

# The Efficacy of Composting Compostable Packaging



# Introduction

One of the most frequently raised questions on compostables is whether certified compostable packaging effectively biodegrades in industrial composting systems. Yet, addressing this question may be complex as operating conditions at composting facilities may vary.

Composting facilities' operational conditions differ based on multiple factors including: the composting technologies/ systems used (e.g. In-Vessel, Open Windrow, Aerated Static Pile), the specific conditions and timescales used, and the type of incoming materials received alongside other variables.

All of these have an effect on the quality of the finished compost and whether it can be classified

as 'Quality Compost' based on national standards such as PAS100 (plus other criteria) in the UK, NFU 44-051 in France or other voluntary standards (such as the STA Certified Compost program operated by the USCC in the US). In addition, the question whether or not certified compostable

materials effectively biodegrade in industrial composting systems arises because there may be a gap between the biodegradation timescale considered acceptable at the time of writing by various national and international standards (e.g., EN13432 (Europe), ASTM D6400 (USA), AS 4736-2006 (AUS)) versus



the real-life timescales that composting facilities typically to produce compost fit for use (e.g. a single facility can produce different compost product types for a range of market sectors, some requiring mature compost and others able to use compost produced over a shorter timescale).

'Compostable Coalition UK' conducted a large-scale study to address the question of whether certified compostable packaging effectively biodegrades in the context of the existing in-vessel composting infrastructure in the UK and common practices employed by local composting facilities.

### **The trial was designed to provide evidence on the following aspects:**

- What is the average disintegration/biodegradation rate of various compostable materials and formats in a real-life industrial composting system?
- Would the finished compost - derived from bio-waste processed with compostables - differ in quality when compared with minimum quality requirements in the British Standards Institution's PAS 100?
- Can any traces of compostable micro plastic be found in the finished compost?

### **The objectives of the study were as follows**

- 1.** Provide local evidence from the UK on the efficacy of composting compostable packaging via the dominant composting technology currently used by composting operators that process food (and garden) waste in the UK and within the average timescales used by local composters.
- 2.** Add new evidence to other international studies on the efficacy of international standards such as EN13432 and ASTM D6400 to reflect the effective speed of disintegration/biodegradation of compostables according to industry's typical treatment timescales.
- 3.** Provide useful information to composting operators on best practices for composting compostable packaging, from pre-treatment methods to effective treatment times to support the production of quality compost that meets a relevant standard.
- 4.** Use the data alongside other data collected via the entire 'Compostable Coalition UK' research project to suggest a practical roadmap to increase the collection and treatment of compostable plastics in the UK, in support of the UK Plastics Pact targets.

# Overview of the Composting Process

Industrial/commercial scale composting can be defined as a managed, biological process in which microbes turn bio-waste into compost. They use oxygen, moisture and the 'food' they can get from the bio-waste (its nutrients and some of its forms of carbon) to increase their population.

Microbes' activities generate heat and, given the pile sizes and conditions within each pile, the bio-wastes biodegrade at faster rates than they would in the natural environment, e.g. on the ground in woodland.

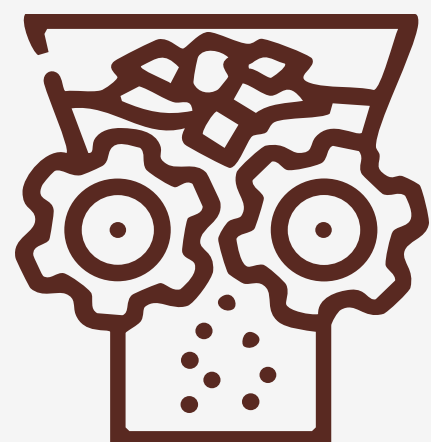
Biodegradation is activated by the presence of oxygen, moisture and naturally occurring microorganisms while composting process operators

monitor conditions inside the composting piles and employ minimal interventions to control the process. The process of degradation develops through

**mechanical, chemical, microbial,** and **thermal** modes in this managed process.

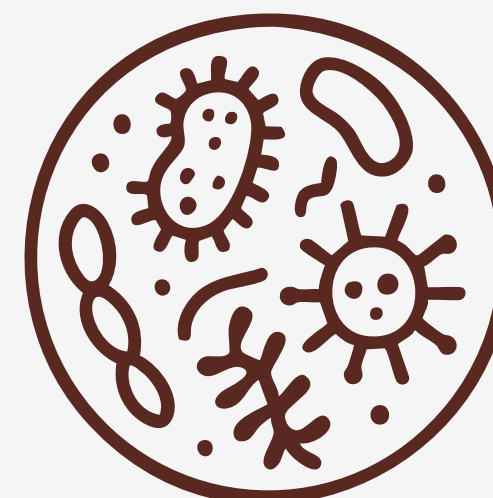


## Mechanical



Breaking up of material is undertaken in the form of shredding the homogenised feedstock prior to the composting of materials. The purpose of this is to reduce the size of large items, increase the materials' surface area to volume ratio and to homogenise the materials. High nitrogen and high carbon materials are blended as best as possible, helping to ensure effective breakdown via microbial and thermal modes of degradation.

## Microbial

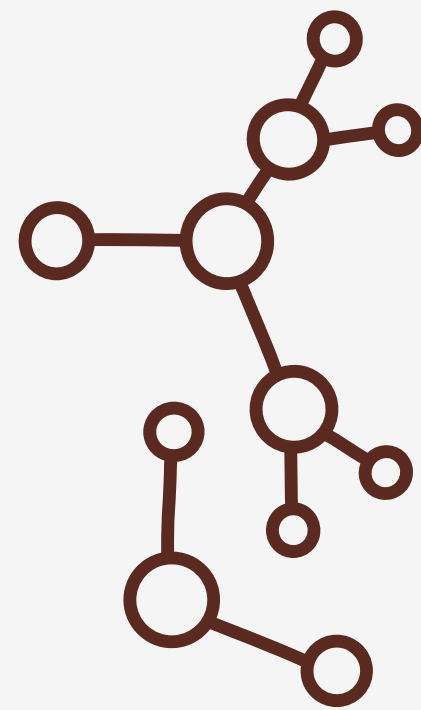


Microbial action is responsible for the thermal degradation as a secondary effect of the metabolic processes of the microbes which are inherent in the waste materials. Microbes release various enzymes and absorb nutrients from the degrading material. Oxygen from the air is also utilized by the microbes in respiration. The release of carbon dioxide (respiration) by microbes coincides with the uptake of carbon and nutrients (microbial assimilation).

