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Field Study: Foodservice Packaging as Compost Facility Feedstock

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Submitted to: Foodservice Packaging Institute and Biodegradable Products Institute

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The following CMA member compost facilities provided field testing space, staff, and support throughout the study:

- A-1 Organics
- Olympic Organics

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- Dart Container
- Eco-Products
- Genpak
- Georgia-Pacific
- Graphic Packaging International (formerly International Paper)
- Huhtamaki
- Novamont / BioBag

THANK YOU!

Combining the expertise of stakeholders in designing, communicating, and executing various phases of new projects that pioneer new areas within the collective solid waste and supply chain system cannot be executed without the support, knowledge, and resources of all involved.

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Executive Summary

Background and Study Question

As solid waste jurisdictions across the country are being charged with progressively ambitious landfill diversion goals, they are increasingly turning to commercial composting as a desirable and beneficial alternative to landfilling organic materials.

However, the compost bin is not a disposal bin; rather, it is an input into a manufacturing process whose raw materials are known as "feedstocks." These feedstocks serve as the main ingredients in the compost recipe. Compost feedstock management is therefore one of the most important elements in producing quality products and ensuring optimal operational targets are met within an industrial compost manufacturing facility.

Composting is the natural process of decomposition by which organic substances are broken down into simpler organic matter. Of the many elements required for microbial decomposition, carbon and nitrogen play a vital role. The primary source of carbon (which also serves as a bulking and porosity agent) is wood and woody material. However, during some months of the year, such as heavy grass season, compost manufacturers seek additional carbon sources to meet carbon-to-nitrogen ratio targets. Common sources of nitrogen include grasses and food scraps. Other characteristics that are closely monitored and managed include moisture content and nutrient values.

Due to its prevalence in the waste stream and the environmental impacts of landfilling organic materials, food scraps are a high priority for diversion. Compostable foodservice packaging is designed to carry food scraps into composting programs and break down under commercial composting conditions. Therefore, more and more businesses and communities have implemented food scraps collection programs that allow compostable paper and packaging to boost participation and diversion. As a result, these items are emerging as a larger portion of the feedstock profile within both commercial and residential food waste streams.

However, there is little current information available to both the packaging and compost manufacturing industries on other benefits that these items may provide in terms of traditional feedstock characteristics targeted to meet recipe requirements for compost production.

It is in this context that the Foodservice Packaging Institute (FPI) and the Biodegradable Products Institute (BPI) chose to study the degree to which foodservice packaging (e.g. plates, cups, food trays, cutlery, napkins, bags, etc.) possess the properties sought in conventional feedstocks such as yard trimmings and wood waste. To this end, this field study was designed to answer the following question:

How does compostable foodservice packaging compare with other conventional organic inputs (e.g. yard trimmings, straw, wood shavings, grass, food scraps, etc.) in its contribution to balancing targeted carbon to nitrogen (C:N) ratios, providing nutrients, and acting as a bulking agent in compost feedstocks?

Study Methodology

For this study, Compost Manufacturing Alliance (CMA) conducted full scale parallel operational field tests at two commercial composting facilities located in two geographies. The test sites employed two of the most common composting methods: aerated static pile (ASP) and open windrow.

The study consisted of six phases:

- **Phase 1: Foodservice Packaging Selection and Analysis.** The study design team identified the desired mix of foodservice packaging for inclusion in the study, including product categories, substrates, and the ratios at which they would be mixed. Special attention was paid to ensuring that the proportions of substrates was reflective of real-world operational observations. Each foodservice item type was independently tested for carbon availability to ensure minimum feedstock preparation targets were met.
- **Phase 2: Feedstock Preparation.** Products were then mixed, ground, and incorporated into test piles and windrows using each site's normal feedstock preparation protocols. Each test pile or windrow was divided into four sections: two control samples created from the sites' seasonal recipes and two test samples using compostable foodservice packaging in place of the facilities' customary bulking agents and carbon sources. The test samples incorporated the FSP mix at rates of 15 and 30 percent respectively. Each sample contained 130 cubic yards of the mixed material, or 520 yards for all samples combined at each facility. Both project sites used pile sizes typical of normal processes. ASP bays are 600 yards (the same size as the four collective samples were processed in), and windrow piles can vary between 100 to 1000 yards.
- **Phase 3: Pre-process Sampling and Analysis.** Samples of all control and test samples were tested by an independent laboratory using Test Method for the Examination of Composting and Compost (TMECC) methods for target parameters including bulk density, moisture, organic carbon, nitrogen and the carbon-to-nitrogen ratio.

- **Phase 4: Active Composting and Monitoring.** The samples were in active composting for 45 days in ASP and 90 days in windrow per normal facility operations. Both sites extended active processing for an additional 21 days beyond their normal timeframe, with adjusted moisture and temperature profiles, to allow the compostable products to disintegrate further. Throughout the duration of the project, temperature and bulk density monitoring was performed on site. Moisture levels were monitored, with water applied when needed, and windrow turning activities were tracked.
- **Phase 5: Post-process Sampling and Analysis.** After processing, finished compost samples were tested by an independent soil testing laboratory using TMECC methods for pertinent compost characteristics including pH, nutrient content, organic matter, and moisture content, according to Seal of Testing Approval (STA) standards.
- **Phase 6: Reporting and Review.** This study report and its findings were reviewed by industry experts including members of the United States Composting Council (USCC) and BioCycle Magazine (BioCycle).

Findings

The results of the analyses performed before, during, and after active composting provide evidence that foodservice packaging at 15% and 30% of tested blends did not affect the balance of C:N ratios, nutrient levels, moisture content, or porosity to feedstocks or finished compost at these two facilities. Further, compostable foodservice packaging performed as an adequate bulking agent compared to wood and other traditional feedstocks used in compost production.

It should be noted that both test sites extended active composting three weeks beyond their typical operational timeframes and implemented pile management strategies to adjust moisture and temperature to attempt full disintegration of all compostable foodservice packaging feedstocks. However, at the end of the extended and modified processing, additional disintegration was achieved and characteristics of the finished compost for all test blends fell within acceptable ranges that were comparable with the control blends. The compostable foodservice packaging did not add or take away any nutrient value from the finished product.

Adding significant levels of diverse foodservice packaging to feedstocks did not appear to change the quality of the finished product positively or negatively, and it appeared to perform as well as traditional feedstocks used in compost production except for requiring extended processing time with a modified moisture and heat profile.

Given these findings, compost manufacturing facility operators may want to consider the value of compostable foodservice packaging as a viable feedstock, in addition to the added benefit of bringing in food scraps. This is especially significant in areas where composters are sourcing traditional bulking agents and carbon sources (or where these materials are seasonally scarce), when these compostable foodservice items could be an alternative.

However, prior to introducing new or additional foodservice packaging, composters should make sure that the foodservice packaging they include will disintegrate within their facility's normal operating parameters keeping an eye on feedstock and pile parameters of C:N ratio, moisture content, free air space and temperature profiles in particular.

The Importance of Carbon and Nitrogen Sources for Compost Production

Of the many elements required for microbial decomposition, carbon and nitrogen are key to the production of quality compost. Carbon provides an energy source for microorganisms and carbon-bearing materials serve as bulking and porosity agents during the composting process. Nitrogen is a crucial nutrient necessary for healthy plant growth. Compost feedstock preparation involves measuring the ratio of carbon-to-nitrogen of combined feedstocks. Carbon-to-nitrogen ratios vary from facility to facility, and seasonally, with a typical target of a 30:1.

Figure 1: Clean wood as carbon source

Primary sources of carbon are wood and woody material, including those from land clearing projects, construction sites, used pallets, residential and commercial yard debris. Depending on commodity markets and climate, woody materials may require labor, time and some expense to source. For example, the cost of wood is directly tied to the price of oil; when oil prices rise, wood is sometimes used as hog fuel for industrial burners, creating challenges to finding plentiful and low-cost wood sources for compost facilities.

Figure 2: Used pallets as carbon source

Primary sources of nitrogen include food scraps, grass, and plant clippings.

Carbon Content of Compostable Packaging

One of the big questions about the inherent value of compostable foodservice packaging is how it contributes to the C:N ratio, or what portion of the organic carbon is available to the microbes. The short answer is that products tested and certified to the ASTM standards must achieve greater than 90% of conversion of the total organic carbon into CO_2, demonstrating that it can be used as food for composting microbes, just like the conventional feedstocks a composter accepts. The non-organic carbon components in products are just as important, such as lingo-cellulose, which results in the generation of humus (i.e., finished compost to sell), rather than carbon converted and “lost” as CO_2.

Other Important Characteristics in Feedstock and Compost Quality Management

In addition to managing the total available carbon, nitrogen, and the carbon-to-nitrogen ratio, other critical characteristics of feedstock and compost quality management include:

- **Bulk density –** Compost weight per unit area; composters may use this value to calculate free air space to measure the porosity within a pile (or how well oxygen will permeate the pile).
- **Moisture content –** Moisture content, expressed as a percentage of total weight, is the measure of the quantity of water present in a compost feedstocks and end products. In active composting, moisture provides microorganisms a medium for carrying out the biological and chemical reactions required for disintegration to occur in feedstocks. The moisture content of feedstock affects its bulk density (weight per unit volume) and therefore affects handling and transportation. When compost is finished, overly dry compost can be dusty and irritating to work with, while very wet compost can become heavy and clumpy, making its application more difficult and delivery more expensive. A preferred moisture percent for finished compost is 40 to 50%.
- **Electrical Conductivity –** Used to estimate the concentration of soluble salts, which supply essential nutrients to plants. Most composts have a soluble salt conductivity of 1.0 to 10.0 dS/m, whereas typical conductivity values in soil range from 0 to 1.5 in most areas of the US.
- **pH -** pH is the measure of acidity (or alkalinity), or hydrogen ion activity of a soil or compost (on a logarithmic scale). The pH scale ranges from 0 to 14, with a pH of 7 indicating neutrality.

Definitions

The following terms and their definitions (as they are related to compost operations and/or foodservice packaging) are provided.

- **Bulking agent –** Woody material or other carbon rich material used to add porosity or free air space in a composting pile that is sometimes used to increase the carbon to nitrogen ratio (C:N).
- **Disintegration –** The visible disappearance of an item/material.

- **Feedstock -** Discarded, acquired or procured organic materials such as yard, food and wood residuals that are collected from both commercial and residential sources and used to manufacture compost.

Study Timeline

There were several phases of this project, the timelines of which are noted below.

July 2017
Project Planning Scheduling, site logistics planning, test materials targeting and acquisition, team communications, facility visits, client communications.
August through October 2017
Product Sample Acquisition Calculating product sample needs, working with Cascadia and others on shipping logistics.
November 2017
Operations Coordination, Carbon and Feedstock Samples Tested, Feedstock Sample Preparation Facility test sites set up, supply purchases, samples removed from cases and "un-nested," sample mixing, weighing, grinding and prepping, bay and row build out and configuration. Initial feedstock samples pulled and shipped to laboratory.
November 2017 through March 2018
Active Composting Olympic Organics: November 2017 through January 2018 A1 Organics: November 2017 through March 2018
January through March 2018
Site Sampling and Finished Compost Material Analysis Full range of TMECC tests conducted for eight feedstock samples and eight finished compost samples for a total of 72 outsourced analytical tests.

April 2018
Data Analysis, Conclusions, Report Analytical data were reviewed, charted, analyzed and report produced.
May 2018
Draft Report Review Draft report was reviewed by various organizations before final publication of report.
June through October 2018
Final Report Review Additional changes were made and reviewed for final draft.

Study Facilities

In determining where to conduct the study, FPI requested that two different sites be used to enable evaluation of study results across different technologies and locations. The following two CMA member facilities agreed to participate in the study.

Facility Test Site 1: Olympic Organics

Address:	7890 NE Ecology Road Kingston, WA 98346
Process Technology:	Aerated Static Pile (ASP)
Annual Tonnage:	25,000 tons
Feedstock Types:	Landscape trimmings, source separated commercial food waste, residential YW/FW, brewery process by-products.

Test Site #1 is located within processing bays at the Olympic Organics facility in Kingston, Washington which processes approximately 25,000 tons of feedstock per year (and is currently undergoing significant expansion in 2018). The Kingston facility is located approximately 30 miles northwest of Seattle (by water) and serves local school districts, commercial foodservice operators, hauling companies, and Seattle processors with yard waste/food waste composting services. In addition, they receive significant volumes of brewery by-products. Olympic Organics uses an aerated static pile (ASP) composting system. In the ASP system, compost is produced in piles where mechanical aeration (using perforated plastic pipes and fans) forces or draws air through the compost pile. Active process duration is approximately 47 days, with 3 to 4 weeks added after screening for product curing.

