UKRI Project – 10020315
Work Package Four

COMPOSTABLE COALITION UK
Closing the Loop for Compostable Packaging

Summary of Compost Testing, Analysis and Degradation Trials

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With thanks to: BIOME BIOPLASTICS, FUTAMURA, TIPA Compostable Packaging, vegware

...who contributed materials for the project.

Background Information

Soil Health:

Soil health refers to soil's ability to function as a living ecosystem that supports plants, animals, and humans. In England and Wales, soil faces threats such as compaction, erosion, and loss of organic carbon due to intensive agriculture. Soil degradation costs £1.2 billion annually and affects agricultural productivity and climate resilience. UK soils store around ten billion tonnes of carbon, equivalent to 80 years of the country's annual greenhouse gas emissions. Adding organic matter like composted bio-waste can improve soil structure, water retention, and biodiversity, helping to combat these issues.

Traditional Plastics Problem:

Traditional plastics contaminate compost feedstocks, hindering degradation and increasing management costs.

Industrial Composting of Waste Biomaterials - Types of Breakdown Processes:

Mechanical: Shredding increases surface area and homogenises materials but complicates plastic removal.

Microbial: Microbes break down organic matter through extracellular digestion, releasing nutrients and carbon.

Chemical: Hydrolysis and other reactions aid in nutrient release and material degradation.

Thermal: Heat from microbial activity accelerates breakdown, especially in large compost piles.

Compost in Agriculture:

Historically, bio-based fertilisers and soil improvers, such as animal manures and mushroom composts, have been integral to farming. Certified composted bio-waste (PAS 100) meets safety standards and provides essential nutrients (Nitrogen (N), Phosphorous (P), Potassium (K)) and organic matter, supporting plant nutrition and microbial biodiversity. Unlike fast-release mineral fertilisers, compost offers slow-release nutrients, reducing pollution risks and enhancing soil health.

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Inputs & Sample Preparation

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Material Collection and Preparation:

Compostable materials and finished products were pre-collected (Table 1), stored securely, and incorporated with food and garden waste on-site. Materials varied in format (loose, compressed, baled) and required different handling.

Shredding and Mixing:

Most materials, except for specific samples (Sample 8 and Sample 6), were unused and unsoiled. The bales (Sample 9) were shredded separately, then all materials were shredded together. Mechanical blending followed before a final shredding. This material was then incorporated directly into the compost (Results 1).

Sample Bagging:

As an alternative method, samples of each compostable material were placed in individual mesh bags for degradation analysis, bypassing pre-treatment shredding. These bags were buried within the composting mass for subsequent recovery and analysis (Results 2).