During decomposition the organic molecules are broken down into simpler compounds which require further decomposition or into mineralised nutrients. Compounds in organic matter vary in the ease with which microorganisms can break them down. The first organic compounds to be broken down include amino acids and sugars. Cellulose will break down more slowly and lignin, phenols and waxes will degrade over a longer period.

It is worth noting that the degradation of the later listed more complex materials is slower, which means they may not be completely broken down by the time the treated material (compost) is considered "stable" by the relevant product standard, e.g. PAS100. This is acceptable and beneficial to the soil carbon cycle. Chemical reactions aid in the breakdown of composting materials. For example, Polylactic acid has a backbone of (C<sub>3</sub>H<sub>4</sub>O<sub>2</sub>).

## Chemical

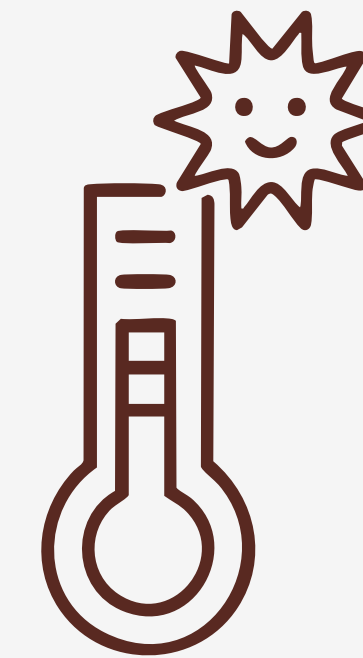


The addition of H<sub>2</sub>O hydrolyses this to C<sub>3</sub>H<sub>6</sub>O<sub>3</sub> – Lactic Acid. Oxidation then converts lactic acid into carbon dioxide and water through metabolic oxidation.

Water is also absorbed into natural fibres such as cardboard, paper, and compostable fibre-based items where it weakens the bonds

between the fibres, thus allowing for further mechanical or microbial action through a larger surface area.

## Thermal



Degradation speed is affected by the energy in the material available for the microbes to use. When microorganisms metabolise they also use oxygen to create energy, with heat produced as a by-product. In a sufficiently large composting pile, enough of this heat is retained for long enough that the pile can be described

as 'self-heating'. Temperatures during the most active phases of the composting process regularly sit at 60-75 degrees Celsius. Increased temperature increases the rate of hydrolysis of the material.

# Contamination at Composting Facilities Processing Food Waste

As collection of food waste from households as well as from business/commercial, public sector, and NGO sources of food waste is rapidly growing, not only in the UK, but globally, the most widespread problem all composters which accept food waste face is contamination of feedstocks by traditional (non-compostable) plastics.

This is because the modes of degradation in composting do not affect traditional plastics beneficially or at all, and in certain circumstances the contaminating traditional plastic becomes worse under treatment.

A recent study conducted in the US, found that 85% of contamination in food waste bins was derived from non-compostable conventional plastics<sup>1</sup>.



# Our Study

## Chosen Composting Technology and Operator

In the UK, all composting facilities that have a permit to treat food-waste types that are within scope of the Animal By-Products Regulations use processes that enclose each composting pile for at least the minimum time required in these regulations.

Typical systems used are described as In-Vessel Composting (IVC) or Enclosed

Composting To conduct this study, we collaborated with EnVar Composting Ltd. who operate the largest IVC plant in the UK, processing over 100K tons of bio-waste per year.

This company mainly processes food and garden wastes from local authorities (residential waste) and commercial clients. It also routinely processes

compostable packaging received via residential waste (typically bags used to collect food waste) and private bio-waste collection schemes.

EnVar operates such that its composting process and compost is certified compliant with PAS 100, the Compost Quality Protocol and REAL's Compost Certification Scheme rules.



# Our Study

## Selected Compostable Packaging

'Compostable Coalition UK' research project focuses on three plastic packaging application categories where reusability is less feasible for the entire category and on formats that are considered 'hard-to-recycle' with no or minimal effective recycling. Items within these categories represent a wide diversity of formats from very thin films to thick rigid containers.

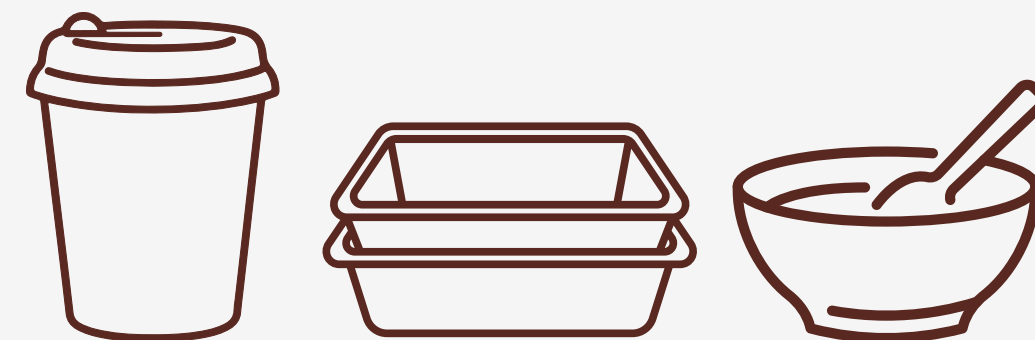
Such items are also typically made from a wide variety of compostable materials types. Compostable tea bags, for example, are usually made from polylactic acid (PLA) or PLA blends. Compostable food waste bags and shopping bags are made most frequently from starch-based blends. Compostable food containers and cutlery for the Hospitality/

Restaurant/Catering (HORECA) sector may be made from fibre-based materials or from compostable polymers such as PLA, as examples.

