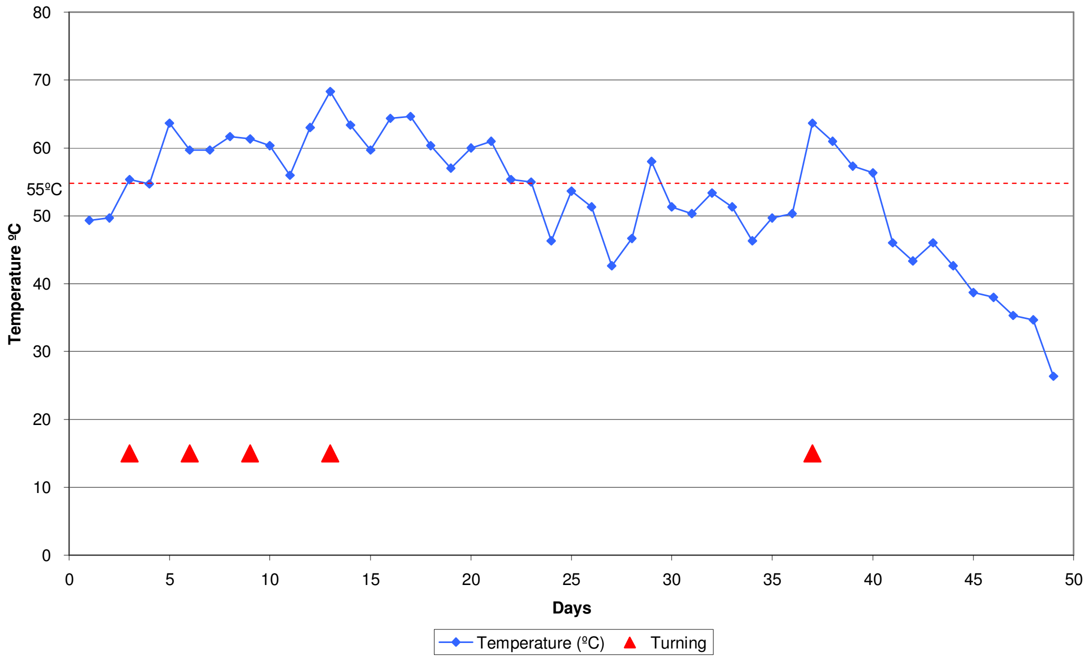

Figure 2: Active Composting Temperature - FORCE 2

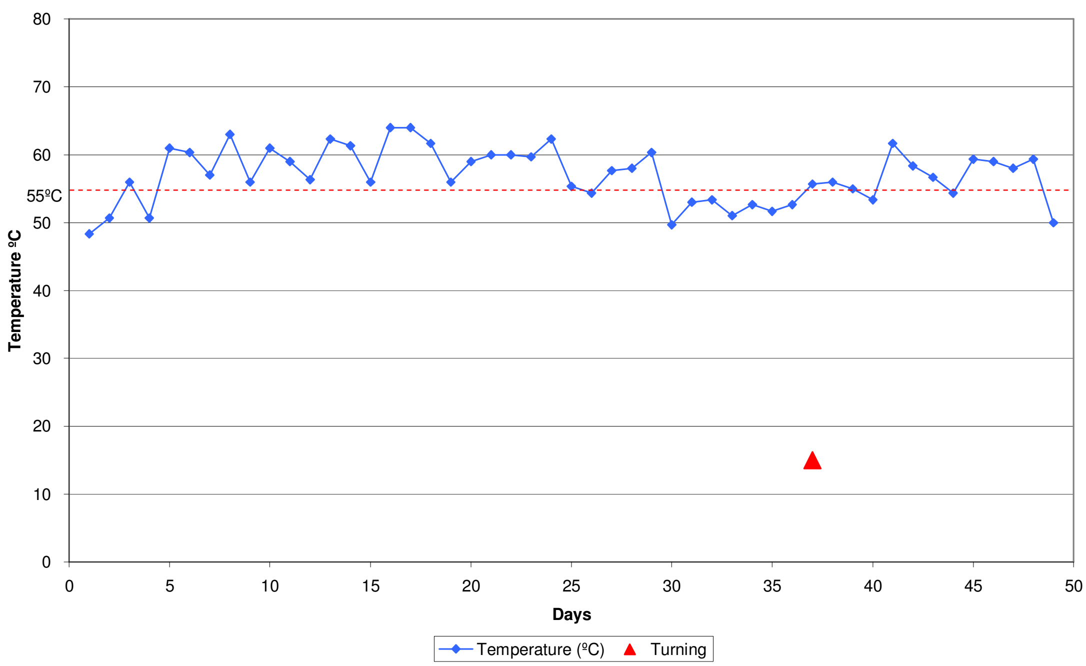

