

## Compostable Foodware Degradation in a Commercial Composting System

### Abstract

Compostable foodware is becoming more common in food service settings, as amusement parks, zoos, and similar venues move away from traditional plastic and non-recyclable products. These compostable products are made from a blend of materials, including PLA, cPLA, paper and fiber-based products. Although compostable foodware is designed to break down in industrial composting systems, the way that these products behave is better understood through field-based experiments carried out at active commercial composting facilities.

This pilot study documents a composting experiment conducted during the summer of 2025 at San Pasqual Valley Soils, a state permitted composting facility located in Escondido, California. Compostable foodware items were placed into labelled mesh bags and then buried within a single active windrow with each bag attached to a rope for ease of recovery. The windrow feedstock was made up of animal manure and bedding from the San Diego Zoo and the San Diego Zoo's Safari Park. Over the course of the study, mesh bags were carefully removed prior to windrow turning, inspected, and returned to the windrow to observe biological degradation over a period of 3 months.

The results showed clear differences in how the various compostable materials degraded over time. Compostable plastics tended to break down faster during the early stages of composting, while fiber-based materials remained largely intact over the same period. Although composting temperatures within the windrow reached thermophilic ranges, breakdown was not uniform across all materials. These observations indicate that compostable foodware

performance is strongly influenced by composting conditions and system management, rather than product labeling alone. This pilot study highlights the need for continued research focused on real world commercial composting conditions, material performance and how compostable foodware can be better integrated into existing industrial and agricultural composting systems.

## **Introduction**

The San Diego Zoo and the San Diego Zoo Safari Park invest significant money in compostable foodware as part of their sustainability goals. These products are intended to replace traditional plastic items used in food service and are designed to be composted under industrial, aerobic composting conditions. In theory, compostable foodware should help reduce the volume of organic waste going to landfills to mitigate increased methane production and meet current environmental regulatory goals while also supporting the production of value-added compost for delivering ecosystem services.

The current is that many compostable products never reach composting facilities. Because of the cost and logistical challenges of source-separating foodware from food waste, compostable items are often discarded and sent to landfills along with residual food scraps. In landfills, these food residues break down under anaerobic conditions, where oxygen is limited, and this process produces methane, a potent greenhouse gas.

While compostable foodware itself is not the primary source of methane, the food waste left on or mixed with these products contributes to methane generation when landfilled. As a

result, compostable foodware can become a liability rather than a solution if it is not properly collected and diverted to aerobic composting systems.

Composting facilities operate under aerobic thermophilic conditions, which are necessary for compostable materials to break down as intended. Simply purchasing compostable products does not guarantee sustainability unless there is a system in place to collect and divert them to a composting operation. True sustainability depends on how these materials are handled after use, not just what they are made from.

San Pasqual Valley Soils already plays a role in regional nutrient recycling through their partnership with the San Diego Zoo and the San Diego Zoo's Safari Park. The San Diego Zoo is located at 2920 Zoo Drive in San Diego, California, within Balboa Park just north of downtown San Diego. This urban location is distinct from the San Diego Zoo Safari Park, which is located approximately 35 miles away in Escondido, California. Due to dense urban surroundings, locations such as Balboa Park are not suitable for large-scale composting operations. Instead, composting infrastructure such as San Pasqual Valley Soils operates outside of urban centers on land designated for agricultural use, where composting activities are compatible with surrounding land uses and farming operations. Animal manure and bedding from the parks are delivered to SPVS, where they are composted and used to amend nearby fields. These fields grow forage crops that are harvested and fed to neighboring dairy cows. Animal manure and bedding from the parks are delivered to SPVS, where they are composted and used to amend nearby fields. These fields grow forage crops that are harvested and fed to neighboring dairy cows.