Chosen products for the study were carefully selected to ensure sufficient diversity of formats and material types within the three mentioned application categories.

### Application Segments

#### Food service-ware for the HORECA sector



#### Small formats



#### Flexible Packaging



All chosen items are certified compliant with the European standard EN13432. Most products used in the trials are certified also under other standards such as ASTM D6400 (a standard widely used in the US and Canada). Companies contributing materials for the trials included:



## Selected materials and final products for testing included the following:



### Tea bags

made from PLA and PLA blends



### Coffee pods

made from a blend of compostable polymers



### Film for sweet wrappers

made from cellulose



### Waste bags and shopping bags

made from starch blends and PBAT blends



### Bags for pre-packaged fresh produce

made from different compostable polymer blends and in different thicknesses



### Selection of rigid food service-ware items

such as cups, plates, bowls and cutlery - made from plant fibres, polymer-coated plant fibres or PLA

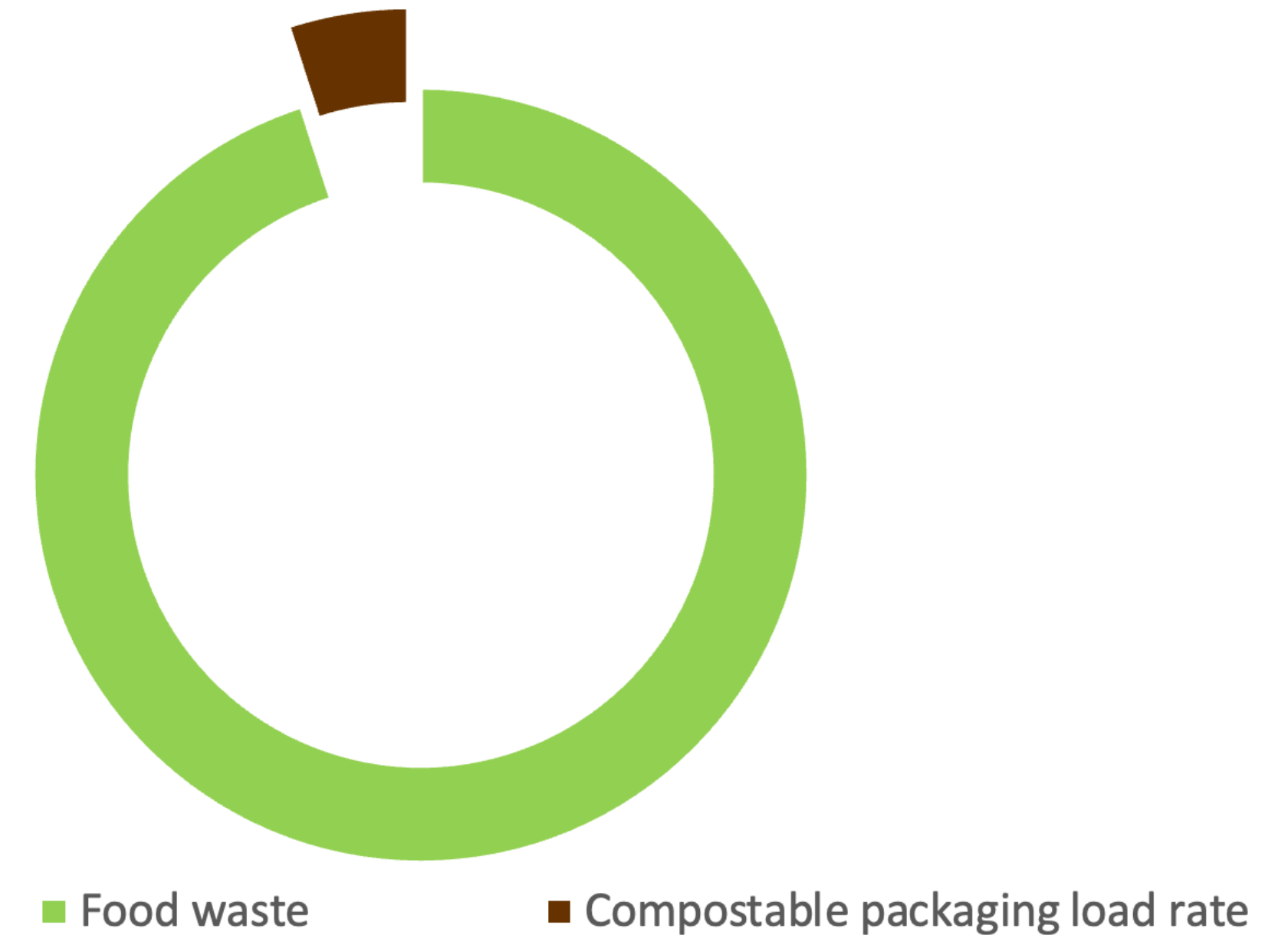
# Our Study

## Determining load-rate for the Compostable Materials

In-Vessel Composting (IVC) operators typically process local authorities' food and garden wastes (usually collected co-mingled) and some food wastes from commercial/business sources..

Balancing between the different types of bio-wastes composting sites receive and form into piles is critical to control each pile's biodegradation and guarantee the finished compost's quality.

When forming a composting pile there needs to be enough carbon-rich waste to provide pile structure and enable oxygen from the air to get into the pile, and a suitable amount of nitrogen-rich waste that microbes can readily use.



Food waste, for example, is rich in nitrogen while garden/plant waste and compostable packaging and non-packaging items consist of more carbon.

In order to determine a relevant load-rate for compostables to be added to the bio-waste pile that was studied during the composting trial, Envar benchmarked the amount of

food waste in the UK against a hypothetical future high penetration scenario in which compostables replace 5-10% of plastic packaging in the UK. WRAP estimates that in 2021 food waste amounted to **~10.7 million tonnes** (Mtpa)<sup>2</sup>. Total plastic packaging waste in the UK amounts to **~2.3 million tonnes**<sup>3</sup>.