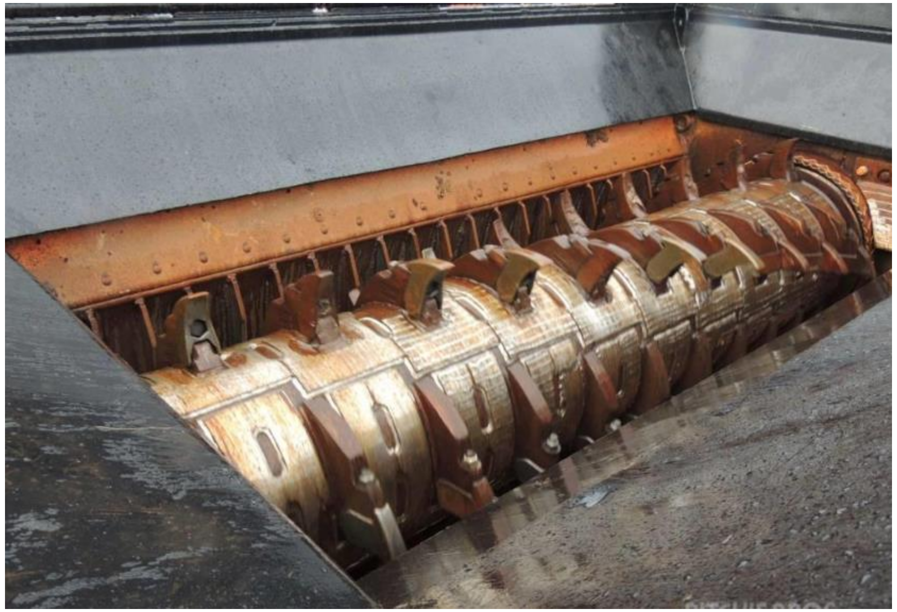

Figure 1 *– Samples were shredded using a Doppstadt 3060 biopower industrial shredder, shred to a maximum of 400mm in any one plane.*

Table 1 *- Details of materials used in degradation trial, their sub-total weights, and their collective total weight.*

Product Code	Product	Form	Weight (kg)
Sample 1	Dry - Bags	Loose	1125
Sample 2	Dry - Bags	Loose	2000
Sample 3	Dry - Bags	Loose	80
Sample 4	Tea bags	Loose	67
Sample 5	Unused coffee pods	Loose	145
Sample 6	Used Coffee Pods	Loose	66
Sample 7	Dry - Compound	Loose	589
Sample 8	Used Compostables – tableware	Semi-compressed	5980
Sample 9	Film used in sweet wrappers	Baled and compressed	3000
Comingled Food & Green	Normal incoming feedstock		159,960.00
	Total Weight (kg) Packaging		**13,052.00**
	Total All		**173,012.00**

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Processing

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December 21, 2022

Total Duration: 77 Days

Materials were loaded into a sealed composting tunnel. Woody materials were used to create air gaps to support aerobic bacteria, generating heat and aiding breakdown. A **5% volume load of compostable plastics was used** to simulate a scenario where 20% of plastics in the UK were replaced with compostables, which is a higher percentage than is currently envisioned. This higher load rate therefore **tested the system's capacity to handle future increases in compostable plastics**. Liquid was added periodically, and compost parameters, such as temperature, were monitored throughout the in-tunnel composting process, to ensure optimum composting (Fig. 2).

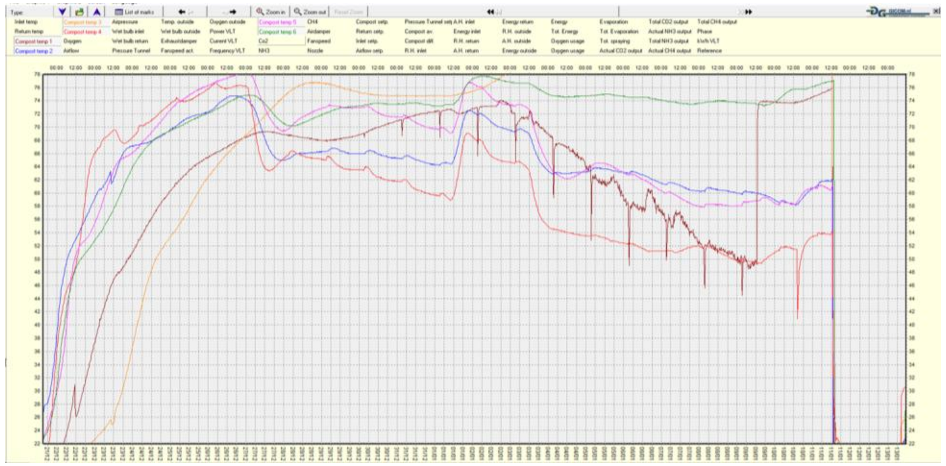

Figure 2 *– Time temperature data from the computer. The controlled SCADA systems use process feedback to adjust the composting parameters, ensuring optimum composting conditions are maintained.*

January 12, 2023

3 weeks later, the **composting batch was removed** from the tunnel. The mesh bags were removed, and the rest of the **compost was placed into a compost turning machine before being placed on a composting pad** (windrow composting).

