Carbon Clarity Commentary on the 'Big Compost Experiment' Published in the Journal *Frontiers in Sustainability*

January 2023

Summary of key points

- Home composting is not an exact science; rather it is an art that requires skill, knowledge, practise and patience. Participants should therefore have received instruction in how to compost effectively.
- Home composting can mean different things to different people, but unless 'compost' is produced, the organic materials cannot be described as having been 'home composted'.
- As participants were able to terminate their experiments at a time of their choosing, it is unclear whether this would have been when they would normally harvest and use their compost; notably it is not mentioned in the experimental methodology. Therefore, it is unlikely that some participants in the Big Compost Experiment actually carried out 'home composting'.
- It takes most large-scale composting facilities over two months of intensive processing at elevated temperatures to produce compost, whilst in an outdoor home composting system in the UK it generally takes over one year. By allowing participants in the Big Compost Experiment the option to terminate the experiment after three, six and nine months, it was unrealistic to expect items of test packaging to have disintegrated sufficiently. Adjectives such as 'partial', 'limited', 'incomplete' or 'interrupted' should have been used to qualify the truncated composting processes.
- Instructing participants to introduce test samples in small woven bags without any accompanying feedstock meant that samples would not necessarily have been in direct contact with the composting medium and the microbiota necessary for biodegradation.
- The aim of a standard for compostable products is to ensure that conforming items have no adverse effects on compost quality, that there would be no subsequent environmental or ecological harm, and that disintegration and biodegradation is theoretically possible under simulated, controlled conditions. This does not mean that they would necessarily disintegrate and biodegrade over a set period of time in undefined processes.
- It thus seems unwise for the authors to have concluded that "*home composting is not an effective or environmentally beneficial waste processing method for biodegradable or compostable packaging in the UK*" given the experimental methods they employed.
- The paper would, perhaps, have been better called: 'The Big Citizen Science Experiment: Assessing citizens' interaction with home composting, home compostable products and gardening'.

Introduction

Between 2019 and 2021 University College London (UCL) conducted The Big Compost Experiment (BCE) a citizen science project aimed at assessing **'the impact and effectiveness of biodegradable and compostable packaging' in UK home composting**. It involved a group of self-selecting citizens from across the United Kingdom who tested a range of products in their own home composting units. Participants were free to decide which products they would test and how long their individual experiment would last. The results were published in the journal *Frontiers in Sustainability* in November 2022 (Purkiss et al., 2022), and appeared to suggest that a majority of products did not fully disintegrate, leading the authors to conclude that "home composting is not an effective or environmentally beneficial waste processing method for biodegradable or compostable packaging in the UK".

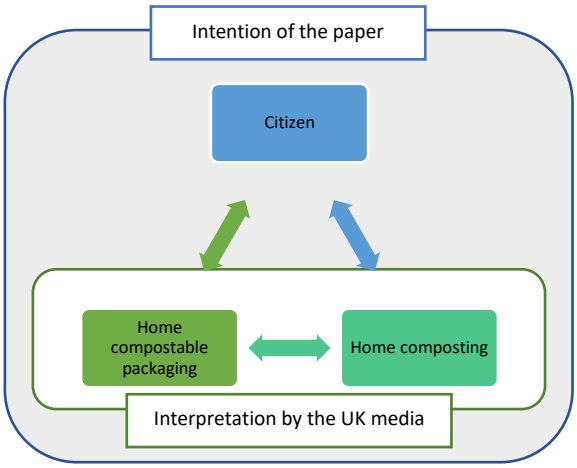
Publication of the paper was accompanied by release of a policy briefing by the UCL team (Plastic Waste Hub, 2022), sparking extensive media interest with some suggesting that certified home compostable products "don't work" (Weston, 2022). This is shown schematically in Figure 1. Professionals active in the field of compostable packaging and organic waste recycling understand the complexity of ways in which these products disintegrate and biodegrade, hence their performance in real world situations. The simplistic messages portrayed by some in the media served to have a detrimental impact on a nascent and growing sector, resulting in publication in January 2023 of an opinion piece by the original reviewer of the BCE paper (Degli-Innocenti, 2023); the key points he raised are summarised in the text box below.

The purpose of this commentary is not to replicate what has already been set out by Degli-Innocenti, but to provide additional perspectives and further information. Moreover, it does not discuss the numerous inaccuracies in the introductory section of the BCE paper.