In a hypothetically high penetration future scenario, if compostables replace ~10% of plastic packaging (~200K Mtpa) in the UK, compostables would represent **less than 2%** of total annual food waste arising. During the composting trial **~5% by volume** and **~ 8% by weight** of compostable packaging was added to a mix of food and garden waste.

This higher load rate therefore **tested the system's capacity to handle future increases in compostable plastics.**

Table 1 details the type and weight of compostable products tested.

**Table 1- Format type and weight of compostable added to the bio-waste pile**

Product Code	Product	Mode of arrival	Weight (kg)
Sample 1	Dry – Bags	Loose	1125.00
Sample 2	Dry – Bags	Loose	2000.00
Sample 3	Dry – Bags	Loose	80.00
Sample 4	Tea bags	Loose	67.00
Sample 5	Unused coffee pods	Loose	145.00
Sample 6	Used Coffee Pods	Loose	66.00
Sample 7	Dry - Compound	Loose	589.00
Sample 8	Used Compostables – tableware	Semi compressed	5980.00
Sample 9	Film for use as sweet wrappers	Baled	3000.00
<b>Comingled Food &amp; Green</b>	Normal incoming feedstock		15,9960.00
	<b>Total Weight (kg)- Packaging</b>		<b>13,052.00</b>
	<b>Total All</b>		<b>159,973.52</b>

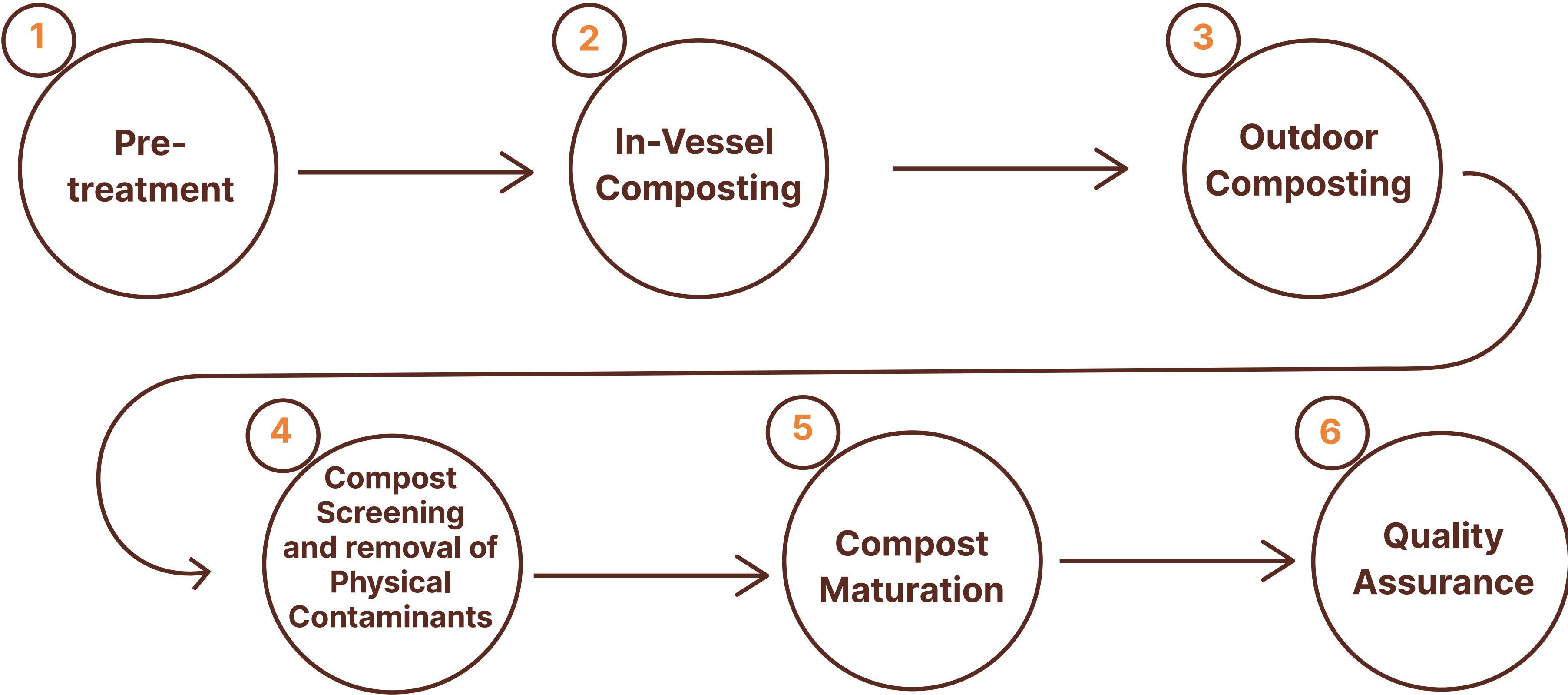
An additional aspect studied during the test was the effective biodegradation of compostable packaging, considering not only the material type and format but also the method by which these products were packaged and transported to the site.

Approximately 4 tonnes of different compostable packaging arrived in a loose format, approx 6 tonnes of compostable tableware / food service- ware was semi compressed prior to arrival and approx 3 tonnes of compostable film for use as sweet wrappers arrived in a baled format.

# Our Study

## The Composting Process

The composting process included five key steps and quality assurance checks



## Pre-treatment phase

Shredding and mechanical blending of incoming bio-waste is an important key step prior to the in-vessel composting phase. Shredding and blending increases the biowastes' surface area to volume ratio. The greater the surface area and smaller the volume of each bio-waste piece in the composting pile the faster it will disintegrate and become biodegraded by naturally occurring organisms in the composting pile.

All samples of compostables that were received loose or compressed were directly added to a co-mingled mix of food and garden waste (samples 1-8). Sample 9 arrived in a baled format and therefore was

separately shredded via a slow speed shredder before being added to all other materials that were then shredded together. Next, mechanical blending was performed followed by a final shredding process.