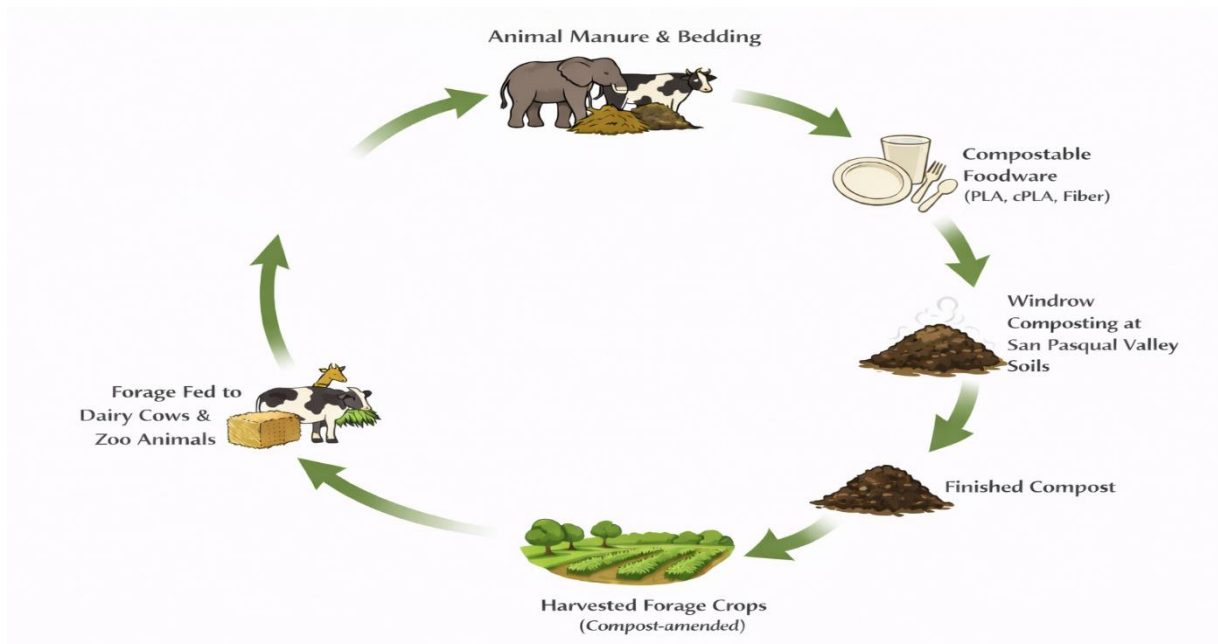
Konyn Dairy, the last remaining commercial dairy in San Diego County, operates as the parent company of San Pasqual Valley Soils located adjacent to the dairy. Together, these operations represent a circular economic partnership between the San Diego Zoo Safari Park, the San Diego Zoo, and regional agriculture.

Animal manure and bedding generated at the Safari Park and Zoo are trucked to San Pasqual Valley Soils for composting. Compostable foodware purchased and used by these institutions could be incorporated into this same system rather than being disposed of as waste. By diverting compostable foodware to San Pasqual Valley Soils alongside manure and bedding, these materials can be processed aerobically into high quality compost instead of becoming a liability in landfills.

The finished zoo compost is currently being applied to soil as an amendment to support the health of forage being grown on the same land which is then harvested and fed directly to dairy cows at Konyn Dairy. This integrated, co-located system highlights how compostable foodware can become an asset within a closed-loop model that links waste diversion, soil health, and local food production. Beyond supporting forage production for Konyn Dairy, this loop could be further expanded by using this compost to amend soils for growing feed in support of select animals at the San Diego Zoo and San Diego Zoo Safari Park. You would effectively be cycling compostable foodware, animal manure, and bedding back into the same animal systems where these materials originated and creating a truly sustainable, closed-loop system.

This pilot study was designed to better understand what happens when compostable foodware is placed into a real commercial composting system. As an undergraduate student, this project was conducted as a learning experience to gain hands-on experience with composting

operations, soil health, and sustainable waste management, and identifying future areas for research addressing where current systems fall short.



An example of a closed-loop system involving livestock, compostable foodware, an active compost facility and local agriculture.

## Objectives

The objectives of this pilot study were to:

1. Observe how effectively compostable foodware made from PLA, cPLA, and fiber-based materials breaks down in an active commercial compost windrow.
2. Compare how several types of compostable materials behave under the same composting conditions.
3. Identify practical composting processes that may influence material breakdown in real-world settings.

This study was exploratory in nature and intended to inform and identify future applied research needs associated with the composting of compostable foodware.