The mesh bags were then re-introduced deep into the compost to ensure the composting parameters were maintained. **The location of the bags were marked with flags** so that they could be easily located and removed periodically for degradation analysis.

Screening & Oversize Handling:

After composting, materials were screened using a Doppstadt SM-720-SA. **Compostable materials not fully degraded were returned to the start of the process** for further composting.

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Results 1 – Samples Placed in Main Composting Mass

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Method: The **compostable materials were placed directly into an in-vessel composting batch**, bypassing the use of mesh bags. **Samples were periodically taken from the composting batch**, which transitioned from in-vessel to an outdoor composting pad and the samples were analysed.

Results: **The proportion of small particles (<5mm) increased rapidly during composting.** By day 56, these particles comprised >40% of the compost mass and appeared brown - typical of compost. Compostable samples were hand sorted by Envar's in-house lab team, who identified and categorised materials visually. **Initial percentages of compostables ranged from 3-4% of the total mass, reducing to about 1% by the end of the trial.** Traditional plastics remained stable, with minor variations.

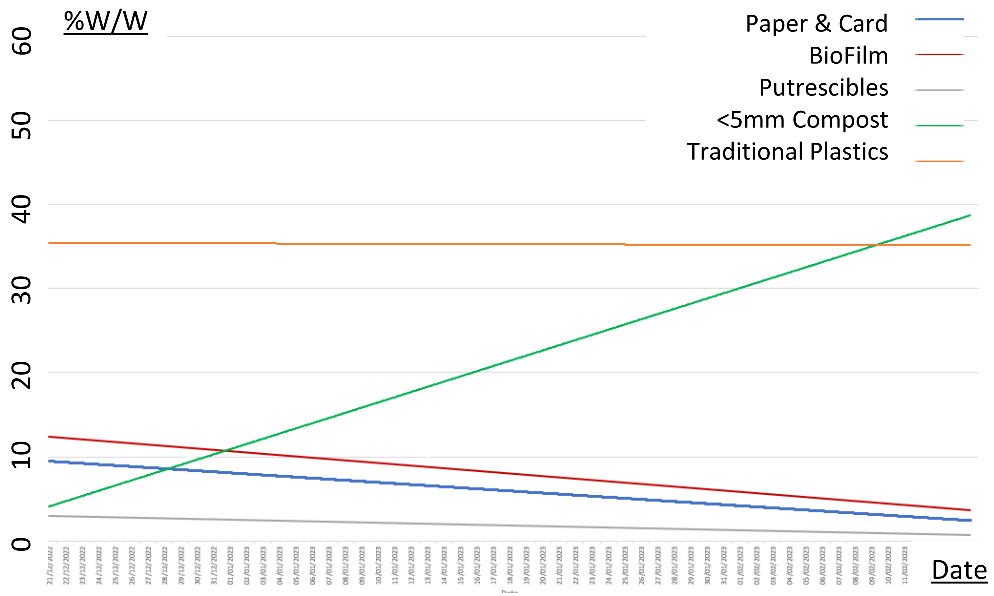

Figure 4 *– Trendlines for degradation of key materials over 56 days (8 weeks) of in-vessel then windrow composting.*