## In-Vessel Composting phase

After completion of mechanical blending and shredding of bio-wastes and samples of compostables described above, this mixture of 'materials' was loaded into a composting tunnel. During loading these materials into the tunnel, some woody 'oversize' materials - that had been separated from compost when mechanically screening it - was added, after some removal of traditional plastics and checking it was 'virtually free' from physical contaminants. This enabled the composting batch to start out with a nearer to optimal ratio of carbon-rich and nitrogen-rich materials and gave the woody oversize a further composting cycle, enabling its further break-down.

During loading of materials into the composting tunnel, additional samples of each compostable material/item (listed in Table 1) were placed in individual mesh bags for degradation analysis. These bags were buried within the composting mass for subsequent recovery and analysis. The composting tunnel's doors were then closed and composting process monitoring began.

Three weeks later, the **composting batch was removed from the tunnel.**



## Outdoor Composting Phase

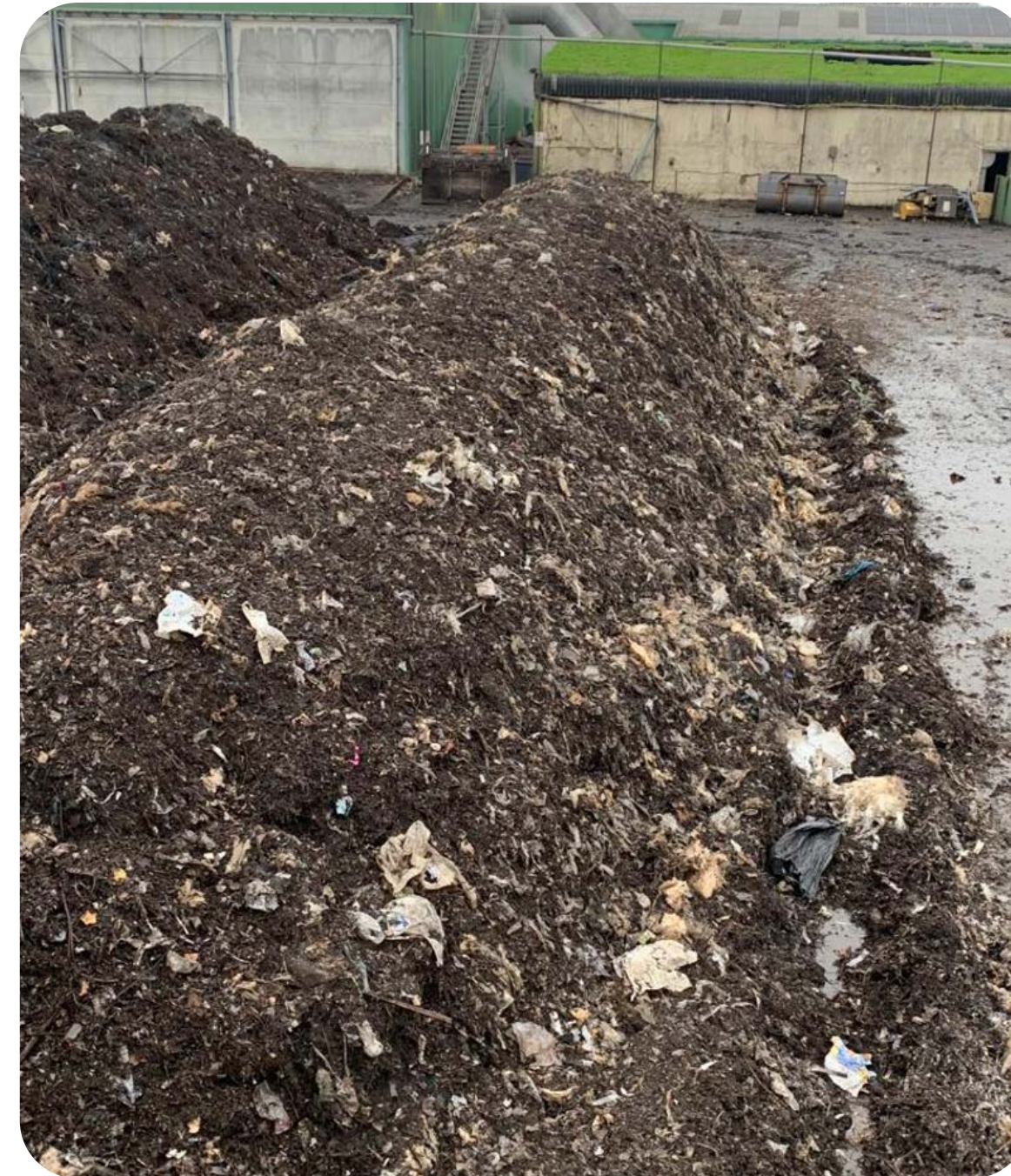
The next step after treatment in the closed vessel (tunnel) for three weeks was to move the composting batch onto the outdoor, concrete composting pad. Here the batch was formed into a long pile called an 'open windrow', which was composted on the pad for eight weeks.

Turning the material, as a routine procedure, ensures materials in the batch's surface zone are moved to the centre of the composting mass, to ensure that over the period of the composting process all matter is exposed to the same conditions conducive to break down as the rest of the mass. The turning of the compost also provides for additional mechanical breakdown