### **Composting Site and Materials**

The experiment was conducted at San Pasqual Valley Soils, a commercial composting facility located in Escondido, California. Composting was performed using a traditional outdoor windrows system of composting managed according to commercial industry standard practices. The compost feedstocks were zoo animal manure and animal bedding from the San Diego Zoo Safari Park. The study took place from May 15 to August 14, 2025.

San Diego Zoo dropping off feed stock (manure and bedding).



San Diego Zoo and Safari Park manure and bedding being formed into a row.

### **Compostable Foodware**

Compostable foodware used in this study was provided by two companies: Eco-Products and BsiBio (Besics). A total of 19 mesh bags were used in the experiment, with ten bags containing compostable foodware from Eco-Products and nine bags containing compostable

foodware from BsiBio (Besics). Both companies supplied similar types of compostable items made from PLA, cPLA, and paper fiber materials that are commonly used in food service operations. All bags were placed within the same windrow to ensure similar exposure conditions.



Compostable products such as PLA, cPLA and fiber materials before being placed into the mesh bags.

### **Mesh Bag Method**

The mesh bag method was used because it is a commonly recommended approach for testing compostable material degradation in composting systems. The field-testing protocol followed in this study was provided by the Compost Research and Education Foundation (CREF) Composting Field Testing Program, which outlines standard procedures for evaluating compostable materials under real world composting conditions. In this study, representative compost feedstock was enclosed within mesh bags with compostable foodware products from Eco-Products and BsiBio (Besics). The mesh bags were then positioned within an active compost windrow and monitored over time to observe how the materials physically broke down under

normal composting conditions. This was my first experience using the mesh bag method in a commercial composting environment.

The experiment was conducted within a recently established (one week old) single compost windrow beginning on May 15, 2025. I coordinated the placement and removal of mesh bags with routine windrow turning events occurring every 3 days for a period of 2 weeks. Before the windrow was turned, the mesh bags were removed to prevent damage, inspected, and then reburied in the compost upon completion of the turning operation. While this repeated handling was time-consuming, it allowed the materials to remain recoverable while still being exposed to composting conditions.

Initial guidance on the mesh bag method and final evaluation of materials was provided by collaborators from Eco-Products, which helped ensure that the method was correctly followed while allowing me to gain hands-on research experience.



Compostable products from Eco-Products and BsiBio placed in the mesh bags and ready to be placed into the windrow.



Placing the mesh bags into the windrow, the rope was tied to each pair as indicators and helped locate the bags at each turn.

## **Compost Temperature**

Daily temperature monitoring of the experimental windrow showed that thermophilic composting conditions were reached quickly and maintained throughout the active composting period. Temperature records collected between May 9 and July 2, 2025, indicate daily bay temperatures generally ranging from approximately 140 to 155 °F well above the required 131-degree minimum temperature. The windrow met the Process to Further Reduce Pathogens (PFRP) requirements throughout the first 15 days and remained in compliance for the entirety of the 3-month long field trial.

Temperature data shows short-term drops followed by recovery, which correspond to routine windrow turning and water management activities. These fluctuations are typical in commercial windrow composting systems and suggest that materials within the pile experienced varying temperature exposures depending on placement and movement over time. Overall, the sustained required thermophilic conditions confirm that the composting environment was suitable for evaluating compostable foodware degradation under standard operating conditions.

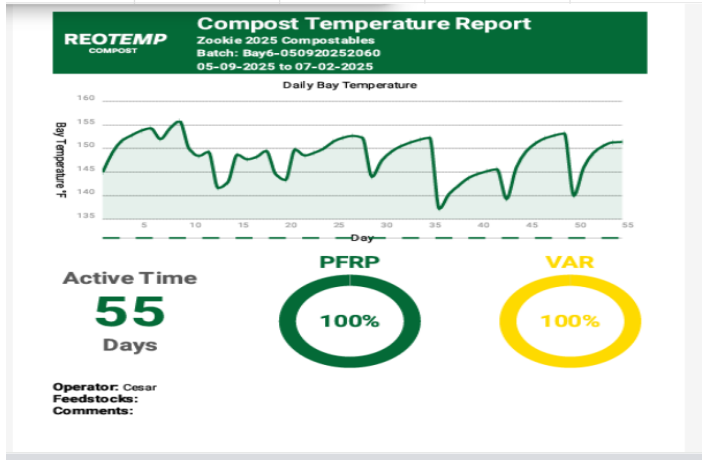


Figure 1.