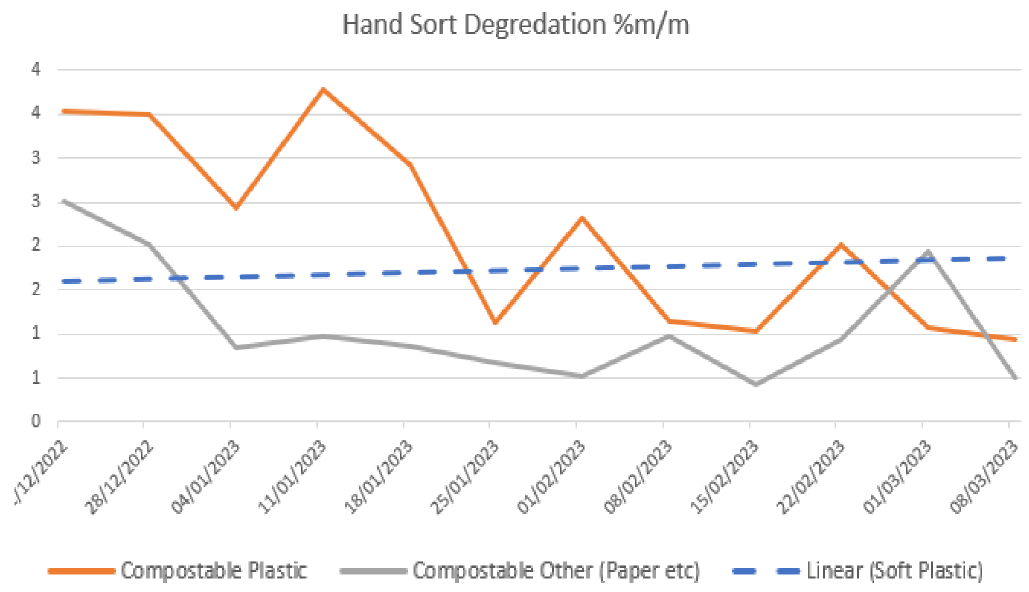

Figure 5 *– Hand sort degradation profile per material over 56 days (8 weeks) of in-vessel then windrow composting.*

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Overall, the study showed significant degradation of compostable materials, while traditional plastics did not degrade effectively.

Results 2 – Samples Placed in Mesh Bags

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Method: Compostable **material samples were placed individually in mesh bags** (3 mm x 3 mm holes) without additional waste. Whole tea bags and coffee pods were used as-is, while other samples were manually cut to simulate shredding. **Each bag contained 20 pieces of each sample** and was placed into an **in-vessel composting batch before being transferred to a composting pad**. Over 77 days, samples were **periodically weighed** and returned to the bags. Initially, individual items were weighed, but this was impractical as the materials degraded. Instead, the entire mesh bags were weighed periodically.

Results: Some materials **initially gained mass due to moisture absorption** before rapidly decreasing. **Degradation rates varied by material format (loose, compressed, etc.)** and were affected by the material's surface area exposure to microbes.