Facility Test Site 2: A1 Organics

Address:	12002 WCR 59 Keenesburg, CO 80643
Process Technology:	Open windrow
Annual Tonnage:	355,000 tons
Feedstock Types:	Yard waste/food scraps, commercial food scraps, and brewery by-products from cities, haulers, and directly from generators.

Test Site #2 employs open windrow processing at A1 Organics two facilities located in Eaton (63 miles north of Denver), and Keenesburg (35 miles northeast of Denver), Colorado. A1 processes approximately 355,000 tons of organic material per year, to process residential yard waste/food scraps, commercial food scraps, and brewery by-products from cities, haulers, and directly from generators. Open windrow involves the placement of materials into long rows that are turned periodically to provide aeration to the piles.

The active composting process for YW/FW takes approximately 90 days, with an additional 4 weeks of curing time after screening. A1 also receives biosolids from wastewater treatment plants that are processed in a separate modified aerated static pile system (not related to the study).

Study Methodology

Phase One: Foodservice Packaging Selection and Analysis

During the design phase of this study, discussions were held to share collective expertise on the types of foodservice packaging used in commercial collection programs, as well as what the most common substrates that make up the profile of foodservice packaging within a public collection system. From those discussions, product types were identified, along with substrate categories determined for reference in the study. In addition, compost facility feedstock experts discussed what volume of estimated foodservice packaging material would need to be introduced to create measurable differences among traditional wood, yard waste and food waste feedstocks that arrive at a facility during various times of the year.

FEEDSTOCK MIX RATIOS

For commercial composting facilities that accept source-separated front-of-house commercial food waste and commingled yard and food waste, CMA estimates that compostable products can comprise between two and ten percent of incoming feedstocks, depending upon time of year and geography.

This study was designed to test the effects of introducing higher than normal levels of compostable foodservice packaging, at 15% and 30% of the total feedstock mix respectively, to evaluate whether foodservice packaging has value as a standalone feedstock category that is comparative with other traditional sources. By evaluating whether these “super-loaded” foodservice packaging feedstock mixes are comparable to conventional sources at these higher levels, the team hoped to learn whether foodservice packaging could be considered by compost facilities to serve a dual purpose as both a feedstock contributor in addition to a carrier of food scraps.

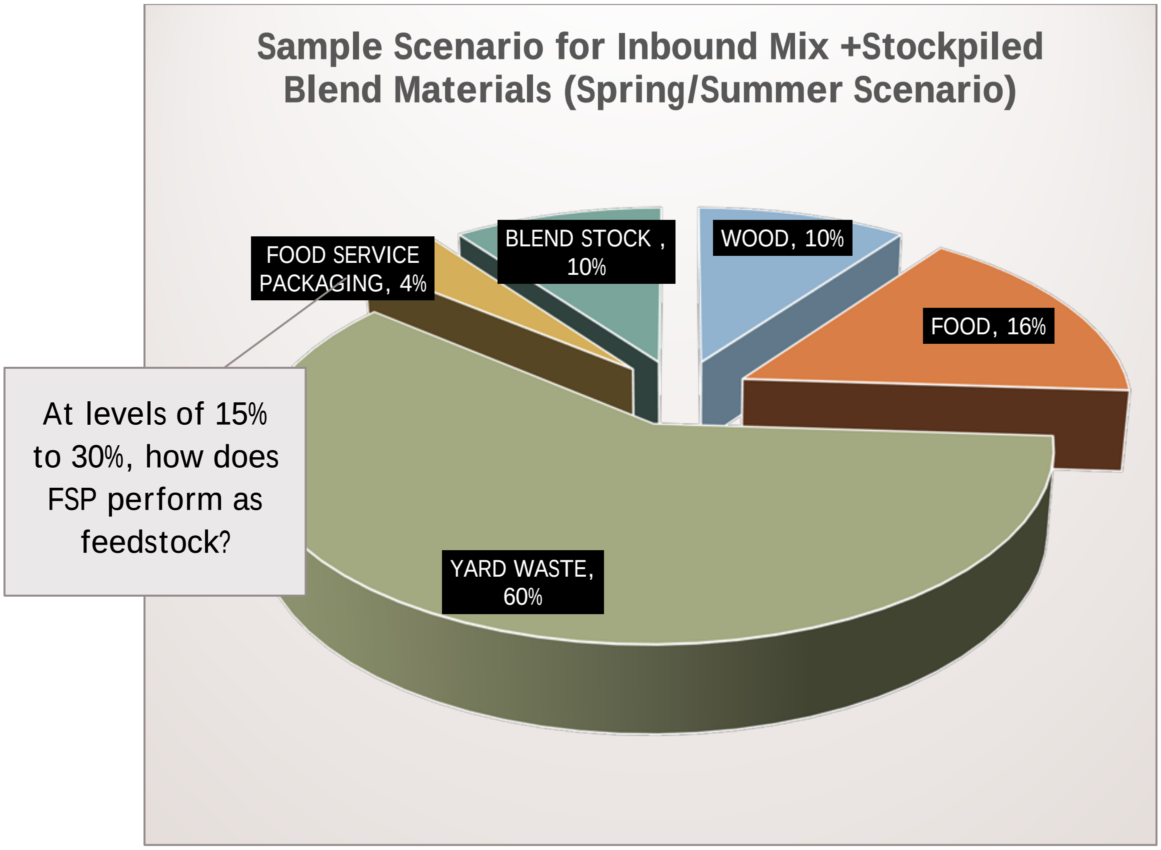

Figure 3: Inbound Feedstock Mix Sample

To help explain this concept, **Figure 3** represents a possible real-world scenario for spring/summer feedstocks mixes that arrive at a compost facility and are mixed with stockpiled carbon sources. Could employing foodservice packaging in collection programs be counted as a feedstock source to offset importing materials that are not part of inbound feedstocks that must be added to hit target recipes prior to composting?

Figure 3 shows a potential spring/summer mix of materials blended with acquired carbon sources and bulking agents that may include approximately 4% of foodservice packaging material in observed programs where the employment of foodservice packaging in source separated commercial food scrap collection occurs. The study tries to take a general approach to determine if this material can be differentiated as a feedstock. To measure that, piles were blended with high levels of foodservice packaging (15% and 30%) to “super-load” traditional feedstocks (shown above) with foodservice packaging levels high enough to note any measurable positive or negative differences, or to determine if the materials at those levels made no discernible difference in measuring compost quality characteristics at the end of the process.

SUBSTRATE MIX SELECTION

In consideration of the available compostable foodservice packaging in the marketplace, there are various substrates identified for use in the study as listed in **Table 1**.

Table 1: Study Substrates

Primary Substrates	Items
Paper/Paperboard (including PLA-coated)	Uncoated paper plates, beverage cups (hot), food trays, portion cups, napkins
Molded wood pulp	School food trays, plates
Bagasse (sugarcane fiber)	Clamshells, plates
Wheat straw	Clamshells
Polylactic acid (PLA)	Beverage cups (cold), portion cups
Crystallized polylactic acid (cPLA)	Cutlery
Polybutylene succinate (PBS) film	Bags
Aliphatic co-polymers	Bags

FOODSERVICE PACKAGING QUANTITY CALCULATIONS AND PROCUREMENT

A mix of common compostable foodservice items was included in the study, with details on volumes used per site listed below in **Table 2**. To ensure the study's findings would be relevant for the broadest possible audience of commercial composters, the study was designed to include a mix of the full suite of foodservice packaging product types and substrates. To determine the appropriate ratio of paper to plastic substrates within the foodservice packaging mix, the team conducted a review of publicly available organics waste composition data from the City of Seattle and CalRecycle.

Although the material category definitions used in these studies did not explicitly separate foodservice packaging from other materials of similar substrates, the team concluded that a 4 to 1 ratio of paper to plastic in the foodservice packaging mix would be feasibly representative of real-world conditions based on a combination of the data reviewed and anecdotal in-field observations over many years. Once the foodservice packaging product suite and paper-to-plastic ratio was set, CMA recommended percentages by product type and substrate based on its experience from the field. The final percentages used in the building of the piles for the study were ultimately dependent on the availability of all products in the desired quantities. Specifically, compostable bags were initially slated to represent 9% of the foodservice packaging mix, but due to difficulty obtaining product in such large quantities they ended up being 2% of the foodservice packaging mix.

Table 2: Mix of Compostable Foodservice Items Included in Study

Product Type	FSP Mix	Acquired yds^3 15%	Acquired yds^3 30%	Total yds^3
Hot Beverage Cups (PLA-lined paper)	16%	2.92	5.84	8.76
Cold Beverage Cups (PLA)	11%	2.14	4.28	6.42
Clamshells (bagasse and wheat straw)	15%	2.92	5.84	8.76
Plates (molded fiber and uncoated paper)	15%	2.92	5.84	8.76
Lunch Trays (molded fiber)	7.5%	1.46	2.92	4.38
Food Containers (paper)	7.5%	1.46	2.92	4.38
Napkins (paper)	10%	1.95	3.89	5.84
Cutlery (modified PLA)	10%	1.95	3.89	5.84
Compostable Bags	2%	0.39	0.78	1.17
Portion Cups (paper)	3%	0.58	1.17	1.75
Portion Cups (PLA)	3%	0.58	1.17	1.75
Totals	**100%**	**19.27**	**38.54**	**57.81**

Phase Two: Feedstock Preparation

It is important to understand the process involved in compost production in relationship to the study. **Figure 4** outlines this process and shows where foodservice packaging was introduced into variable feedstock blends during the *Feedstock Preparation* phase. The product blends prepared reflected an approximate ratio of test items in commingled YW/FW streams at 15%, as well as an extreme range of 30% foodservice packaging to standard feedstocks.

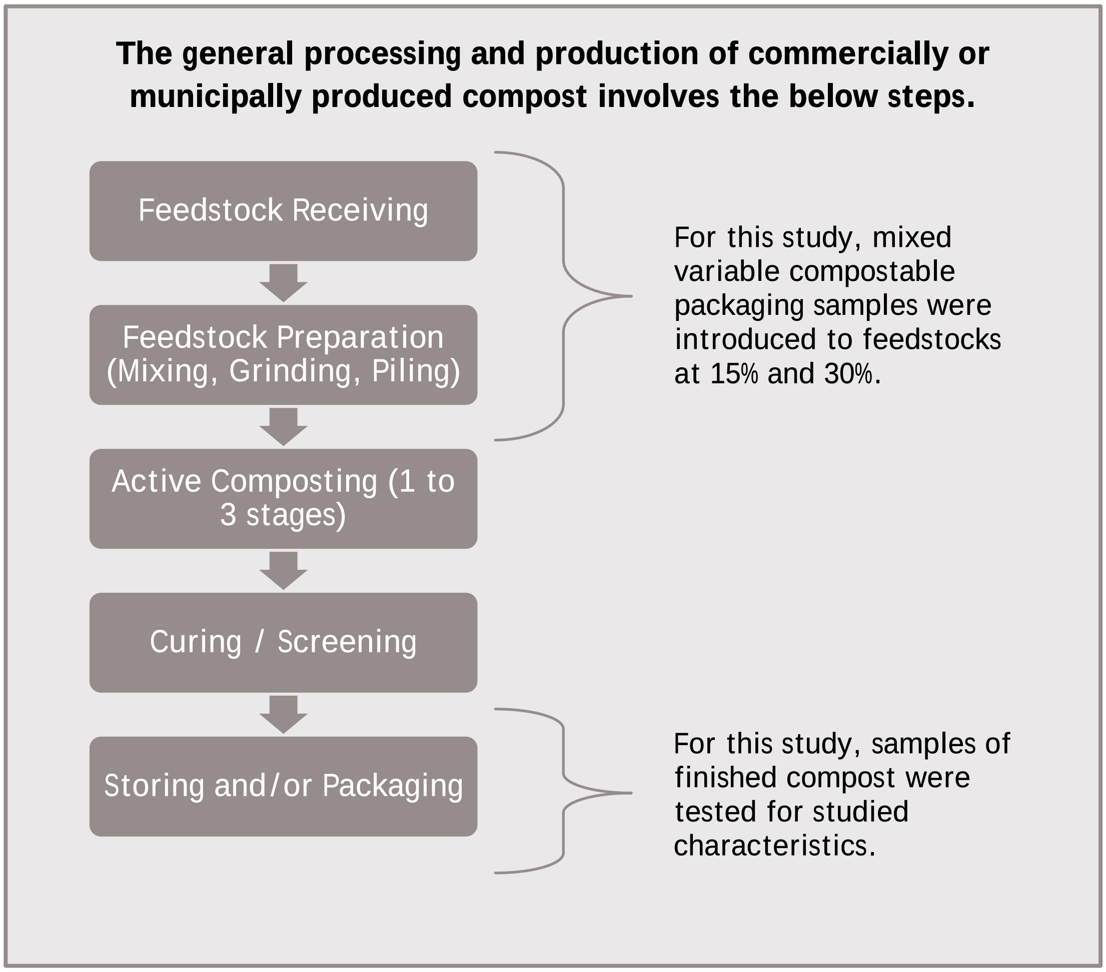

Figure 4: Typical Commercial Composting Process

MIXING AND GRINDING

Figure 5: FSP at A1 Organics is prepared for mixing and grinding.