**REOTEMP**  
COMPOST

**Compost Temperature Report**  
Zookie 2025 Compostables  
Batch: Bay6-050920252060  
05-09-2025 to 07-02-2025

Daily Bay Temperatures (°F)

Date	Day	Temp	Date	Day	Temp	Date	Day	Temp
05-09-2025	1	145.0	06-08-2025	31	149.3		61	
05-10-2025	2	149.1	06-09-2025	32	150.5		62	
05-11-2025	3	151.7	06-10-2025	33	151.3		63	
05-12-2025	4	152.8	06-11-2025	34	151.9		64	
05-13-2025	5	153.8	06-12-2025	35	152.3		65	
05-14-2025	6	154.3	06-13-2025	36	137.2		66	
05-15-2025	7	152.0	06-14-2025	37	140.3		67	
05-16-2025	8	154.3	06-15-2025	38	142.1		68	
05-17-2025	9	155.8	06-16-2025	39	143.7		69	
05-18-2025	10	149.9	06-17-2025	40	144.6		70	
05-19-2025	11	148.4	06-18-2025	41	145.2		71	
05-20-2025	12	149.3	06-19-2025	42	145.6		72	
05-21-2025	13	141.6	06-20-2025	43	139.3		73	
05-22-2025	14	142.8	06-21-2025	44	145.9		74	
05-23-2025	15	148.7	06-22-2025	45	149.3		75	
05-24-2025	16	147.7	06-23-2025	46	151.1		76	
05-25-2025	17	148.2	06-24-2025	47	152.2		77	
05-26-2025	18	149.5	06-25-2025	48	152.8		78	
05-27-2025	19	144.5	06-26-2025	49	153.2		79	
05-28-2025	20	143.3	06-27-2025	50	140.0		80	
05-29-2025	21	149.8	06-28-2025	51	145.9		81	
05-30-2025	22	148.5	06-29-2025	52	149.0		82	
05-31-2025	23	149.1	06-30-2025	53	150.5		83	
06-01-2025	24	150.0	07-01-2025	54	151.3		84	
06-02-2025	25	151.5	07-02-2025	55	151.4		85	
06-03-2025	26	152.3		56			86	
06-04-2025	27	152.7		57			87	
06-05-2025	28	152.3		58			88	
06-06-2025	29	144.0		59			89	
06-07-2025	30	147.4		60			90	

Figure 2.

### Material Breakdown

On day 15 of the study (May 29, 2025), three mesh bags were found to be heavily damaged and were opened for inspection. The remaining damaged mesh bags were repaired as

needed, including re-sleeving to maintain sample containment, and were returned to the windrow. These repaired bags remained intact for the remainder of the trial and were successfully recovered at the end of the study. At this stage, most PLA and cPLA compostable plastics had already deteriorated significantly and were broken into small fragments. Small green plastic fragments were observed, likely from Eco-Products items.

Paper and fiber-based compostable materials were still mostly intact at this time, showing much slower breakdown compared to compostable plastics. These observations confirm that heat, moisture and microbial thermophilic bacteria were sufficient to break down compostable plastics early in the process, while fibrous materials require additional mechanical action to physically shred and degrade this material.

The mesh bags were protected from the direct force of the windrow turner by physically removing them temporarily. While this helped preserve samples for observation, it likely slowed the breakdown of fiber-based products, which would degrade more quickly if directly exposed to turning and agitation.

Compost temperature recordings for the Zookie 2025 compostables windrow at San Pasqual Valley Soils show sustained thermophilic conditions over the 3-month field trial with temperatures generally ranging from approximately 140 to 155 °F. (Figure 1 and Figure 2). The windrow achieved 100% compliance with Process to Further Reduce Pathogens (PFRP) and

Vector Attraction Reduction (VAR) requirements. Periodic temperature fluctuations reflect routine turning and aeration events typical of commercial composting operations.

Image shows damage from removing the bags from the windrow caused by pitchfork/ equipment



I attempted to patch the mesh bags with zip ties while I waited to receive a shipment of new mesh bags.



Dr. Craig Kolodge examining the compostable products at PFRP.



Compostable plastics made by Eco-products showing degradation at PFRP.