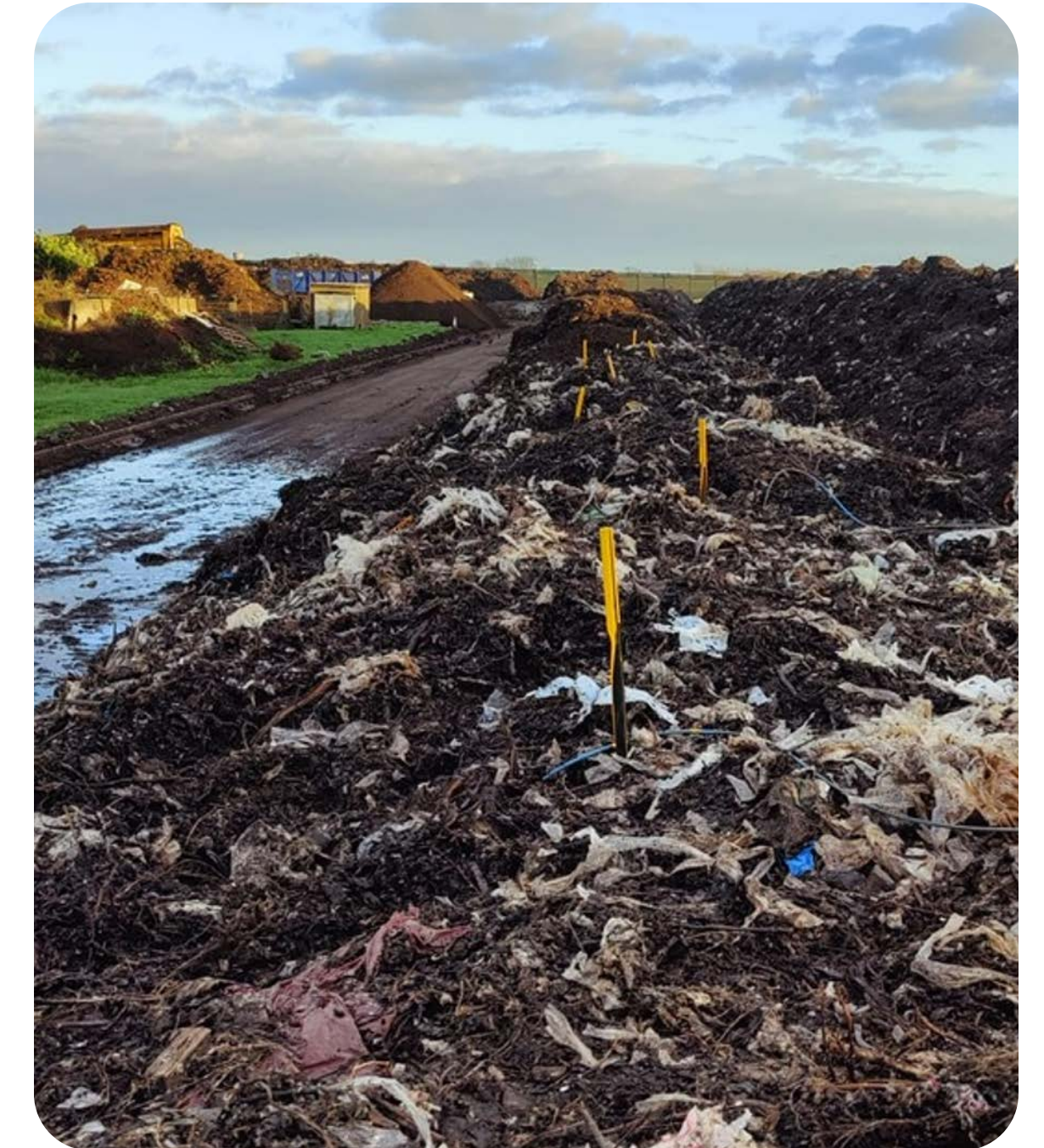


of the composting material, impacting larger particles and tearing fibrous or film-like materials.

Samples of the Compostable materials were put inside mesh bags (when forming the



composting batch in-vessel) and positioned in the composting batch (during in-vessel and windrow treatment phases) deep enough to ensure the time, temperature and moisture parameters the rest of the mass received were the same as was



experienced by the samples. The samples were then removed and analysed weekly before being reinserted in the composting batch; this was repeated until composting of the batch was finished.

## Compost Screening and Contamination removal

After completion of the in-vessel and outdoor windrow composting phases the composting batch was moved to the screening area for separation into 1) compost product and 2) oversize for reprocessing into compost.

The screening process was conducted using a screening machine with 10mm holes. “Oversize” material which is too large for the 10mm holes is ejected from the rear of the screening drum. This oversize is stockpiled for reincorporation at the reception stage of material processing or separated into aggregate, wood and plastics for further recovery or recycling as biomass/ secondary aggregate.

Remaining over-sized biowaste (such as tree branches and woody sticks) was screened for undergoing a second

composting cycle, along with some remnants of identifiable compostable items. Special care was taken with the quality

control checks to ensure that any existing residuals from the compostable materials are sufficiently identifiable.



Important to note is that some bio-waste materials such as woody sticks and branches require a longer time to sufficiently break down than one full composting cycle. Thus, composters often re compost some of the oversize by mixing it in with new deliveries of bio-waste materials when forming a new composting batch.

Recomposting some of the oversize not only supports its further but is also useful for improving the Carbon to Nitrogen ratio of incoming food and green waste, thus supporting the composting process.

The rules system that controls production of certified Quality Composts in the UK includes that any oversize being reintroduced should be

virtually free from contamination such as (non-compostable) plastics and any other non-compostable materials. In this context, because the woody particles and any remnants of certified industrially compostable packaging / non-packaging items are biodegradable, they are not classed as physical contaminants and can therefore undergo processing once more

All other rejected non-bio-waste materials were screened out for disposal or recovery. Removal of plastics from oversize does mean some compostables (partially degraded) may be recovered for disposal or recovery. However, considering the degradation prior to this, the percentage would be low.

Overall, the assessments of compostable samples in mesh bags and observations were performed over an eleven week period of in-vessel plus outdoor windrow composting, corresponding with EnVar's typical timescale for producing compost.

In England, 73% of all compost operators in 2018 were using a composting timescale of **between 10 and 19 weeks**, with a **mean of 13 weeks** and a **median of 14 weeks**<sup>4</sup>. An eleven-week composting timescale could be assumed to represent the current norm in England. This timescale also compares favourably with standards for compostable packaging and plastics suitable for industrial composting, which set a maximum disintegration test timescale of **12 weeks**.