After receiving the necessary quantity of compostable products from varying substrate categories, the items were introduced and mixed into the facility feedstocks. All mixtures were processed using normal facility operations' mixing, grinding and pile building protocols. At both sites, mixtures were blended together following normal operating procedures for feedstock preparation. A1 Organics used a Doppstadt DW 3060 K Slow Speed Shredder with 6" screens, then material was mixed with green waste from other operations that were preliminarily ground to 3" minus. Olympic Organics used a Peterson 4400 horizontal shredder with 4" screens.

PILE FORMATION AND SEGMENTATION

Figure 6: Mixed FSP and feedstock materials ground and coming off the conveyor prior to placement in quadrant for active composting at Olympic Organics.

Four quadrants were created at each facility (**Figure 7** and **Figure 8**). Two of the four quadrants (ASP) or rows (windrow) were created from the sites' seasonal recipes, and the other two were created using compostable foodservice packaging in place of the facilities' customary bulking agents and carbon sources (such as chipped wood, leaves, etc.).

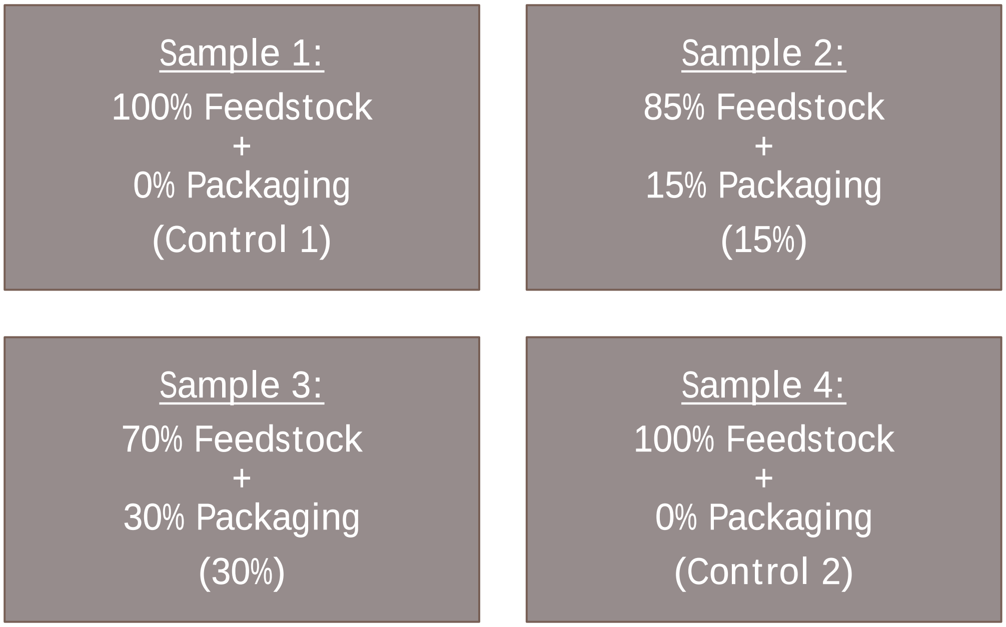

Figure 7: Pile quadrants at Olympic Organics (ASP Bays) containing 130 cubic yards of material for each sample, or 520 cubic yards for all samples combined. These pile sizes represent actual bay sizes used in normal processing.

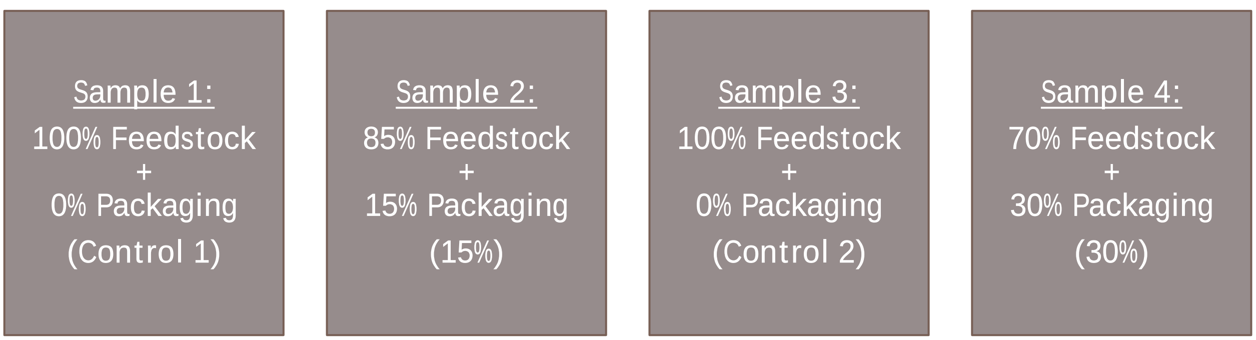

Figure 8: Windrow segments at A1 Organics (Windrow) containing 130 cubic yards of material in each sample or 520 cubic yards for all samples combined. Windrows built in normal operations can range in size from 100 to 1,000 yards each.

Phase Three: Pre-Process Sampling and Analysis

In order to draw a baseline for measurement during future phases of the study, mixed samples were taken at both facilities and sent to Spectra Laboratories in Tacoma, Washington for feedstock analysis. The samples were analyzed for the target parameters as listed in **Table 3**. Feedstock analysis is important for composters to understand where their recipe falls within targeted operating parameters as they build the piles. The general goal is to operate at a 30:1 carbon to nitrogen ratio and above 50% moisture content.

Table 3: Feedstock Analysis Testing Parameters

Analysis	Matrix	Method Reference
Bulk Density	Feedstock	TMECC 03.01-A
Moisture	Feedstock	TMECC 03.09-A
Total Organic Carbon	Feedstock	TMECC 04.01-A
Total Nitrogen	Feedstock	TMECC 04.02-A
Electrical Conductivity	Feedstock	TMECC 04.10-A
pH	Feedstock	TMECC 04.11-A
C:N Ratio	Feedstock	TMECC 05.02-A

Phase Four: Active Composting and Monitoring

Throughout the duration of the project, temperature and bulk density monitoring was performed on site. Temperature measurements were taken continuously, and bulk density measurements were taken weekly. Moisture and windrow turning was also monitored at the windrow facility. Field measurements were sent to the project manager monthly.

Figure 9: Visible fragments of non-composted foodservice packaging at 45 days.

Observations were noted at the end of each the facility's standard processing timeframe. At the end of the normal processing timeframe at both facilities, non-composted product fragments were observed. Therefore, both technologies were run for an additional three weeks beyond the normal process timeframe to allow the compostable products to disintegrate further. It should be noted that every composter determines their own processing time based upon customary operational protocols, procedures, seasonality and feedstock types.

Phase Five: Post-Process Sampling and Analysis

After processing, finished compost samples were taken and sent to Soil Control Laboratories in Watsonville, California for analysis. Evaluations were conducted using the US Composting Council's Seal of Testing Assurance program's TMECC methods (USCC STA).

Characteristics analyzed are listed below in **Table 4**.

Figure 10: Finished compost sample collection at A1 open windrow facility.

Table 4: Finished Compost Testing Parameters

Final Testing	Material Type	Method
Soluble Salts	Finished Compost	TMECC 04.10-A
pH	Finished Compost	TMECC 04.11-A
Nutrient Content (N-P-K)	Finished Compost	TMECC 04.02-D
Organic Matter	Finished Compost	TMECC 04.01
Moisture Content	Finished Compost	TMECC 03.09
Maturity	Finished Compost	TMECC 05.05-A
Stability	Finished Compost	TMECC 05.08-B
Inerts	Finished Compost	TMECC 03.08
Trace Metals	Finished Compost	TMECC 04.06, 04.12, 04.14-A

Phase Six: Reporting and Review

All data was pulled into a report with project photos, charts and other information supplied from field notes and participating facilities. The report was reviewed by various facility participants and staff for comments and other observations. In addition, the draft report was also reviewed by USCC's Cary Oshins, BioCycle's Nora Goldstein and operations' staff at CMA facilities that participated in the project.

Study Sampling & Analysis Summary

Table 5 summarizes the sampling and analysis activities that were conducted over the course of the study.

Table 5: Study Sampling and Analysis Schedule

Study Phase	Analysis Inputs	Test Parameters	Tester	Frequency	Protocol(s) Followed
3	Raw mixed feedstocks	• Bulk Density • Moisture • Total Organic Carbon • Total Nitrogen • Electrical Conductivity • pH • C:N Ratio	Spectra Laboratories	• Once	• TMECC 03.01-A • TMECC 03.09-A • TMECC 04.01-A • TMECC 04.02-A • TMECC 04.10-A • TMECC 04.11-A • TMECC 05.02-A
4	In-process compost	• Temperature • Bulk density	On-site On-site	• Continuously • Weekly	• On-site probes • TMECC 3.01-C
5	Finished compost	• Soluble Salts • pH • Nutrient Content (N-P-K) • Organic Matter • Moisture Content • Maturity • Stability • Inerts • Trace Metals	Soil Control Laboratories	• Once	• TMECC 04.10-A • TMECC 04.11-A • TMECC 04.02-D • TMECC 04.01 • TMECC 03.09 • TMECC 05.05-A • TMECC 05.08-B • TMECC 03.08 • TMECC 04.06, 04.12, 04.14-A

Evaluating Study Findings

The question posed in this study was: how does compostable foodservice packaging compare with other conventional organic inputs (e.g. yard trimmings, straw, wood shavings, grass, food scraps, etc.) in its contribution to balancing targeted carbon to nitrogen (C:N) ratios, providing nutrients, and acting as a bulking agent in compost feedstocks?

Because finished compost target characteristics vary across facilities based on the primary markets for the compost application, there is no single industry standard of acceptable ranges against which to evaluate the study parameters. For example, for weed suppression and erosion control, a finished compost C:N ratio of 25:1 may be acceptable. For a garden or agricultural soil amendment, a lower C:N value may be preferred (such as 15:1). In most cases, targets are assessed by facilities and their operational teams. Therefore, the study results discussed in this section will focus on comparing and contrasting the results of the control samples and the foodservice packaging samples. That said, **Table 6** outlines generally accepted ranges and limits, where known, of parameters including the source for the standard or guideline.

Table 6: Generally accepted ranges for feedstock and finished compost characteristics

References for ranges:

- EPA's 40 CFR, section 503.13, Table 3 (EPA column below)
- Washington Administrative Code 173-350-220 rules for compost facilities, updated 2014 (WAC column below)
- Washington State Department of Ecology's 2011 publication *Siting and Operating Compost Facilities in Washington State: Good Management Practices* (WAGMP column below)
- US Composting Council's Seal of Testing Assurance (STA) program guidelines (USCC STA column below)

Feedstocks	Characteristic	EPA	WAC	WAGMP	USCC STA
	Bulk density	NR	NR	NR	NR
	Carbon to Nitrogen	NR	NR	20:1-40:1	NR
	Moisture Levels	NR	NR	40-70%	NR
Finished Compost	Arsenic	< 41 ppm	< 20 ppm	NR	NR
	Cadmium	< 39 ppm	< 10 ppm	NR	NR
	Copper	< 1500 ppm	< 750 ppm	NR	NR
	Lead	< 300 ppm	< 150 ppm	NR	NR
	Mercury	< 17 ppm	< 8 ppm	NR	NR
	Molybdenum	NR	< 9 ppm	NR	NR
	Nickel	< 420 ppm	< 210 ppm	NR	NR
	Selenium	< 100 ppm	< 18 ppm	NR	NR
	Zinc	< 2800 ppm	< 1400 ppm	NR	NR
	pH	NR	5.0-10.0	5.0-10.0	NR
	N-P-K (measured as attribute)	NR	NR	NR	NR
	Moisture	NR	NR	NR	40-50% (preferred)
	Conductivity	NR	NR	NR	1.0-10.0 dS/m

NR = no specified range (facility ranges are referred to directly for standards not listed here within subsequent sections).