## Finished Compost Analysis and Germination

Finished compost generated from the experimental windrow was submitted to Wallace Laboratories for analysis. To provide context, compost from the zoo windrow without compostable foodware (Zookie compost) was analyzed as a baseline reference, alongside compost that included decomposed compostable food ware (Eco-Products compost). Laboratory testing included compost chemistry (pH, salinity, sodium and chloride levels, macronutrients and micronutrients) and a seed germination bioassay.

Seeds were grown using distilled water as a control and a diluted compost extract (20%) to evaluate differences in germination and early growth. Clear differences were observed between compost with and without compostable foodware. The baseline zoo compost exhibited a relatively low germination rate (approximately 36%), but seedlings that did emerge showed high vigor, with vigor values approximately 176% greater than the control. In contrast, compost containing compostable foodware from Eco-Products showed substantially higher germination, with approximately 50% greater germination compared to the zoo compost alone. Seedling vigor in the compostable-containing extract was slightly lower than the distilled water control, indicating improved early establishment but somewhat reduced growth intensity relative to the baseline compost.

Chemical analysis helped explain these biological responses. Compost containing compostable foodware showed lower overall salinity compared to the zoo compost, but a higher proportion of ammonia nitrogen relative to nitrate nitrogen. The zoo compost, while more saline, appeared to support strong seedling growth once germination occurred, likely due to higher nutrient availability. These results indicate that the presence of compostable foodware influenced

compost characteristics and biological performance, even though both composts were nutrient-rich and low in non-essential heavy metals.

Overall, the laboratory results demonstrate that compostable foodware incorporated into the composting process can measurably alter compost quality and plant response. However, the mechanisms driving these differences, particularly related to nitrogen transformation, salinity dynamics, and compost maturity, require further investigation. These findings reinforce the value of this pilot study and support the need for future research evaluating how compostable foodware affects compost performance and subsequent plant growth when incorporated into soil systems.

### **Final Sample Recovery and End-of-Study Observations**

Final recovery of mesh bags occurred at the end of the study period on August 14, 2025, following completion of the active composting and curing phases. Rather than serving as a separate experiment, this recovery represented the final observation point for materials that had remained in the windrow for the full duration of the pilot study.

Consistent with earlier observations, most compostable plastic materials (PLA and cPLA) had lost structural integrity by the end of the trial and were no longer present as intact products. Remaining material was generally fragmented and difficult to distinguish from surrounding compost. Paper and fiber-based materials continued to show variable breakdowns, with some products exhibiting substantial tearing and weakening while others remained partially intact, suggesting that extended time and mechanical agitation play an important role in complete degradation.

These end-of-study observations confirm trends observed earlier in the experiment and provide context for interpretation of finished compost laboratory results, rather than representing an independent evaluation event. It is possible that once the windrow transitioned out of the thermophilic phase and temperatures declined, conditions would be more favorable for fungal colonization. Fungal activity is known to play an important role in the decomposition of fibrous materials, and continued breakdown of paper- and fiber-based compostable products would be expected to occur during this later curing phase.



Compostable fibrous foodware retrieved from mesh bags at the conclusion of the field study on August 14, 2025.



Some fibrous foodware remained intact and was still distinguishable. Shown is an Eco-Products hot drink cup before and after the study.



Evaluation day August 14, 2025. From left to right: Meghan Ibach (Eco-Products), George Alvarado (Cal Poly Pomona student), Dr. Craig Kolodge (SPVS), and Ciara Aw (Eco-Products).

### **Limitations**

This study had several limitations. The experiment was conducted in a single windrow within an active commercial composting facility, which limited replication and experimental control. The mesh bag method restricted mechanical breakdown and required repeated handling of samples. Some mesh bags were lost or damaged during routine operations, further limiting the dataset.

An additional limitation was my lack of direct control over equipment upon mesh bag retrieval. Windrow turning and movement were performed by facility staff whose primary focus

was maintaining normal operations rather than protecting research samples. As a result, mesh bags were occasionally handled less carefully than ideal, contributing to damage or loss of some samples. While necessary for working within a commercial facility, this constraint reduced the level of control that could be maintained over sample handling and placement.