Key points raised by Degli-Innocenti

- The BCE was a citizen science experiment studying the attitudes and behaviour of a group of volunteers regarding home composting and compostable items.
- It was not an experiment of material science or biodegradation.
- The approach was qualitative and not quantitative.
- The citizens were not a statistically representative sample.
- The citizens were not trained as to how they should recognise different compostable items, detect the fragments and respond homogeneously with respect to the observations made (i.e. they were not 'calibrated').
- The compostable items tested were not provided to the volunteers.
- No control item was included to check the functioning of the composting process.
- There was no respondent validation.
- There was no evaluation of the relationship between the input and retrieved output.
- Nothing can be said about the performance of the certified home compostable products, because the experimental scheme of this test did not allow it. The questionnaires tell of an experiment carried out by proxy whose contours were necessarily undefined.
- The article was about a study of the behaviour of a social group; it cannot be considered as a calibrated "scientific tool".

Figure 1: Schematic diagram showing the different perspectives of the authors and media



Composting and compostable packaging – temperature and time are critical parameters

Composting is a natural process in which waste plant and animal materials biodegrade in the presence of oxygen and are converted into solid material (compost[1]) that confers beneficial effects when added to soil. The detailed biochemical processes and microbes involved are poorly understood, however, the practice of producing compost is well documented and widely carried out successfully on small, medium and large scales.

Factors that are important in the composting process are:

- the materials mix (in particular, the carbon-to-nitrogen ratio),
- the structure of the materials (in order to allow gases to diffuse into and out of the material); and
- the moisture content and oxygen levels.

Temperature is also an important factor influencing the rate of disintegration and biodegradation of materials in a composting system due, primarily, to the type and activity of microbial populations (Insam et al., 2010). Generally, the rate of composting increases as the temperature increases, although it starts to slow down again above about 50 °C (Oshins and Michel, 2022). Collectively, these factors influence the rate at which biodegradation occurs hence the time it takes to produce compost. There is therefore a correlation between the two, as illustrated in Table 1 summarising typical time and temperatures for large and small-scale home composting systems.

Ambient air temperatures in the UK

Mean monthly air temperatures during the study period (2019 and 2020) in the UK ranged from 5.2 °C in winter to 15.0 °C in summer, with an overall annual average of 9.5 °C (Met Office National Climate Information Centre, 2022), suggesting that composting temperatures would likely be below 20 °C for over half the year.

[1] Defined in EN 17427:2022 as: an organic soil conditioner obtained by biodegradation of a mixture consisting principally of vegetable residues, occasionally with other organic material and having a limited mineral content.

This correlation between biodegradation rate and temperature has also been demonstrated with pellets of a commercially biodegradable plastic in soil. Researchers found that the rate of biodegradation increased with temperature in line with the Arrhenius equation at mesophilic temperatures (15-28 °C) (Pischedda et al., 2019). Put simply, **the higher the temperature the faster the rate of biodegradation and disintegration**.

Table 1: Typical temperatures and timescales in large and small-scale (home composting) systems

Scale of composting	**Typical temperatures**	**Typical length of time to create usable compost**
Large scale (industrial)	> 55 °C	> 2 months
Small scale (home composting)	Fluctuate within +10 °C of ambient air temperatures	12-18 months

(Smith and Jasim, 2009; Andersen et al., 2010; Tatàno et al., 2015; Guidoni et al., 2018; Oshins and Michel, 2022)

What this shows is that it still takes most large-scale composting facilities over two months of intensive processing at elevated temperatures to produce compost, whilst in a home composting system in the UK it takes over one year. This is because it is primarily an outdoor practice in which microbial activity is dependent upon the ambient temperature and the rate and type of materials added to the composter. During the winter months, biodegradation would be slow due to a combination of low temperatures and little, if any, nitrogen-rich garden waste. **By allowing participants in the BCE the option to terminate the experiment after three, six and nine months[2], it was therefore unrealistic to expect the test packaging to have disintegrated sufficiently.**

The implicit assumption made by the researchers in the BCE was that participants would continue to manage their home composting bins in their usual way and terminate the experiment at a point when they would normally harvest and use the resultant compost. It was therefore unclear whether the experimental length chosen by the participants reflected this in practice.