Test Site 1, Aerated Static Pile

ASP Conclusion: Feedstock blends of traditional materials and blends of 15% and 30% foodservice packaging to yard waste/food waste were shown at this facility to produce compost close to or within the generally accepted ranges for characteristics for finished compost.

PRE-PROCESS FEEDSTOCK ANALYSIS

Figure 11 shows measurements of pre-processing feedstock characteristics for all samples. **Table 7** outlines generally accepted ranges for each characteristic measured. The subsections that follow provide detailed results for each characteristic measured.

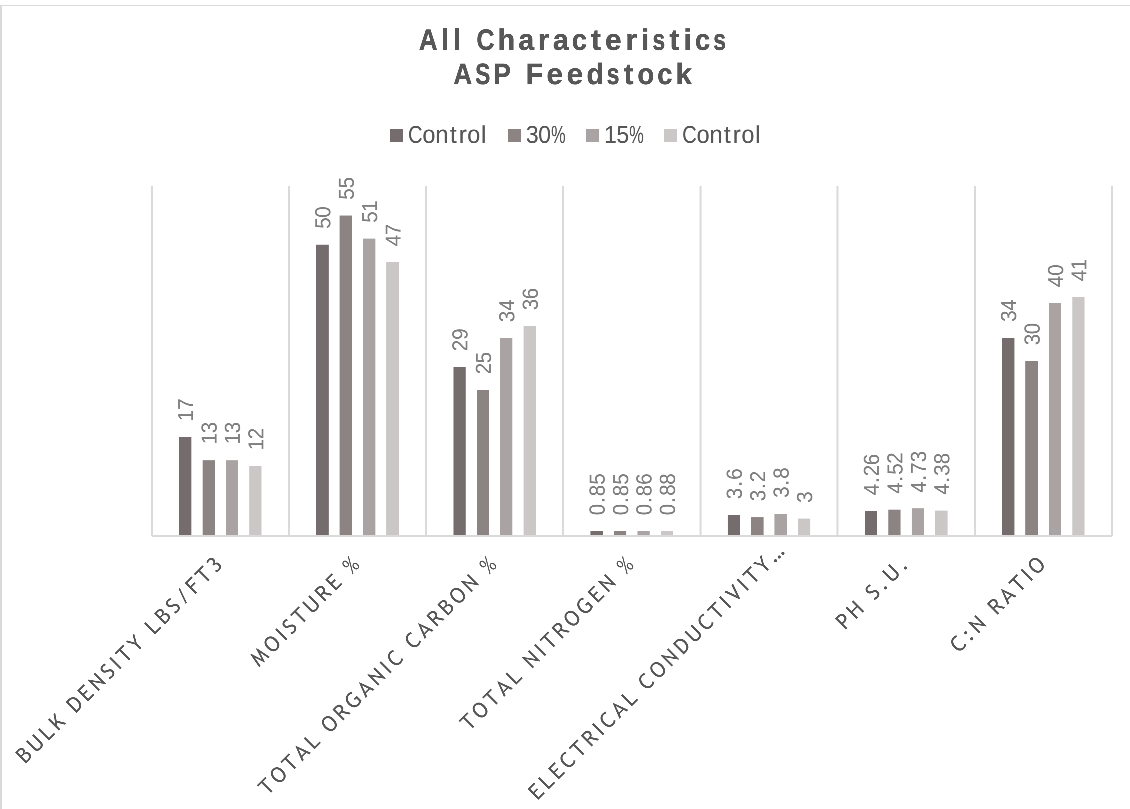

Figure 11

Table 7: Olympic Organics ASP Generally Accepted Ranges for Pre-processing Feedstock Analysis (abbreviations for standards are listed in Table 6).

Characteristic	Range
Bulk Density*	LAB: 30- 55 lbs./ft^3 (wet wt.) FIELD: 30 - 55 lbs./ft^3 (or 800-1500 lbs./yd^3)
Moisture	40 - 70%
Organic Carbon	25 - 40%
Nitrogen	.35 - 1.5%
Conductivity	1.0 - 10.0 dS/m
pH	4.0 - 10.0 s.u.
C:N Ratio	20:1 to 40:1

* See additional comments and comparisons on TMECC field testing for bulk density, **Figure 13**).

ASP FEEDSTOCK-BULK DENSITY (TMECC METHODS, LABORATORY)

Reference	Generally Accepted Range
FACILITY	31-38 lbs. per cubic foot

Initial bulk density measurements were taken on each quadrant of the bay in the aerated static pile system. Bulk density measurements were also taken weekly using TMECC 3.01-C for field evaluation. Bulk density measurements within the four samples ranged from 12 to 17 pounds per cubic foot, which is below generally accepted ranges for this facility. However, field measurements were also taken and were shown to fall within generally accepted ranges for this facility (see **Figure 13**).

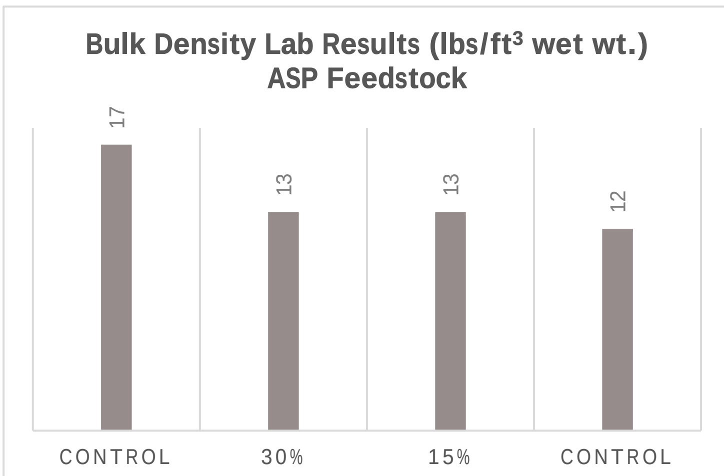

Figure 12

ASP FEEDSTOCK-BULK DENSITY (TMECC METHODS, FIELD)

Reference	Generally Accepted Range
FACILITY	800-1500 lbs. per cubic yard

Bulk density measurements were taken on site initially and then seven times thereafter. **Figure 13** shows that field measurements for bulk density were similar for both controls and FSP samples and were within the generally accepted ranges for this facility. This may indicate that packaging could be used in place of ground wood for porosity and bulk density support in the piles.

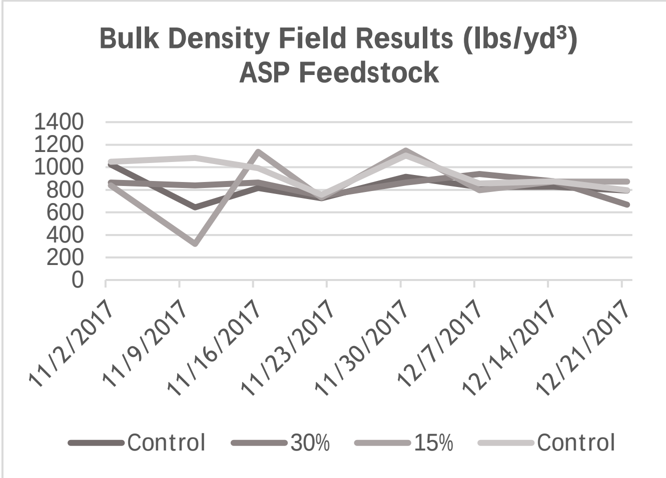

Figure 13

ASP FEEDSTOCK-MOISTURE

Reference	Recommended Range
WAGMP	40-70%

Moisture content of the four samples ranged between 47% and 55%, which is within the Washington State Department of Ecology's Good Management Practices (WAGMP) range of 40-70% for feedstocks as listed in **Table 6**.

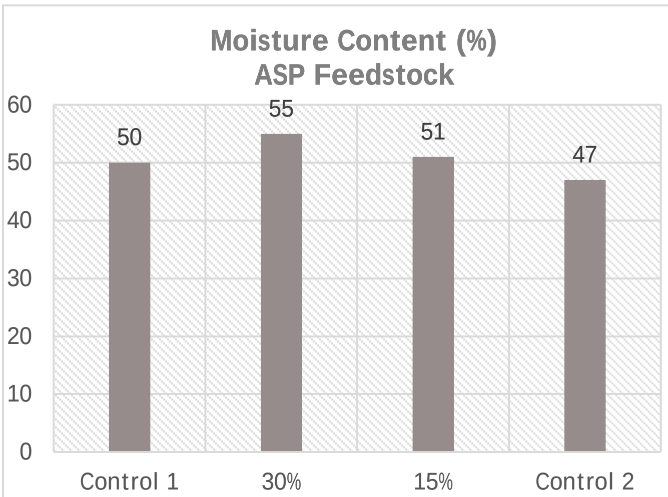

Figure 14

ASP FEEDSTOCK-TOTAL ORGANIC CARBON

Reference	Generally Accepted Range
FACILITY	25-40%

Total organic carbon ranged between 29% and 36% and were within generally accepted ranges for this facility.

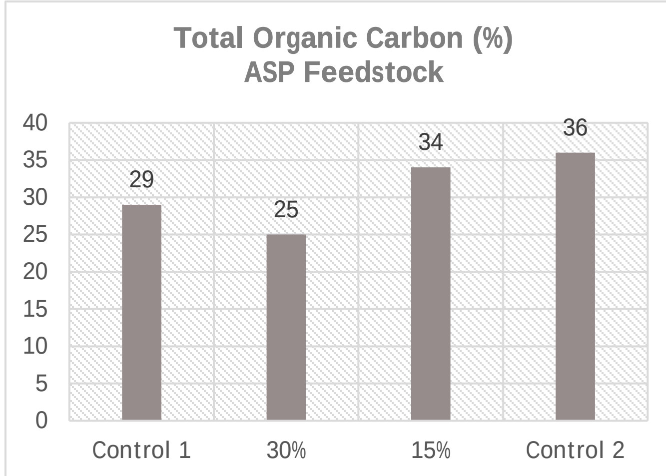

Figure 15

ASP FEEDSTOCK-NITROGEN

Reference	Generally Accepted Range
FACILITY	.35-1.5%

Nitrogen levels of the four samples were in the upper range of generally accepted levels for this facility, which is a positive outcome. As an attribute, compost facilities look for nitrogen levels to be as high as possible, as nitrogen serves as a slow release natural nutrient in soils when compost is used as a soil amendment.

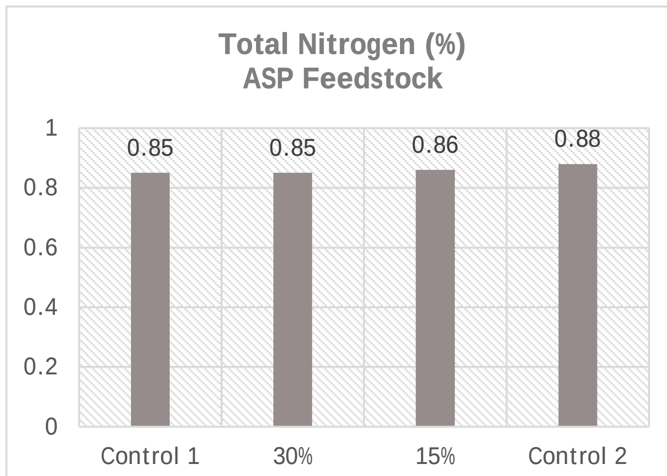

Figure 16

ASP FEEDSTOCK-ELECTRICAL CONDUCTIVITY

Reference	Generally Accepted Range
FACILITY	1.0-10.0 dS/m

Electrical conductivity ranged between 3.0 and 3.8 dS/m and were within the generally accepted range of 1.0 to 10.0 dS/m at this facility.

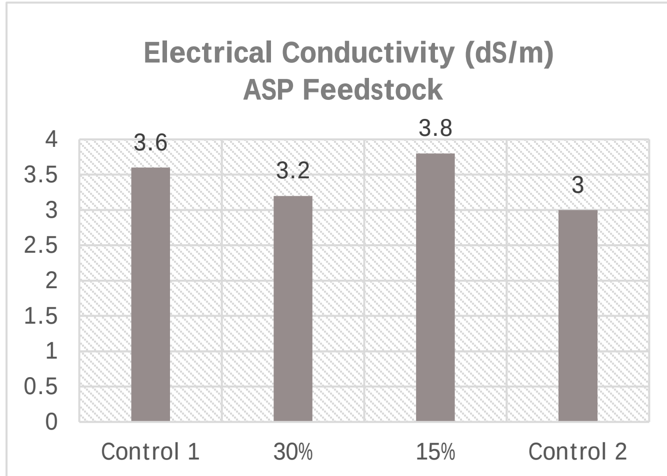

Figure 17

ASP FEEDSTOCK-pH

Reference	Generally Accepted Range
FACILITY	4.0-10.0 s.u.