Compost maturation:

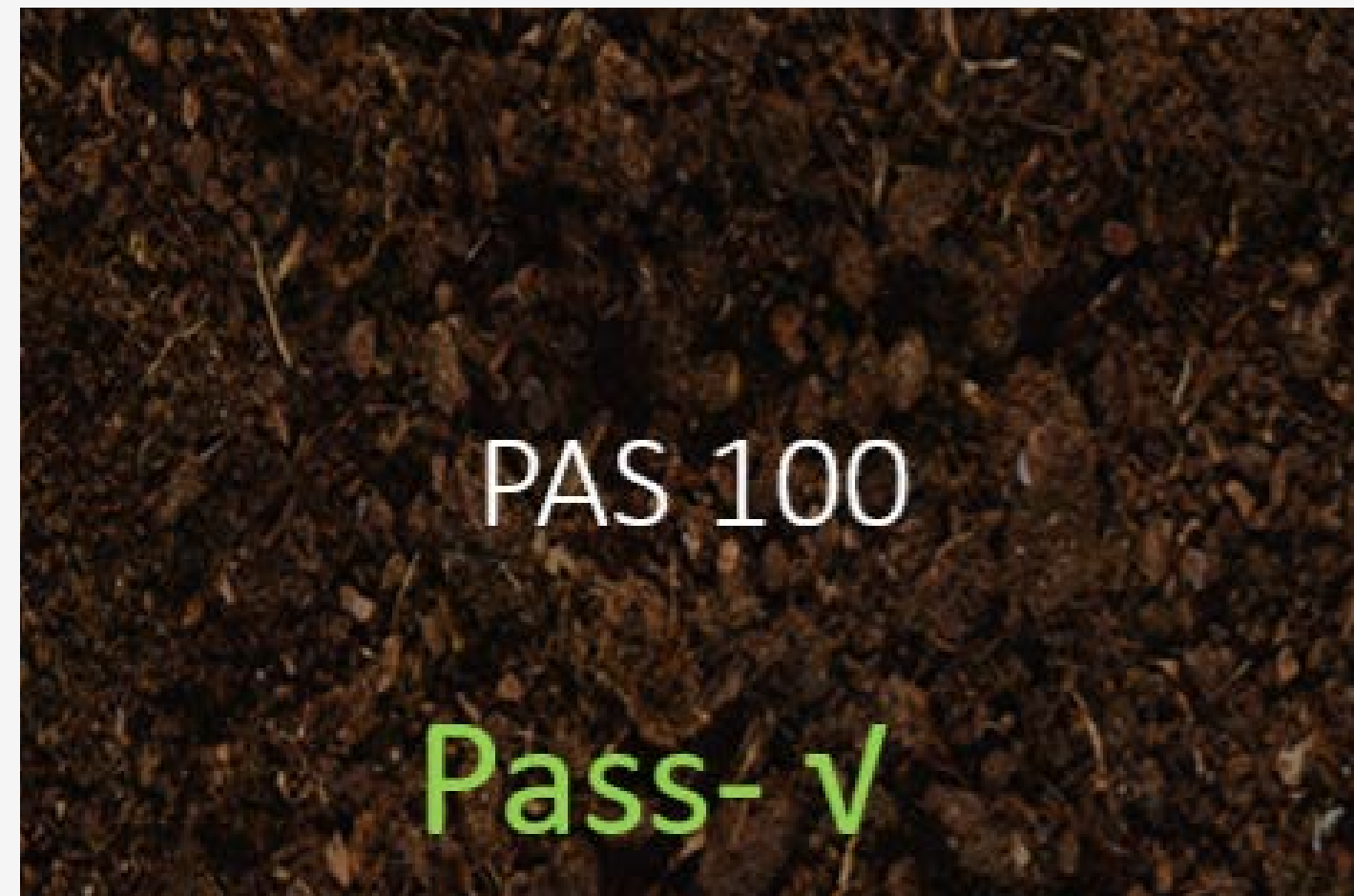
For the purposes of the trial, screened compost from the studied composting batch was matured for a further period.

## Quality Assurance

The finished compost was first sampled at 16.7 weeks after formation of the batch.. An independent lab tested the quality of the finished compost sample according to the UK's compost

quality standard PAS 100. A second sample of the finished compost was taken for a further physical contaminants test by the same lab (see more details below). Another sample of the finished

compost was sent to a different, specialist lab to test whether any traces of compostable microplastics could be found in the sample.



# Our Study

## Results

Degradation rate of samples assessed at Envar’s composting facility:

The degradation rate of all samples of compostable materials used in the trial varied mostly according to the physical state in which they arrived and the effects that mechanical shredding had on them.

Generally, all materials that arrived in a loose format and were then shredded degraded sufficiently within the 11-week in-vessel plus outdoor windrow composting process.

Together, the average degradation of all samples of compostable materials was 89.3% by the end of 11 weeks of composting. The samples included a wide variety of

materials and formats from small formats such as tea bags and rigid coffee pods to various types of bags made from a variety of different compostable materials.

Material	End % Degradation
Sample 7- Compound	97.7%
Sample 4- Used Tea Bags	97.7%
Sample 5 and Sample 6 – Coffee pods	95.1%
Sample 1- Shopping Bags Loose	93.3%
Sample 2 – Bags- Loose	84.7%
Sample 3- Bags- Loose	67.6%
All- Average	89.3%

The sample that arrived in a semi-compressed format (Sample 8) did not complete a full degradation process by the end of 11 weeks of composting, reaching a 60.4% degradation rate (as measured by loss of mass of sample retained inside its mesh bag). This is most likely due to the relatively low surface area to volume ratio of compressed items in the delivered sample. Examples are compostable plates that had been stacked on collection and had become stuck together by food waste, which remained on the plates after shredding at the composting site. Compression limits the surface area that microbes can quickly get in direct contact with. Thus, the items that remained stuck together after shredding were not optimally exposed to

and/or interacting with the full spectrum of conditions in the composting pile, which includes the presence of microorganisms, oxygen, raised humidity and high temperatures. This may have compromised the overall speed of degradation of items in sample 8. Another factor that may have affected the biodegradation time for Sample 8 may have been the fibrous nature of some of the treated compostable tableware / food service ware. In general fibre-based materials, and also shredded tree branches, typically require slightly longer composting time than soft, nitrogen-rich plant wastes\* and consequently they can be re-introduced by composting operators for a second cycle of composting.