### **Economic Considerations**

From what I observed during this pilot study, the difficulty with compostable foodware is less about whether the materials can be composted and more about whether existing systems make diversion practical. In large food service settings such as zoos and amusement parks, properly separating compostable foodware from trash requires time, training, and coordination. Staff must be trained on correct sorting, bins must be clearly labeled, and contamination must be actively monitored. In busy, high-volume environments, these steps increase labor demands and add operational costs.

Commercial composting facilities, including San Pasqual Valley Soils, maintain strict standards for incoming feedstocks and do not accept contaminated loads. These requirements are necessary to protect compost quality, but they can discourage venues from attempting to divert compostable foodware if there is uncertainty about proper sorting. The risk of rejected loads, additional handling, or disposal penalties can make landfill disposal appear to be the safer and simpler option from an operational standpoint.

As a result, landfill disposal is often viewed as easier to manage. Waste streams can be combined, hauling schedules are predictable, and there is little concern about contamination thresholds. Even when compostable products are purchased with sustainability goals in mind, it

is often faster and simpler to dispose of them as trash rather than invest the effort needed to ensure proper composting.

This creates a disconnect between purchasing compostable products and achieving meaningful environmental benefits. Compostable foodware generally costs more than conventional disposable items, but when landfilled, that added cost does not provide any return. At the same time, San Pasqual Valley Soils already receives animal manure and bedding from the San Diego Zoo Safari Park, demonstrating that an organic material hauling and composting system is already in place.

If venues choose to purchase compostable foodware, there is also an implied responsibility to manage those products as intended. Integrating compostable foodware into existing composting systems would require improved collection and source separation, but it would allow these materials to function as designed rather than becoming a disposal liability. While a detailed economic analysis was outside the scope of this pilot study, these observations suggest that labor availability, contamination risk, sorting logistics, and landfill avoidance are key economic factors that must be addressed to make compostable foodware diversion realistic.

### **Future Work and Closing the Loop**

As a pilot study, this work highlights the need for additional research to better understand how compostable foodware can be effectively used within real composting systems. Future studies should involve collecting a known, measurable quantity of compostable foodware from the San Diego Zoo, San Diego Zoo's Safari Park, and scaling up the composting operation to include foodware incorporated uniformly throughout the entire windrow in the absence of plastic mesh

containment bags. This would represent a more practical and accurate assessment of how zoo compost effectively degrades both compostable plastics and fibrous materials as well as the quality of the finished product.

Finished compost from these windrows could then be used to conduct field trials on amended forage fields managed by San Pasqual Valley Soils to determine their impact on crops quality and yields. Comparisons between zoo compost with and without compostable foodware could also be chemically evaluated to gain a better understanding of how compost quality is directly affected by the addition of compostable foodware to compost. Incorporating compostable foodware into the existing composting system has the potential to transform these materials from a disposal liability into a useful resource and move the operation closer to a truly closed-loop, sustainable system.

### **Acknowledgements**

I would like to thank San Pasqual Valley Soils, Eco-Products, BsiBio, and the Compost Research and Education Foundation (CREF) for the opportunity and support provided during this pilot study. I am especially thankful to Dr. Craig Kolodge for his guidance, for taking the time to answer my questions, and for helping facilitate access to the composting facility.

I also thank Ciara and Meghan from Eco-Products for their help in getting the experiment started and for assisting with material evaluation. I am grateful to Dr. Valerie Mellano for connecting me with Dr. Kolodge and helping make this project possible. As a Cal Poly Pomona student, it was meaningful to work with mentors from the Cal Poly community and gain hands-on experience in field-based research.

This was a valuable learning experience that gave me direct exposure to commercial composting systems. This work is part of an ongoing effort taking place in different regions, and I am grateful for the opportunity to contribute by conducting this study in San Diego, Southern California.

This report for the Pilot Study was documented and written by George Avarado during the summer of 2025. We are grateful to George for his hard work during this pilot, documenting the results, and addressing what still needs to be done to help create a more sustainable future.

We are grateful for the opportunity to work with George Alvarado of Cal Poly Pomona, Meghan Ibach and Ciara Aw of Eco-Products, BsiBio, The San Diego Zoo, The San Diego Zoo Safari Park, and Wallace Labs on this research project. Thank you to Sustain SoCal for providing an audience for us to share our research on compostable foodware and sustainability.



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