Sample pH measurements ranged between 4.26 and 4.73 and were within the generally accepted range for this facility.

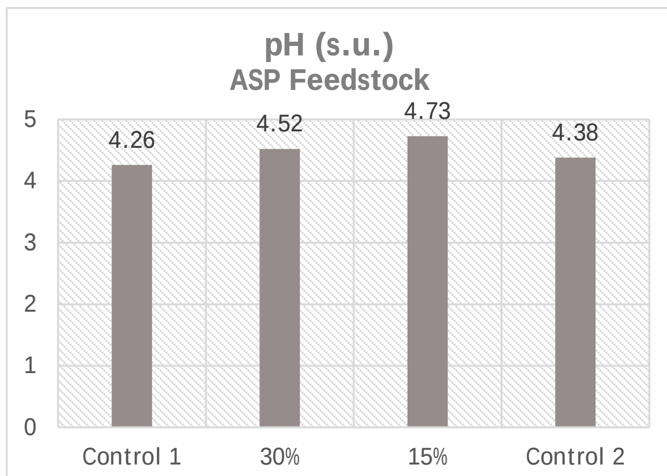

Figure 18

ASP FEEDSTOCK-CARBON TO NITROGEN RATIOS

Reference	Recommended Range
WAGMP	20:1 to 40:1

Carbon to nitrogen ratios from all samples ranged from 30:1 to 41:1 and were within the Washington State Department of Ecology's Good Management Practices (WAGMP) guideline range of 20:1 to 40:1 as listed in **Table 6**.

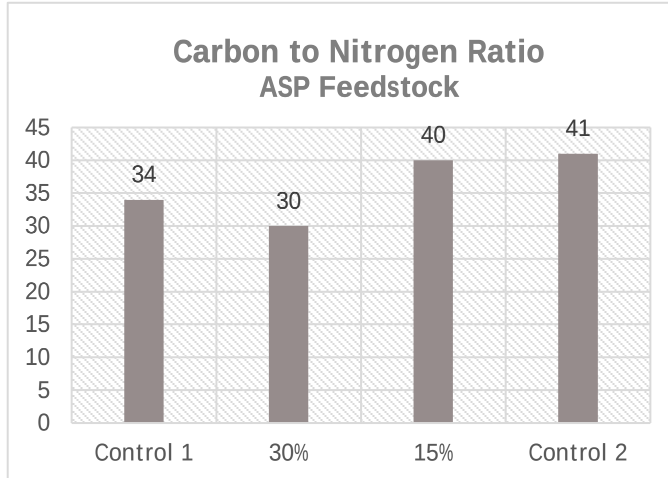

Figure 19

IN-PROCESS TEMPERATURE READINGS

Temperature data at the aerated static pile facility was collected automatically and continuously using two probes hard-wired to a data logger. Temperature values were recorded every hour for the entire life of the active composting pile. The normal duration of processing at the aerated static pile facility is 45 to 47 days. At the 45-day mark, there were visible fragments of non-composted foodservice packaging still present in the material. Because of this, process time was extended for three additional weeks beyond the active composting cycle and forced air applied to decrease temperature to promote the growth of microbial populations that could readily attack resistant substances (such as lignin, which was found in some of the fragments of packaging that were seen). Throughout the 45-day process, temperatures ranged between 135˚F to 168˚F.

During the extended processing period, temperatures were purposely dropped to between 80˚F and 120˚F and the processing time extended to optimize the disintegration of materials so that finished product analysis could be run. **Figure 20** shows the downturn then rise in temperature readings during the final weeks (see green circled area).

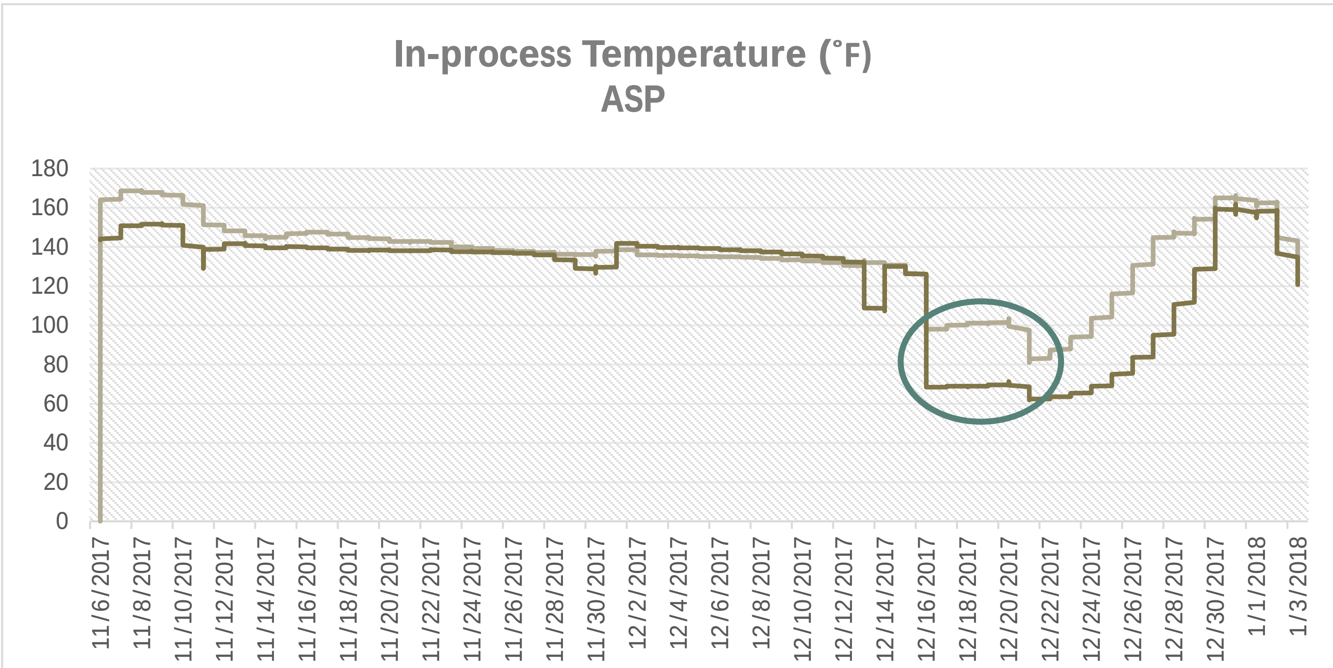

Figure 20

POST-PROCESS FINISHED COMPOST ANALYSIS RESULTS

Composite samples were gathered and sent to Soil Control Laboratories for full TMECC finished compost analysis upon completion of the extended composting cycle. These analyses show the characteristics of the finished compost prior to sale. See **Table 6** for a full listing of parameters tested. The subsections that follow provide detailed results for each characteristic measured.

ORGANIC MATTER, MOISTURE, ORGANIC CARBON, ASH, C:N

Figure 21 shows measurements of finished compost characteristics for all samples. **Table 8** outlines generally accepted ranges for each characteristic measured. Test sample characteristics were comparable to control samples and all samples fell within generally accepted ranges for finished compost.

Figure 21

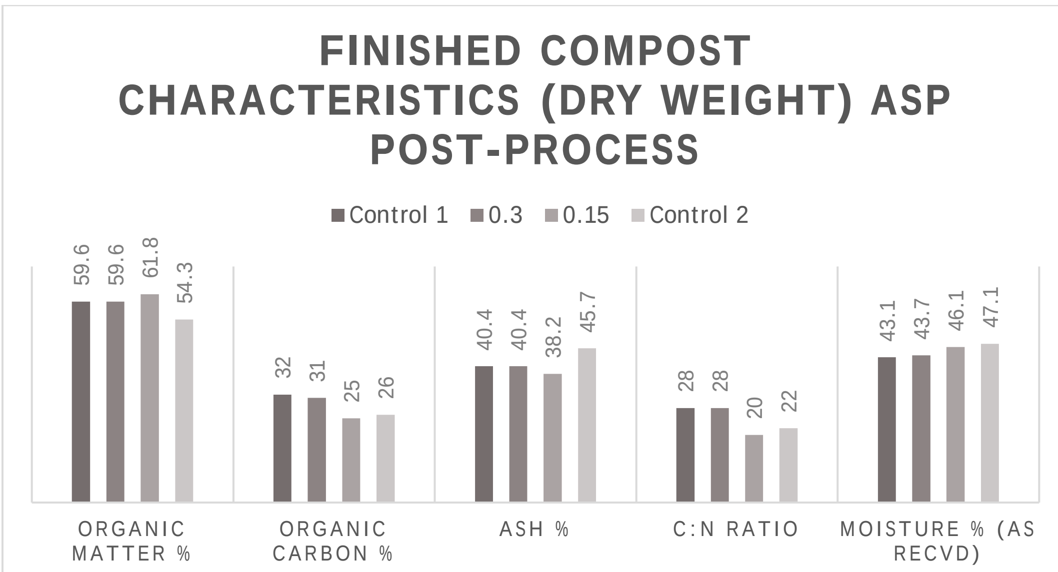

Table 8: Olympic Organics ASP Facility Generally Accepted Ranges for Post-Process Finished Compost Characteristics

Characteristic	Range
Organic Matter	40 - 65%
Organic Carbon	20 - 40%
Ash	40 - 60%
C:N Ratio	10:1 to 30:1
Moisture %	40-50%

VARIOUS NUTRIENTS (COMBINED) PLUS SODIUM, CHLORIDE, CARBONATES

The finished analysis results for the remaining constituents and nutrients measured in the samples determine product viability or certain applications of compost in the field. For example, farms look at the N-P-K (nitrogen, phosphorous and potassium) for plant and crop nutrient values. In other cases, regulations related to construction sites and low impact site development projects call for maintaining a minimum level of organic matter level in soils after construction, such as specified in municipal projects.

Figure 22 shows measurements of constituents and nutrients of finished compost for all samples. **Table 9** outlines generally accepted ranges for each characteristic measured. The data show a relatively low reading for nitrate in the 15% FSP sample, but all levels (in checking this result with the laboratory that conducted the test) are close to or below the detection limit of 1.0.

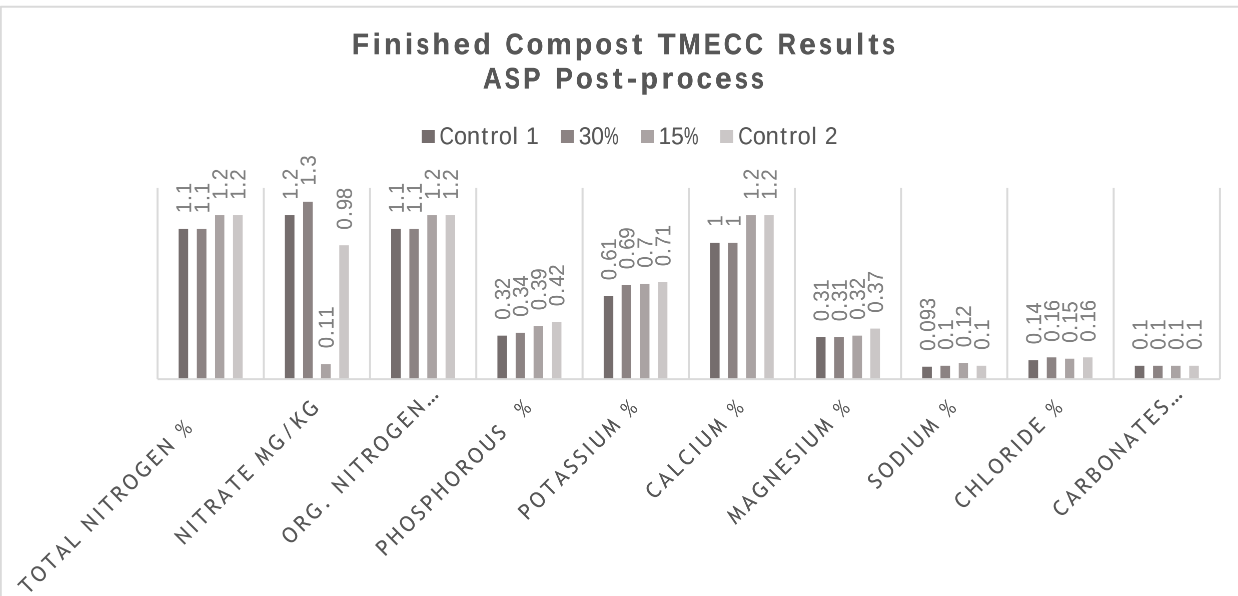

Figure 22

Table 9: Olympic Organics ASP Generally Accepted Nutrient Ranges for Finished Compost

Nutrient	Range	Nutrient	Range
Organic Matter	40 - 65%	Potassium	0.5 - 0.9 %
Organic Carbon	20 - 40%	Calcium	1 - 2 %
C:N ratio	10 - 30:1	Magnesium	0.3 - 0.5 %
Nitrate	5-100 ppm or mg/kg	Sodium	0.1 - 0.2 %
Organic Nitrogen	1 - 3 %	Chloride	0.1 - 0.2 %
Phosphorous	0.3 - 0.8 %	Carbonates	0.10 - 4 lbs./ton

METALS ANALYSIS, PART 1

Metal	Reference	Limit
Iron	FACILITY	<7500 ppm
Aluminum	FACILITY	<6000 ppm
Manganese	FACILITY	< 200 ppm

Iron, aluminum and manganese were within generally accepted ranges for this facility in all four samples.