Figure 3: Active Composting Temperature - FORCE 3

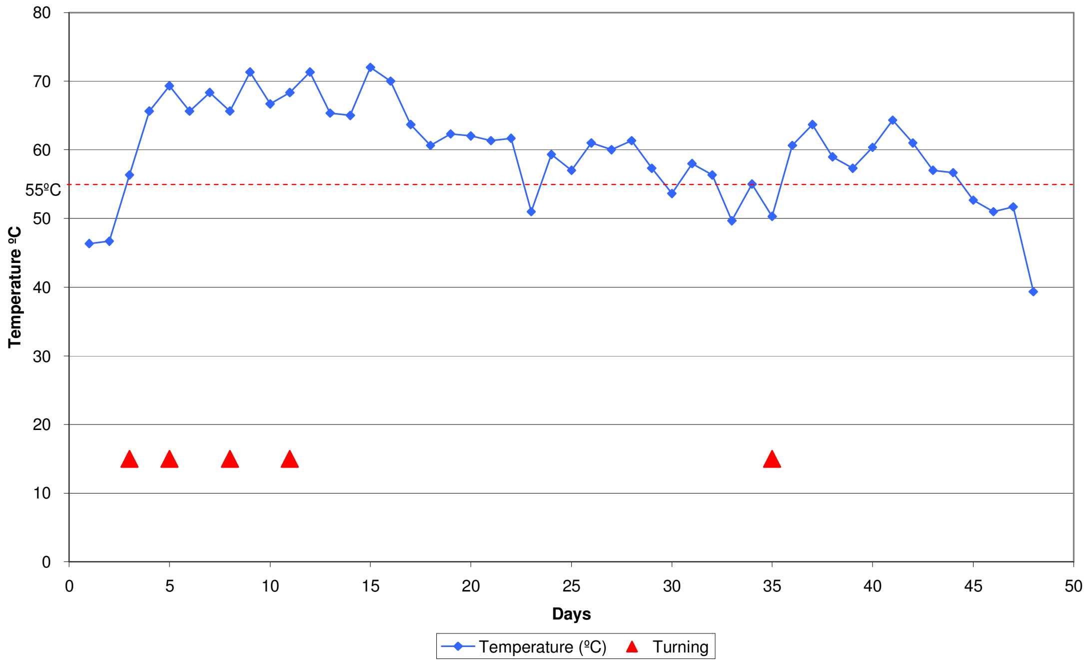

Figure 4: Active Composting Temperature - FORCE 4

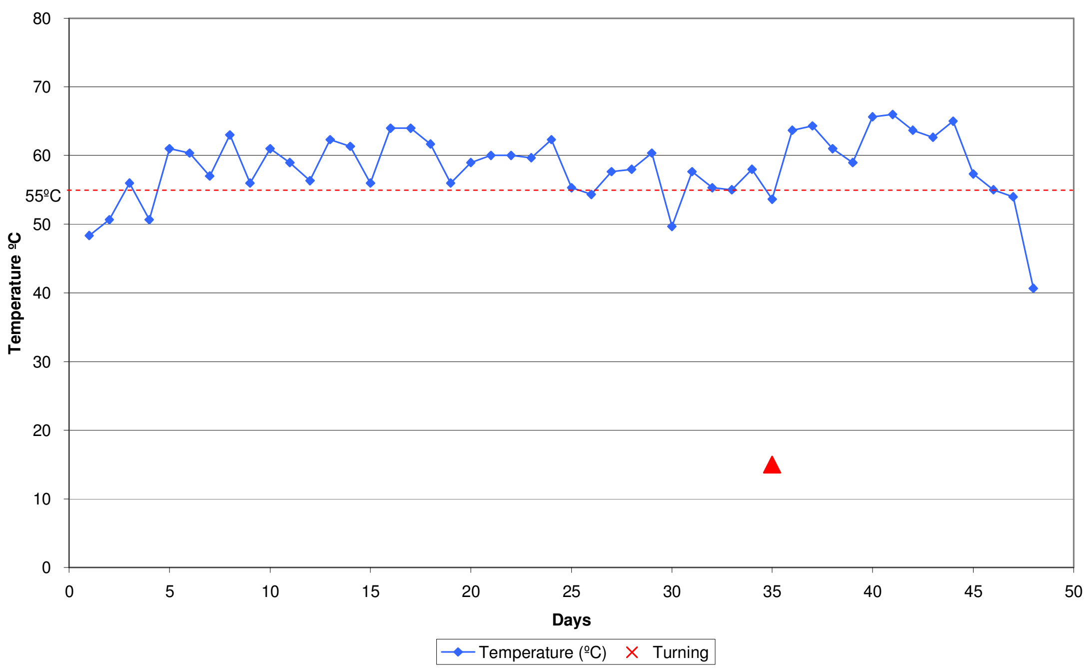