After compost screening, all identifiable tableware / food

service ware remnants from sample 8 were re-inserted for a second composting cycle. Physical contaminants removed during compost screening and from oversize were sent for disposal or recovery.

Sample 9 arrived in a baled sheets format. Most of the sheets were pre-shredded separately via a slow speed shredder before being added to all other samples tested during the trial. It was then shredded alongside all other incoming materials, mechanically blended and shredded again. Some of the Sample 9 sheets were ripped or cut by hand before being placed inside mesh bags with holes of 3 mm by 3 mm, without addition of any other materials or bio-waste. The degradation results by the end of 11-weeks of

composting of Sample 9 inside mesh bags was not sufficient as the sample lost merely 33.9% of its mass. It is important to note that the material in Sample 9 was cellulose. Cellulose is considered one of the fastest materials to degrade in composting and when tested as specified in EN13432 it typically disintegrates in less than 7 weeks. Therefore, it can be concluded that the materials in Sample 9 did not degrade sufficiently due to the bulky nature in which it arrived, which meant it had an insufficient surface area to volume ratio, despite 1) the portion of sample used in the mesh bags part of the trial being ripped/cut by hand during sample preparation, and 2) the portion of sample mixed directly into the composting batch during its formation

having been machine shredded. Subsequent shredding trials demonstrated that this material could be processed at EnVar's composting facility with no issues.

## Quality of the finished compost

Samples from the finished compost were sent to a lab to test whether the quality of the finished compost met the quality requirements in the British Standards Institution's PAS100. Results of the tests on the first sample proved that the finished compost met PAS 100's quality requirements. Electrical conductivity was measured at 1595  $\mu\text{S}/\text{cm}$ , 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<sub>2</sub>/g organic matter/day, indicating **highly stable compost.**

The results prove that processing compostable packaging at up to 5% by volume or up to 8% by weight had no negative effect on the finished compost and that it met the compost quality requirements in the British Standards Institution's PAS 100.

\*EnVar suggested that using fast-speed shredder would be best for received materials that have little risk of contamination.

\*\*Similar results were found in a 'Breaking it Down' study

conducted by Compostable Consortium in 2024 in the US.

## Micro-compostable plastic

Under this research project, microplastics were defined as solids that have a size between 0.3mm and 5mm, are resistant to a wet peroxide oxidation extraction, float in a density flotation liquid (density 1.6g/ml) and are visually recognisable as being a polymer when inspected under a microscope at 40x magnification.

For the purpose of the test, a sample of the finished compost was sent to a specialist lab to determine the presence of biodegradable microplastics, along with samples from each of the compostable products/

materials used during the composting trial.

Particle identification was performed by Fourier Transform Infrared Spectroscopy (FTIR).

Analysis by FTIR of these reference materials showed them to be polymer types used as or in certified compostable products, such as Poly(butylene adipate-co-terephthalate), Starch, Cellulose, Polylactic acid and Polyhydroxyalkanoate.

Analysis of the microplastics recovered from the compost sample showed no detectable evidence of any compostable polymer types.

# Our Study

## Conclusions

### EN13432 and Compost Quality

Results of the study prove that compostable packaging made from a variety of compostable material types and shaped into various formats delivered in a loose or non-compressed format and processed at a load-rate of up to 5% by volume or ~8% by weight sufficiently disintegrated/biodegraded in the in-vessel and outdoor windrow composting system used in the trial.

The quality of the finished compost was also proven to meet the British Standards Institution's PAS 100 (a fast-track version of a British Standard that specifies compost production and quality requirements and which is widely adhered to by commercial/industrial scale

composters in the UK). No traces of biodegradable microplastics were identified in the finished compost, further proving the sufficient biodegradation of the compostable materials tested.

This study, along with multiple other studies conducted in recent years via the US Compostable Consortium<sup>1</sup>, Wageningen University<sup>5</sup> and AgroParisTech<sup>6</sup>, all echo similar results and conclusions and attest that International standards such as the EN13432 are viable and well represents the ability of compostable materials to disintegrate/biodegrade in composting systems. The results of the test also prove the safety to process compostable materials and produce good quality finished compost, provided that the

composting site utilizes relevant means to remove physical contaminants.

For Compostable materials that are delivered in a compressed or baled formats, special pre-treatment care is required to ensure a sufficient surface area to volume ratio is achieved.

# References

1. Closed Loop Partners, Composting Consortium, 2024, 'Breaking it Down', Retrieved from <https://www.closedlooppartners.com/research/compostable-packaging-disintegration-at-composting-facilities/>
2. WRAP, 2023 Food Surplus and Waste in the UK Key Facts. Retrieved from <https://www.wrap.ngo/resources/report/food-surplus-and-waste-uk-key-facts-updated-november-2023>
3. WRAP, 2018. PlasticFlow 2025, retrieved from <https://www.wrap.ngo/resources/report/plasticflow-2025-plastic-packaging-flow-data-report>
- WRAP, 2025, Taking Action, Plastic Packaging, retrieved from <https://www.wrap.ngo/taking-action/plastic-packaging>
4. WRAP, 2021 'AD and composting: Latest Industry, New Summarized of Technologies and Impacts' 8 April 2020, WRAP. Retrieved from <https://www.wrap.ngo/resources/report/anaerobic-digestion-and-composting-latest-industry-survey-report-new-summaries#download-file>
5. Van der Zee. M, Molenveld, K. 'The fate of (compostable) plastic products in a full scale industrial organic waste treatment facility', Wageningen Food & Biobased Research Retrieved from <chrome-extension://efaidnbnmn-nibpcajpcglclefindmkaj/https://edepot.wur.nl/514397>
6. Gastaldi E., et al., (2024, May), 'Degradation and environmental assessment of compostable packaging mixed with biowaste in full-scale industrial composting conditions', Science Direct, Retrieved from <https://www.sciencedirect.com/science/article/pii/S0960852424003730>