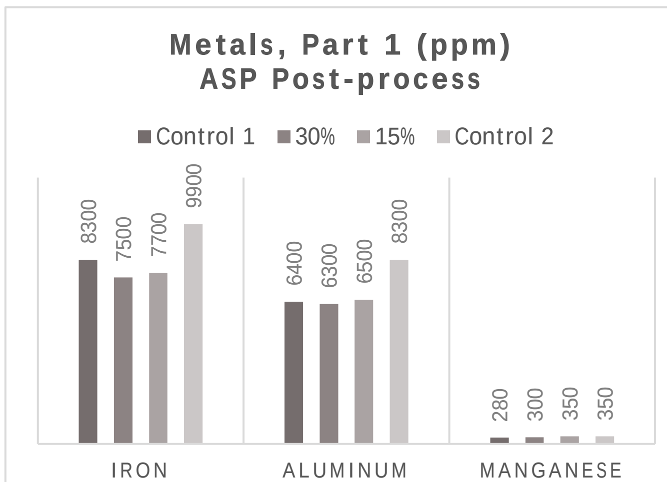

Figure 23

METALS ANALYSIS, PART 2

Metal	Reference	Limit or Range
Cobalt	FACILITY	3.5-6.0 ppm
Arsenic	WAC	< 20 ppm
Lead	WAC	<150 ppm
Molybdenum	WAC	< 9 ppm

Lead, arsenic and molybdenum were within acceptable levels as listed in Washington State Administrative Code (WAC) 173-350-220, Table 220-B and as listed in **Table 6** in this report. Cobalt was within generally accepted ranges for this facility.

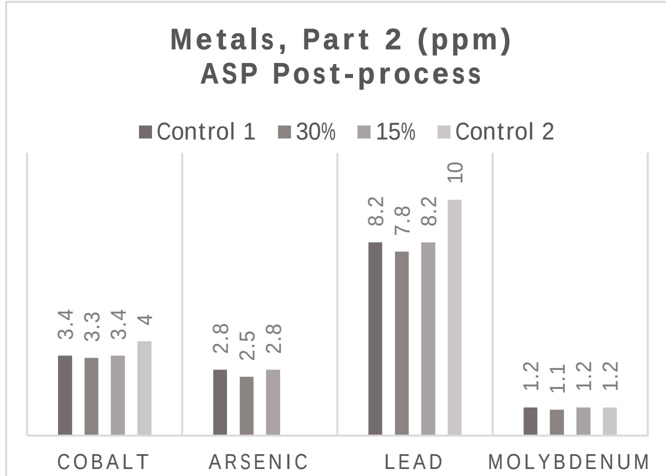

Figure 24

METALS ANALYSIS, PART 3

Metal	Reference	Limit
Chromium	FACILITY	<30 ppm
Copper	WAC	<750 ppm
Nickel	WAC	< 210 ppm
Zinc	WAC	< 1400 ppm

Copper, nickel and zinc were present within acceptable ranges for metals listed under the WAC 173-350-220, Table 2 and as listed in **Table 6** in this report. Chromium levels were within generally accepted ranges for this facility.

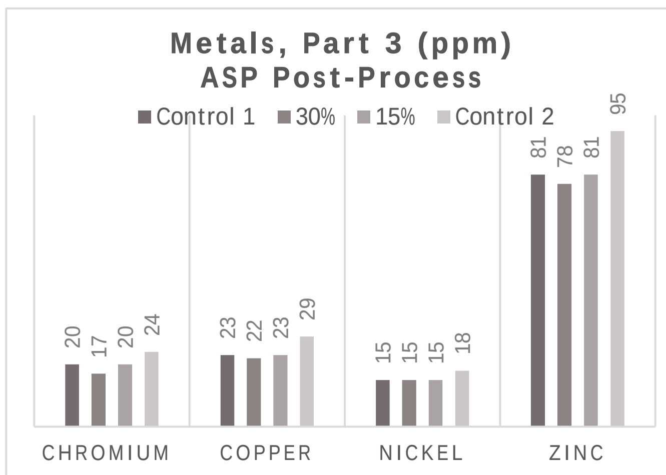

Figure 25

DISINTEGRATION

While not the focus of this study, disintegration is a critical measure of success for compostable products. At the end of the active composting process in the ASP facility, visible fragments of non-composted foodservice packaging were observed. To promote additional disintegration, processing time was extended three weeks and temperatures were decreased. Following completion of the extended processing and curing periods, additional disintegration was achieved and characteristics of the finished compost for all samples fell within acceptable and comparable ranges.

Test Site 2, Windrow

Windrow Conclusion: Feedstock blends of traditional materials and blends of 15% and 30% compostable foodservice packaging to yard waste/food waste showed no consistent difference from other materials used to make compost at this facility. Apart from lower C:N ratios in both the Control 2 sample and the 30% foodservice packaging sample (assumed to be the result of the variations between wood and leaves as blend feedstocks), all were within characteristic target parameters for finished compost.

PRE-PROCESS FEEDSTOCK ANALYSIS

Pre-process feedstock analyses for both controls and test blends fell within generally accepted ranges.

Figure 26 shows measurements of pre-processing feedstock characteristics for all samples. **Table 10** outlines generally accepted ranges for each characteristic measured. The subsections that follow provide detailed results for each characteristic measured.

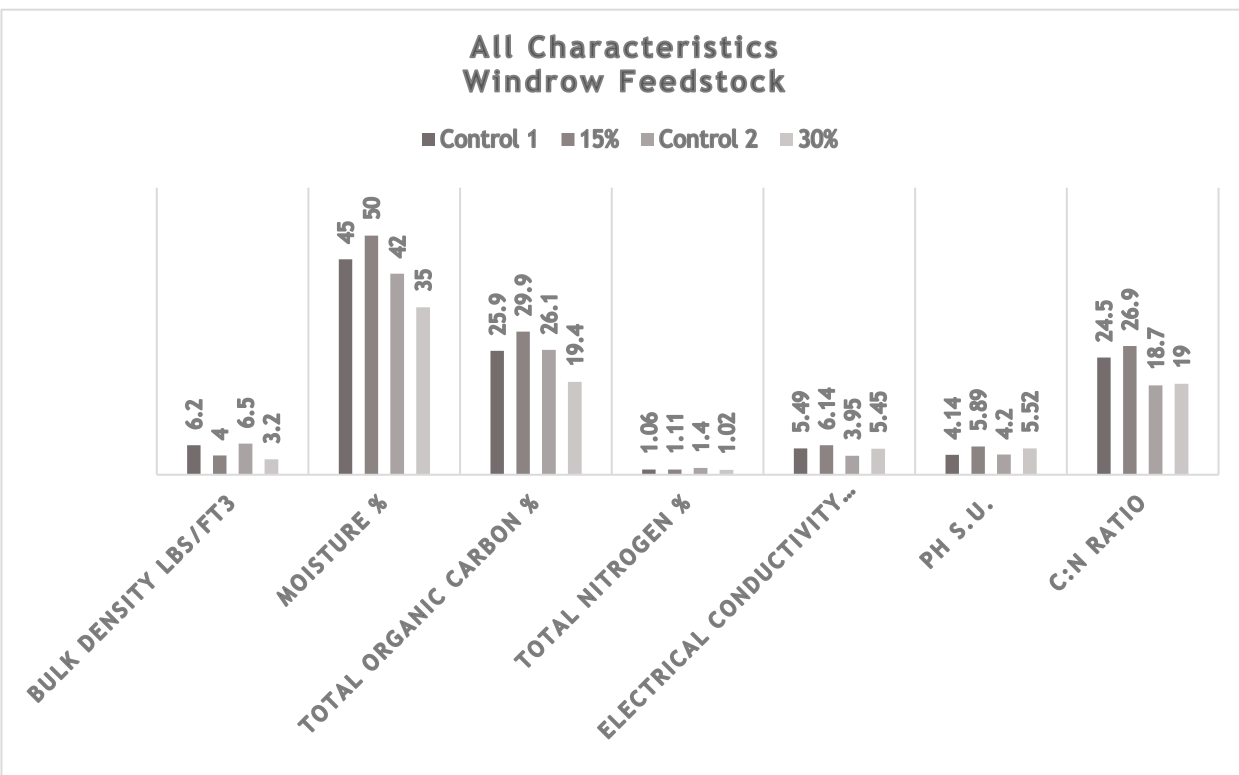

Figure 26

Table 10: A1 Organics Windrow Facility Generally Accepted Ranges for Pre-process Feedstock Analysis

Characteristic	Range
Bulk density	LAB: 30 - 63 lbs./ft^3 (dry wt.) FIELD: 30 - 63 lbs./ft^3 (or 800-1700 lbs./yd^3)
Moisture	40 - 70%
Organic Carbon	25 - 40%
Nitrogen	.75 - 1.5%
Conductivity	1.0 - 10.0 dS/m
pH	4.0 - 8.0 s.u.
C:N ratio	15:1 to 30:1

WINDROW FEEDSTOCK-BULK DENSITY (TMECC METHODS, LABORATORY)

Reference	Generally Accepted Range
FACILITY	30-63 lbs. per cubic foot

Ranges for initial bulk density within the four samples ran from 3.2 to 6.5 pounds per cubic foot. Foodservice packaging blends were notably less dense than the traditional feedstock blends, which could be considered a positive attribute in this test at this facility.

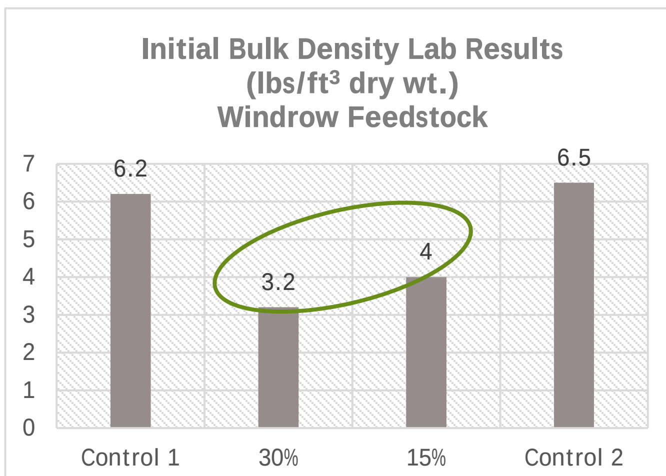

Figure 27

The comparison between the controls and the foodservice packaging mixes at 15% and 30% show variations from current feedstocks containing no foodservice packaging. This may be that most of A1's bulking agent was comprised of leaves versus wood. In instances where wood cannot be used, compostable foodservice packaging would add properties to lower density and increase free air space. Ranges from lab tests were also inconsistent with historically more accurate TMECC field tests (see following section).

WINDROW FEEDSTOCK-BULK DENSITY (TMECC METHODS, FIELD)

Reference	Generally Accepted Range
FACILITY	800-1700 lbs. per cubic yard

The initial bulk density result is a bit higher than the second reading, and it remained lower through the duration of the trial. The first turn of the pile was conducted between the first and second measurements. This may represent the de-compaction of the material from turning. Overall, bulk density measurements for both control and FSP mixed samples were within generally accepted ranges for this facility in field tests.