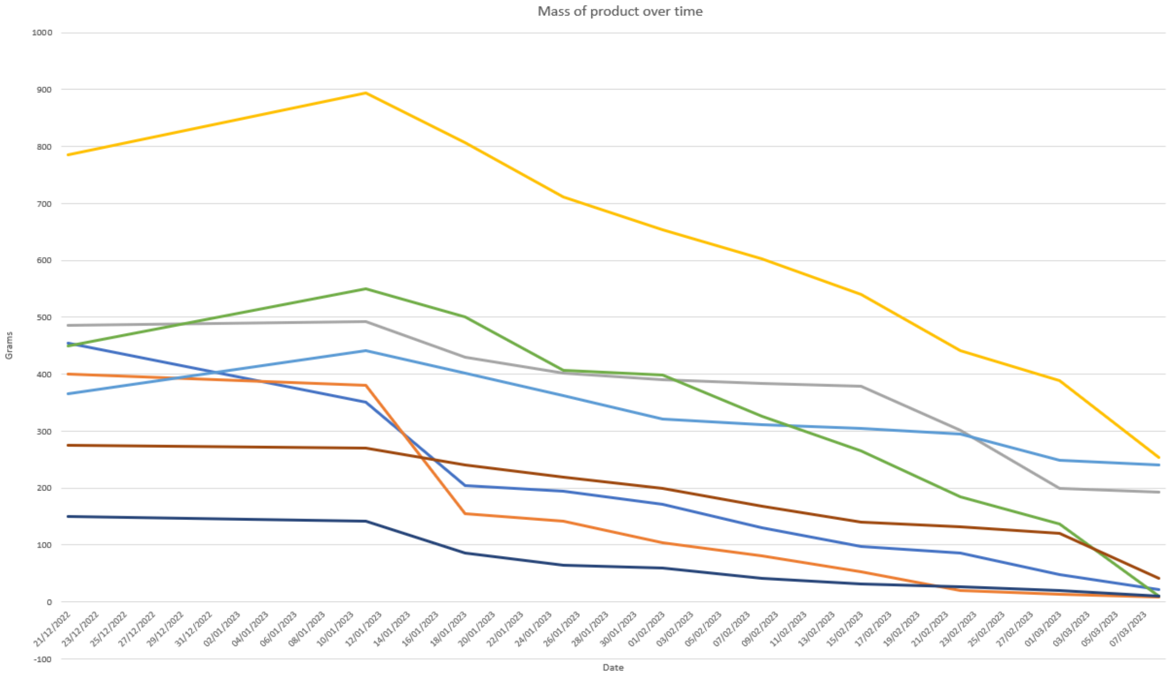

Figure 3 *– Degradation of each sample across the 77 days.*

Degradation Results:

- Samples 5 & 6 COFFEE PODS: **95.16%**
- Sample 4 TEA BAGS: **97.75%**
- Sample 1 DRY BAGS: **67.64%**
- Sample 8 USED COMPOSTABLE TABLEWARE: **60.41%**
- Sample 9 FILM: **33.97%**
- Sample 7 DRY COMPOUND: **97.78%**
- Sample 3 DRY BAGS (another type): **93.33%**
- Sample 2 DRY BAGS (another type): **84.73%**

Overall, the average degradation rate was 78.8% over the 11 weeks.

Conclusion: The results highlighted that composting **plant machinery can address many material formats** and enable successful degradation.

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Evidence & PAS 100 Tests

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Example Images of Materials After Only 4 weeks

Samples 5 & 6
Coffee Pods

Sample 4
Tea Bags

Sample 7
Fibrous Material

Samples 1 & 2
Bags

PAS 100 Tests for Compost Quality:

The compostable inputs utilised were all certified to the British, European, or North American standards for compostability and were composted to comply with PAS 100 – an industry standard for compost.

From February 24th to March 1st, a composting windrow was screened to achieve a 0-10 mm particle size range, removing contaminants larger than 10 mm. The compost was aerobically matured according to PAS 100 procedures.

Results:

- A sample taken on April 17th passed all PAS 100 tests except for glass contamination, likely from an external source, however a subsequent sample **passed all physical contamination tests**.
- Electrical conductivity was measured at 1595µS/cm, typical for green and food-waste derived compost, indicating **suitability for blending or use as a soil improver.**
- Plant growth tests showed **100% germination and 91.86% average top growth compared to a peat-based control.** Compost stability was 4.3mg CO_2/g organic matter/day, indicating **highly stable compost.**

Overall, the PAS 100 tests confirmed the compost's high quality and suitability for use.

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Viability & Conclusions

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Key Findings:

- Materials with larger surface areas break down faster, e.g. coffee pods. Pre-treatment methods like shredding can enhance breakdown efficiency.
- Proper compost management reduces waste and enhances material breakdown.
- High surface contact with the compost mass improves degradation, this meant that the mesh bag experiment gave a worst-case scenario as it did not allow the material to spread as it would in a typical composting process.

Viability:

- Including certified compostable materials in compost produces high-quality compost.
- Compostable packaging reduces non-biodegradable contaminants in compost and supports soil health.
- Using compostable materials in food waste management decreases reliance on non-renewable plastics and simplifies waste sorting.

Conclusions:

- The trial showed effective breakdown of compostable packaging, supporting plant growth and meeting PAS 100 compost standards.
- Compostable packaging reduces compost contamination by non-compostable plastics and is less carbon intensive vs traditional plastics.
- The products of compostable material breakdown are stable organic molecules such as lignin, cellulose, bacterial biomass, water, and CO_2.

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