Moreover, **it is unclear whether the mixture of organic waste into which the test samples were placed had decomposed sufficiently so that it could be used as 'compost'**. (The absence of a control further complicates the issue.) Without this information, **it cannot therefore be assumed that the experiment involved home composting**, in the sense that it is a practice carried out by citizens in their own gardens in which organic wastes are transformed into compost. A review of the photographs uploaded to the BCE website (Big Compost Experiment, n.d.) supports this, suggesting that compost was not, in many instances, created (Figure 2).

[2] 59% of experiments were less than or equal to nine months. Data derived from photographs of completed experiments (n=627) uploaded to https://www.bigcompostexperiment.org.uk/gallery and interrogated using the 'Experiment length' filter [Accessed 30 November 2022]

Figure 2: Selected photos from the BCE website after different experimental timescales showing undecomposed twigs and leaves

Three months

Six months

Nine months

Twelve months

Fifteen months

18 months

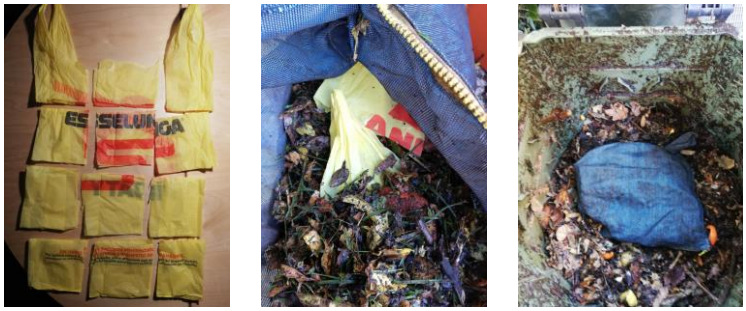
Sample presentation

Participants in the Big Compost Experiment were asked to test samples of packaging items labelled as 'home compostable' in their own home composters by placing them in a loosely woven polypropylene mesh bag. Some photographs showed samples stuffed into small woven bags without any accompanying feedstock (Figure 3); a practice that would have significantly reduced the surface area available for microbial attachment to the test items and subsequent biodegradation.

Testing of compostable products in composting systems usually incorporates measured amounts of feedstock inside fine mesh bags in order to ensure adequate contact with the test items (Figure 4). Again, this highlights a flaw in the experiment's methodology, in that it did not provide the participants with adequate instructions on how to present their samples so that adequate contact would be made with the surrounding organic waste.

Figure 3: Examples of overfilled sample bags

Figure 4: Examples of compostable products tested inside fine mesh bags with accompanying garden waste



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Source: J Gilbert, Carbon Clarity

Standards and certification of compostable products

An important point needs to be made about the role of **standards** and independent **certification** for compostable products, as also noted by Degli-Innocenti, 2023.

Standards

The European harmonised standard, **EN 13432** '*Packaging - Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging*' (CEN, 2000) is the main standard against which compostable packaging items are currently tested in Europe. Similar standards exist in other countries, such as ASTM D6400 in North America and AS4736-2006 in Australasia.

EN 13432 is relevant to the organic recovery of packaging in industrial biological waste treatment facilities (composting and anaerobic digestion). It specifies requirements and procedures to determine the compostability and anaerobic treatability of packaging and packaging materials.

Where packaging products contain more than one material, each component needs to comply with the requirements of the standard in addition to the final composite product. There is a mirror standard, EN 14995, for non-packaging compostable plastics (CEN, 2006).

There is currently only one harmonised European standard for home composting: EN 17427:2022 'Packaging. Requirements and test scheme for carrier bags suitable for treatment in well-managed home composting installations' (CEN, 2022)[3]. As the title indicates, this is restricted to carrier bags and only applies to home composting processes that are 'well managed' (see text box). The test criteria are summarised in Table 2.

[3] It is acknowledged that EN 17427:2022 was published after the start of the BCE. It is noted in this commentary in order to highlight the robustness of the test criteria specified in CEN compostability standards and to note the assumed times for well-managed home composting (12 months).