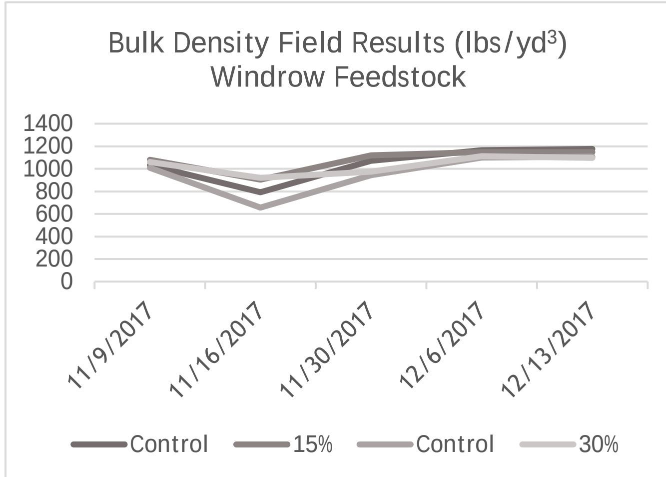

Figure 28

WINDROW FEEDSTOCK-MOISTURE

Reference	Generally Accepted Range
FACILITY	40-70%

Moisture content from within the four samples ranged between 35% and 50% for all four samples. The comparison between the controls and the FSP mixes at 15% and 30% show that sample results were within generally accepted ranges at this facility.

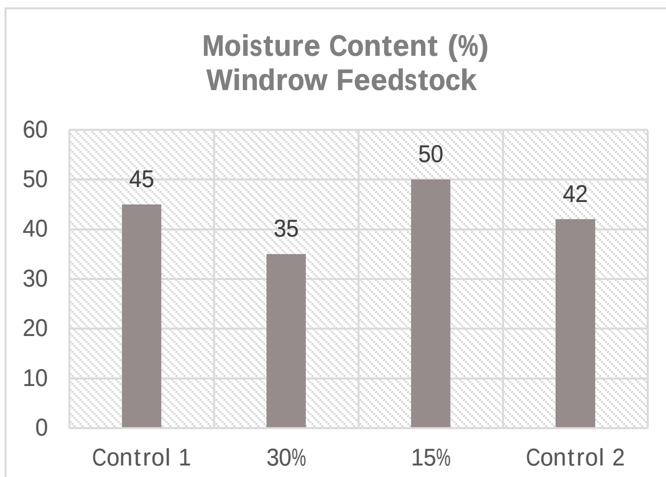

Figure 29

WINDROW FEEDSTOCK-TOTAL ORGANIC CARBON

Reference	Generally Accepted Range
FACILITY	25-40%

Total organic carbon ranged between 19.4% and 29.9% and were within generally accepted ranges for this facility.

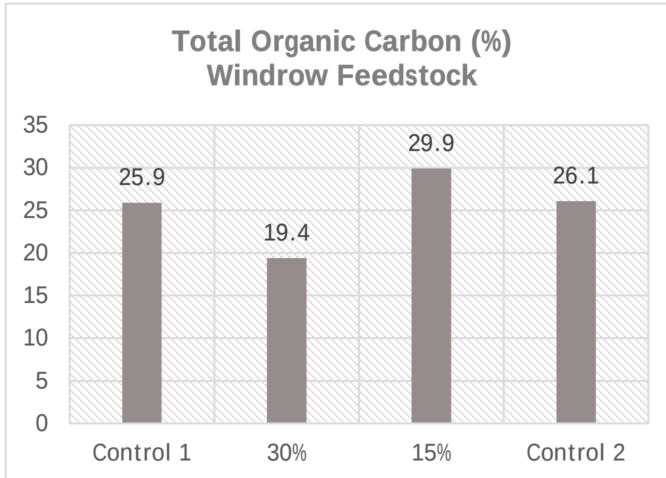

Figure 30

WINDROW FEEDSTOCK-NITROGEN

Reference	Generally Accepted Range
FACILITY	.75-1.5%

Nitrogen levels from the four samples all came in within generally accepted levels at this facility.

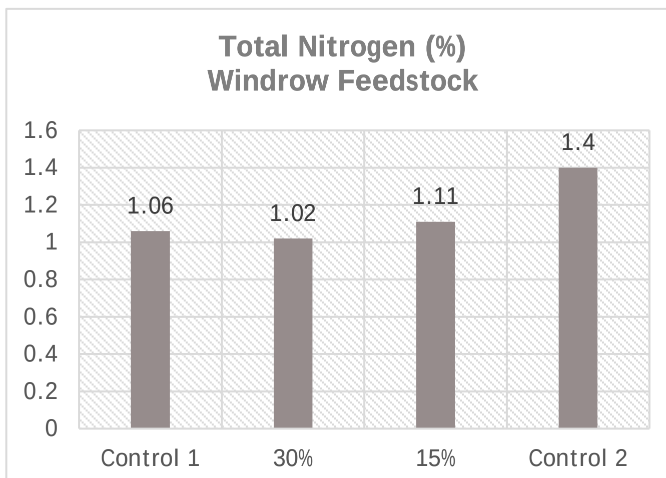

Figure 31

WINDROW FEEDSTOCK-ELECTRICAL CONDUCTIVITY

Reference	Recommended Range
USCC	1.0-10.0 dS/m

Electrical conductivity ranged between 3.95 and 6.14 dS/m were within the generally accepted range of 1.0 to 10.0 dS/m under US Composting Council guidelines and as listed in **Table 6** of this report.

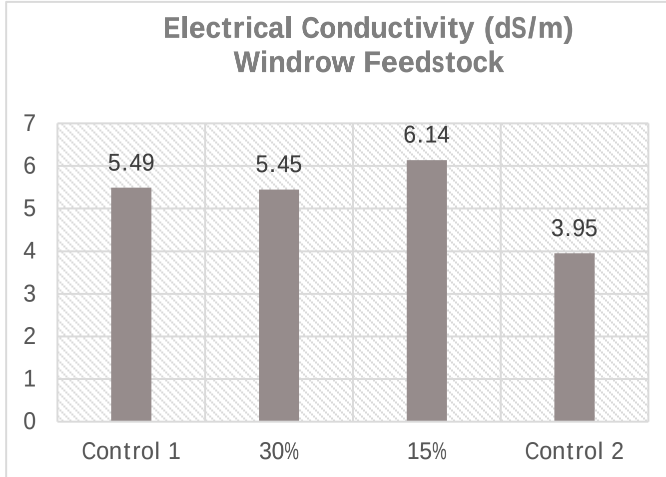

Figure 32

WINDROW FEEDSTOCK-pH

Reference	Generally Accepted Range
FACILITY	4.0-8.0 s.u.

Sample pH measurements ranged between 4.14 and 5.89 and were within the generally accepted ranges of 4.0 to 8.0 for this facility.

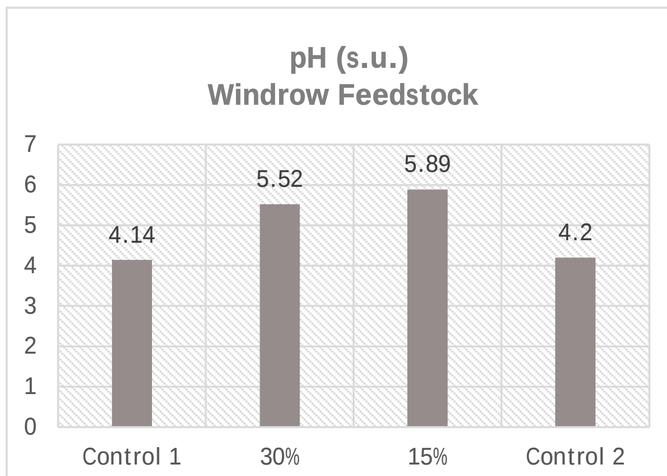

Figure 33

WINDROW FEEDSTOCK-CARBON TO NITROGEN RATIOS

Reference	Generally Accepted Range
FACILITY	15:1 to 30:1

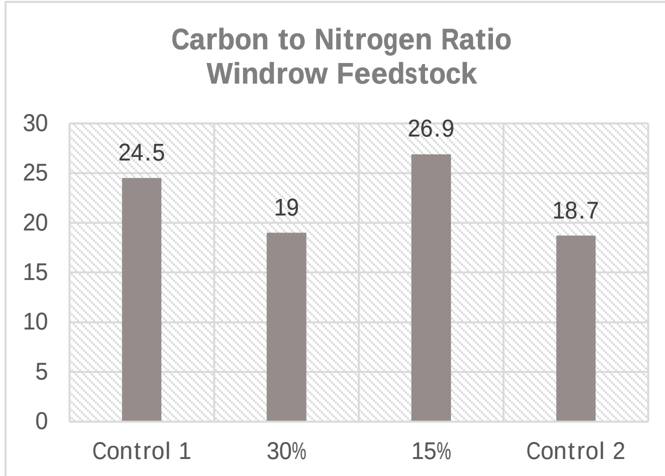

Figure 34

Carbon to nitrogen ratios ranged from 18.7 to 26.9:1. Control 1 and the 15% quadrants were created using chipped wood as the primary bulking agent. Control 2 and the 30% quadrants were created using primarily leaves for the bulking agent as the chipped wood was no longer available. Therefore, the C:N ratios were comparable to each individual feedstock blend recipe, while C:N ratio for these samples fell within generally accepted ranges for this facility.

IN-PROCESS TEMPERATURE READINGS

Temperature data was taken manually at the open windrow facility using a temperature probe placed in the center of the pile. Temperatures stayed consistently at or above 140˚F. It was observed that while most PLA products appeared to have disintegrated entirely, a small portion were left almost completely intact. This may be because in an open windrow system, products are turned into and out of the pile at various intervals, causing them to migrate to various areas of the pile and pile surface areas that have varied characteristics.

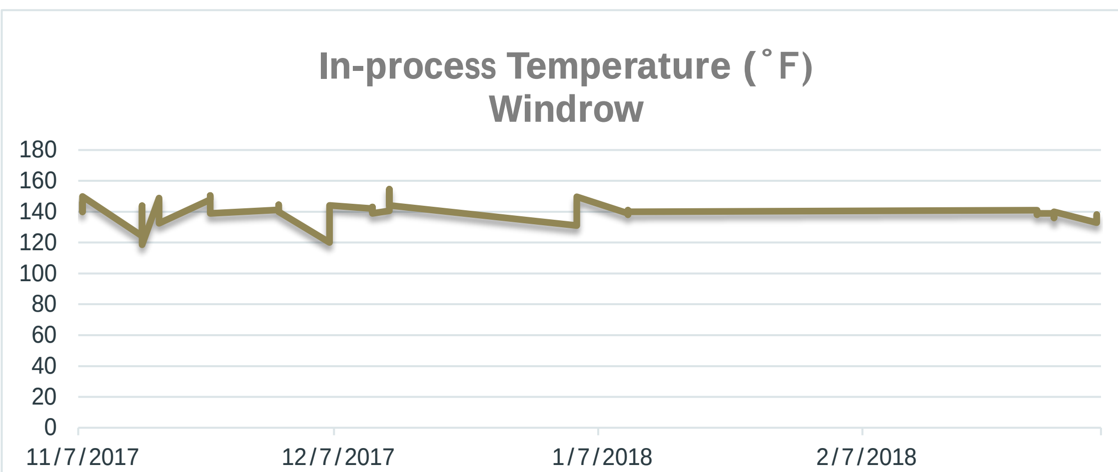

Figure 35

At the end of the active composting process, wheat straw, bagasse and other paper products were still intact. Therefore, process time was extended by an additional three weeks, while the system was also hydrated with water sourced and imported into the final area of the site, as there is no direct water source to draw from. The row was turned when water was added (and subsequently thereafter) to meet moisture percentage requirements to move the product through production and on to screening.

POST-PROCESS FINISHED COMPOST ANALYSIS RESULTS

Composite samples were gathered and sent to Soil Control Laboratories for full TMECC finished compost analysis upon completion of the extended composting cycle.

ORGANIC MATTER, MOISTURE, ORGANIC CARBON, ASH, C:N

Figure 36 shows measurements of finished compost characteristics for all samples. **Table 11** outlines generally accepted ranges for each characteristic measured. Test sample characteristics were comparable to control samples and fell within generally accepted ranges for finished compost for this facility. Although moisture levels fell outside of the USCC STA preferred target range of 40-50%, they were within generally accepted ranges for this facility.