Figure 5: Curing Temperature - FORCE 1

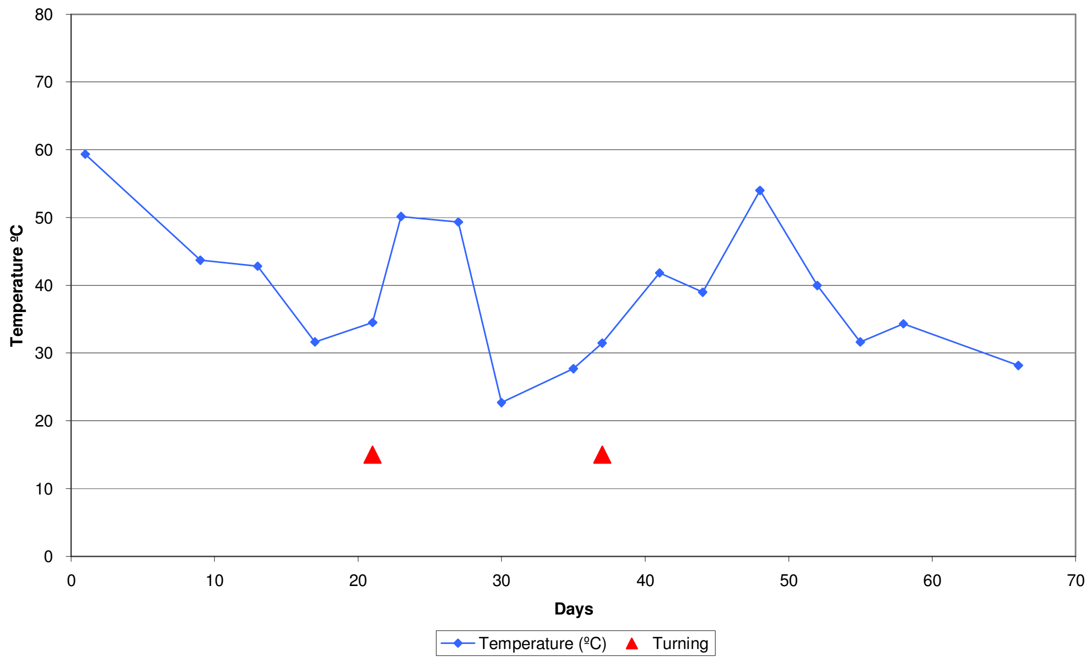

Figure 6: Curing Temperature - FORCE 2