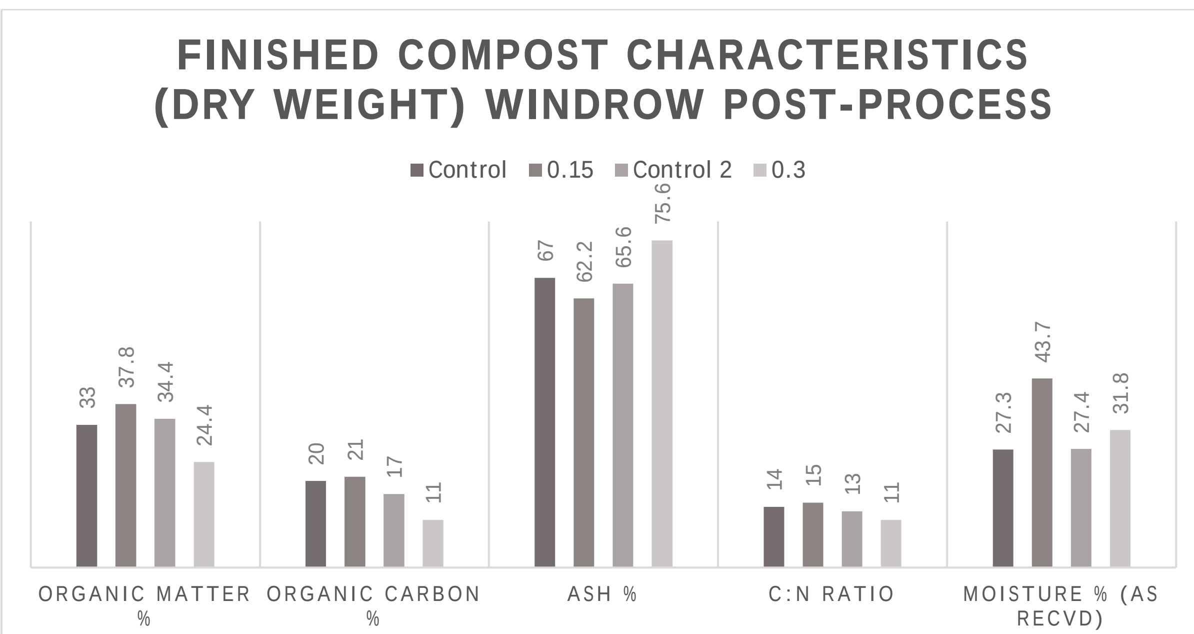

Figure 36

Table 11: A1 Windrow Facility Generally Accepted Ranges for Post-Process Finished Compost Characteristics

Characteristic	Range
Organic Matter	20 - 65%
Organic Carbon	10 - 40%
Ash	45 - 80%
C:N Ratio	8:1 to 20:1
Moisture %	25-45%

VARIOUS NUTRIENTS (COMBINED) PLUS SODIUM, CHLORIDE, CARBONATES

Figure 37 shows measurements of constituents and nutrients of finished compost for all samples. **Table 12** outlines generally accepted ranges for each characteristic measured. There were not significant variations in the final analysis of measured properties in the finished compost produced within the four separate quadrants.

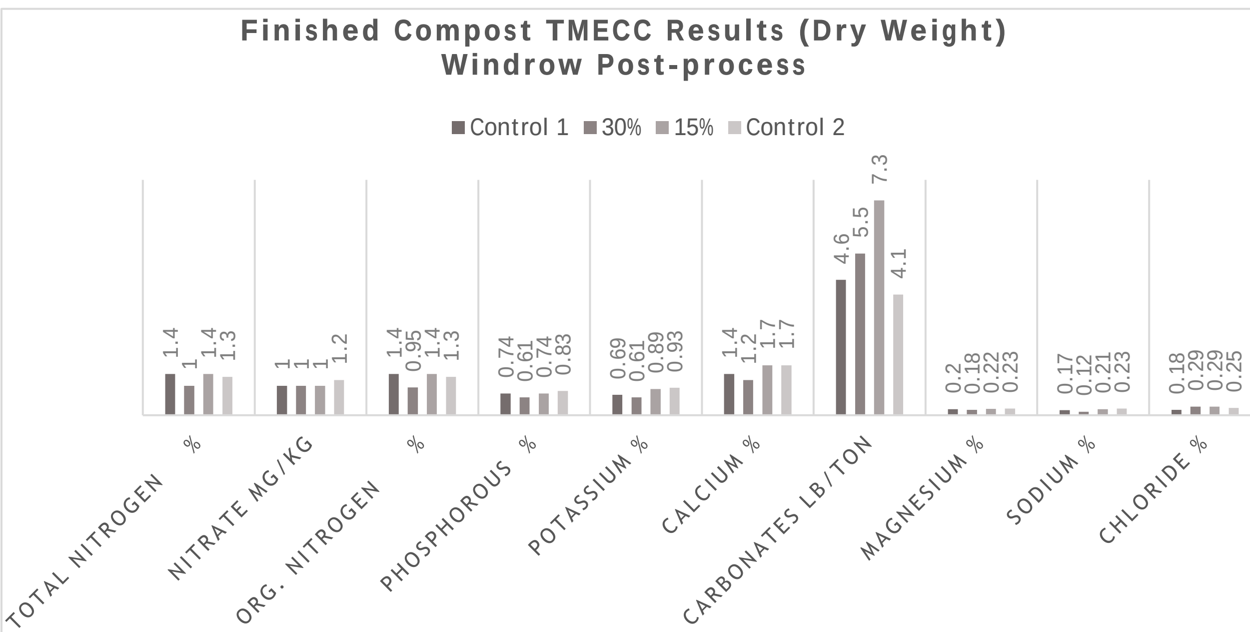

Figure 37

Table 12: A1 Windrow Facility Generally Accepted Nutrient Ranges for Finished Compost

Nutrient	Range	Nutrient	Range
Total Nitrogen	1 - 3%	Calcium	1 – 2%
Nitrate	30 - 600 ppm or mg/kg	Carbonates	5 – 30 lbs/ton
Organic Nitrogen	1 – 3%	Magnesium	0.1 - 0.4 %
Phosphorous	0.3 – 1.5%	Sodium	0.1 - 0.3 %
Potassium	0.5 – 0.9%	Chloride	0.1 - 0.3 %

METALS ANALYSIS, PART 1

Metal	Reference	Limit
Aluminum	FACILITY	<6000 ppm
Manganese	FACILITY	<200 ppm
Iron	FACILITY	<7500 ppm

Iron, aluminum, and manganese were within generally accepted ranges for this facility for finished compost in all four samples.

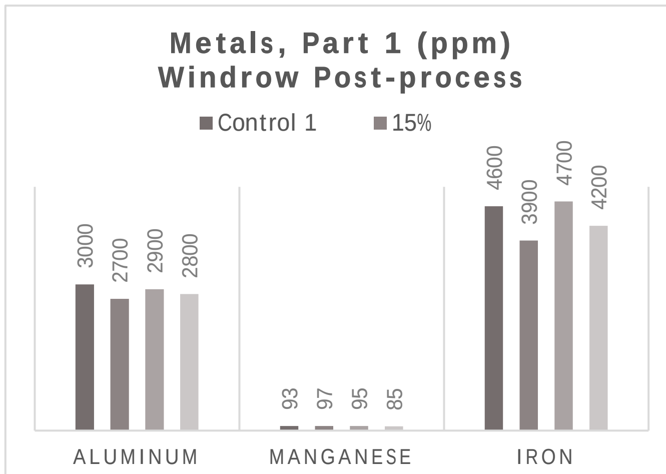

Figure 38

METALS ANALYSIS, PART 2

Metal	Reference	Limit or Range
Arsenic	EPA	< 41 ppm
Cobalt	FACILITY	1.0-3.0 ppm
Lead	EPA	< 300 ppm
Molybdenum	FACILITY	< 9 ppm

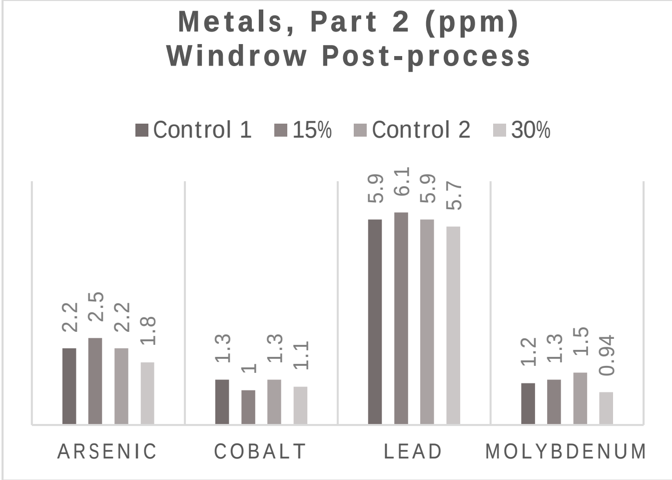

Figure 39

Lead and arsenic were within acceptable levels for finished compost under US Composting Council's Model Rule guideline or CFR, Section 503.13, Table 3 and as listed in **Table 6** of this report. No EPA published standards are listed for molybdenum or cobalt, while generally accepted facility ranges for molybdenum and cobalt are < 9 ppm and 1.0-3.0 ppm, respectively.

METALS ANALYSIS, PART 3

Metal	Reference	Limit
Chromium	FACILITY	<30 ppm
Copper	EPA	< 1500 ppm
Nickel	EPA	< 420 ppm
Zinc	EPA	< 2800 ppm

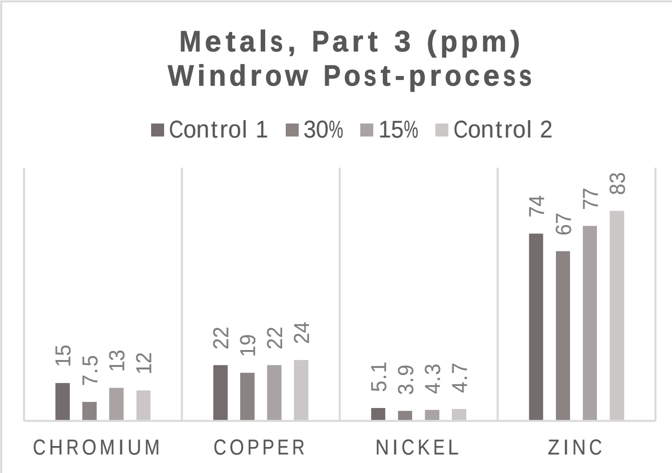

Figure 40

Copper, nickel, and zinc were present within acceptable ranges under US Composting Council's Model Rule guideline or CFR, Section 503.13, Table 3 and as listed in **Table 6** of this report. Chromium was below the generally accepted facility limit of 30 ppm.

DISINTEGRATION

At the end of the active composting cycle process in the windrow facility, some compostable products were still intact. Again, while not the focus of this study, to promote as much disintegration as possible, processing time was extended three weeks while the system was hydrated. Following completion of the extended processing and curing periods, additional disintegration was achieved and characteristics of the finished compost for all samples fell within acceptable and comparable ranges.

Findings and Conclusions

Based on the study results above, below are our conclusions relative to the study question:

> How does compostable foodservice packaging compare with other conventional organic inputs (e.g. yard trimmings, straw, wood shavings, grass, food scraps, etc.) in its contribution to balancing targeted carbon to nitrogen (C:N) ratios, providing nutrients, and acting as a bulking agent in compost feedstocks?

Comparison with Conventional Incoming Feedstocks

- Pre-process feedstock analyses for test blends in both test facilities fell within generally accepted ranges for incoming feedstock characteristics that were comparable with the control blends.

Comparison during Active Composting

- There was no evidence that foodservice packaging negatively or positively affected the balance of C:N ratios, nutrient levels, moisture content, or porosity to feedstocks at these two facilities.
- Compostable foodservice packaging performed as an adequate bulking agent to compliment wood or other traditional carbon bearing feedstocks used in compost production at these two facilities.

Comparison with Finished Compost Made from Conventional Feedstocks

- At the end of the active composting process in both facilities, visible fragments of non-composted foodservice packaging were observed, requiring three extra weeks of processing time to disintegrate. At the end of the extended processing timeframe, additional disintegration was achieved and characteristics of the finished compost for all test blends fell within acceptable ranges that were comparable with the control blends.
- From a nutrient value perspective, compostable foodservice packaging did not add or take away any nutrient value from the finished product at these two facilities.
- At these two facilities, adding significant levels of diverse foodservice packaging to feedstocks did not appear to change the quality of the finished product positively or negatively, and it appeared to perform as well as traditional feedstocks used in compost production.

Conclusion

Given these findings, the traditional view that compostable foodservice packaging is only beneficial in as much as it brings food to the facility may need to be reconsidered. This may be especially relevant in areas where composters are purchasing traditional bulking agents and carbon sources, or where these materials are seasonally scarce; facility operators may even be able to save money by incorporating additional foodservice packaging as a feedstock itself.

However, prior to introducing new or additional foodservice packaging, composters should make sure that the foodservice packaging they include will disintegrate, keeping an eye on target operating parameters like moisture and temperature. As was seen in the two facilities used in this study, some products did not break down sufficiently within the active composting cycles. To address this, three weeks were added, along with additional pile management strategies to help enhance product disintegration.

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