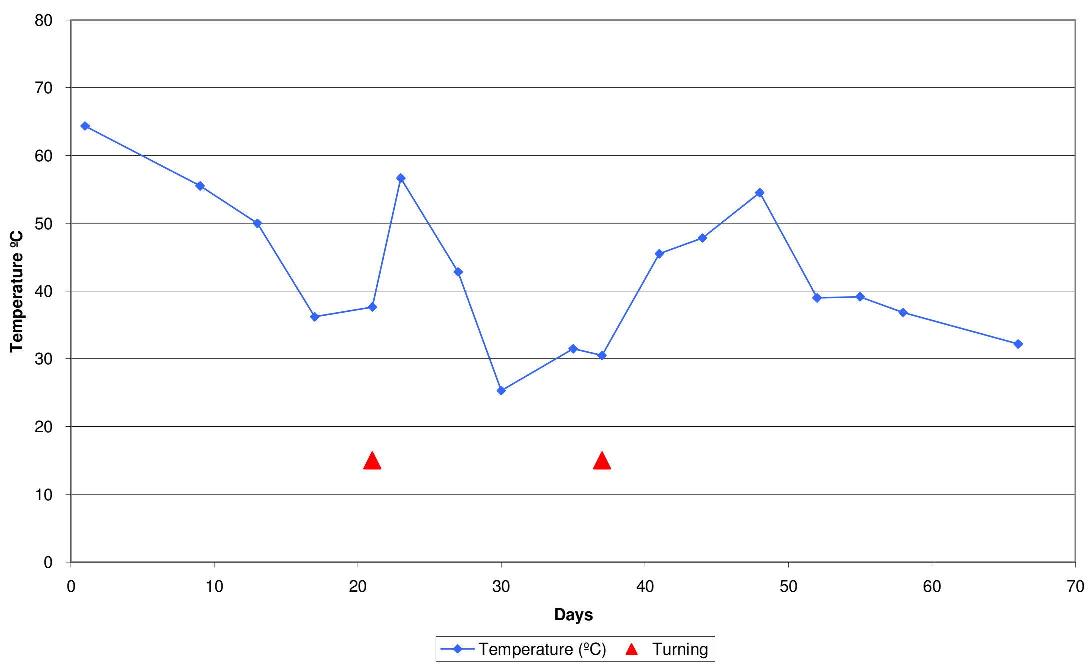

Figure 7: Curing Temperature - FORCE 3

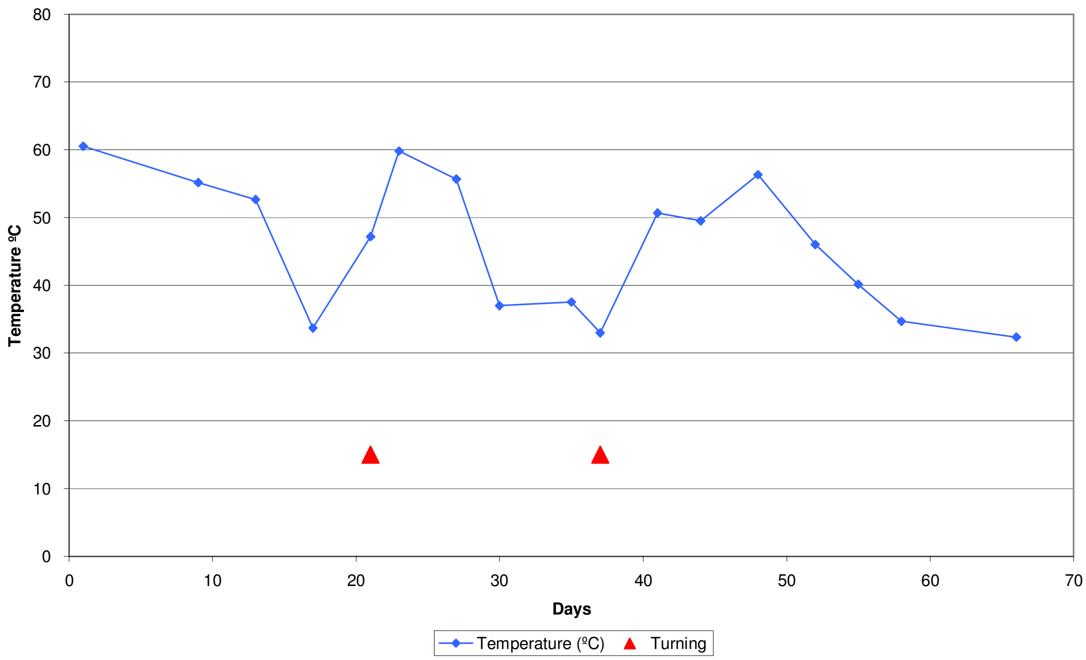

Figure 8: Curing Temperature - FORCE 4