Table 2: Test criteria specified in European compostable standards

Characteristic	Requirements in EN 13432:2000	Requirements in EN 17427:2020
Biodegradability	Aerobic biodegradation test At least **90%** in total after a maximum of **6 months**	Aerobic biodegradation test At least **90%** converted to carbon dioxide after a maximum of **365 days (1 year)** at 25 ± 5 °C
Disintegration during biological treatment	Less than **10%** (dry m/m) shall be > 2 mm after a maximum of **84 days (3 months)**	Less than **10%** (dry m/m) shall be > 2 mm after a maximum of **180 days[a] (6 months)** at 25 ± 5 °C
Effect on the biological treatment process	Comparison with control compost	Comparison with control compost
Effect on the quality of the resulting compost	Heavy metal limit levels Ecotoxicity effects on higher plants	Heavy metal limit levels PFAS[b] and substances of very high concern not permitted Ecotoxicity effects on higher plants Ecotoxicity effects on earth worms Ecotoxicity effects on soil nitrifying bacteria

Notes to table:
a To allow for seasonal variation in temperature and the likely effect of feedstock variation through the year, the maximum time for this test was set at 50 % of a home composting cycle undertaken in a well-managed fashion.
b. PFAS = per- and polyfluoroalkyl substances.

The **aim of a compostable standard** is to ensure that **products would be suitable, in principle, for inclusion in a composting process**, not that they would necessarily disintegrate and biodegrade over a set period of time. **Their main purpose is to ensure that there would be no adverse effects on compost quality, that there would be no environmental/ecological harm and that disintegration and biodegradation is theoretically possible under simulated, controlled conditions.**

Well-managed home composting, EN 17427:2022

Definition

A home composting practice which meets a minimum set of required conditions to convert biowaste into compost

Note 1 (Annex E)

Well-managed home composting includes:

- the presence of sufficient air and moisture in the composting heap,
- a manual rotation or aeration by other means at least three times in a 12-month cycle;
- a minimum size for closed insulated composting systems of 100 l and a minimum size for non-closed,
- non-insulated systems of 0.5 m^3,
- mechanical shredding/chopping of roughly textured raw materials (e.g. branches) before being
- added to composting, and
- a mix of garden and kitchen waste.

Note 2

For home composting a usual cycle time is at least 12 months

Certification

Certification of a product to a published standard may only be carried out by an **accredited certification body** should a manufacturer wish to claim conformance. A certification body is an independent third-party organisation that assesses products, processes and services, operating to the international standard ISO 17065:2012 (ISO/IEC, 2012). This standard sets out a range of criteria that certification bodies need to meet, including organisational, process, resource and impartiality requirements. Certification bodies are themselves audited by a national **accreditation body** that checks their conformance with ISO 17065 and other relevant standards.

The aim of certification by an accredited, independent certification body is therefore to verify that a specified product conforms to a specified standard. This means that all test procedures, materials used in the product and claims of compostability meet the requirements of the standard. The certification body acts as a disinterested third-party. Product manufacturers cannot self-claim certification.

Within Europe there are two main certification bodies certifying compostable products (DIN CERTCO and TÜV AUSTRIA), with the Italian Compost and Biogas Association (CIC) and the Renewable Energy Assurance Ltd (REAL) in the UK running smaller schemes. All but CIC carry out certification for home compostable products (Table 3).

Table 3: Home compostable standards used by European certification bodies

Certification body	Standards they certify to	Label
DIN CERTCO	NF T51-800	DIN Tested - Garden Compostable
TÜV AUSTRIA	NF T51-800 AS 5810 EN 17427	OK compost HOME
REAL	NF T51-800 AS 5810	REAL Home Compostable

(Standards Australia, 2010; NFT, 2015; CEN, 2022)

Assumptions made in the BCE

An implicit assumption in the methodology of the BCE was that home compostable certification of packaging products would *ensure* that they disintegrated in the participants' composters during the course of the experiment. As noted previously, the low temperatures and composting times made it unlikely that certified home compostable products would disintegrate in under a year, **meaning that timescales of over 12 months would be necessary**.

Furthermore, the authors noted that "*Even if some home compostable plastics are shown to fully compost in all UK home composts, it would be wise to assess the environmental impact of these materials, the inks and glues used, before assessing the environmental impact of home compost to properly dispose of biodegradable plastics*". Certification ensures that inks, glues and all other materials used in the construction of a compostable product are tested for conformance to EN 13432 and any additional home compostability standard, both as individual materials, then again as a composite product. Yes, **it is wise to assess the environmental impact of inks and glues, so this is why they are already accommodated within existing harmonised standards and are assessed by certification schemes**.

Conclusions

Defining home composting

Home composting is not an exact science; rather it is an art that requires skill, knowledge, practice and patience. Its aim is to transform organic waste generated by citizens into compost: a material that can be used as a soil improver or component in a growing medium. Home composting can mean different things to different people, but one thing that can be agreed on is that it produces compost. Therefore, **unless compost is produced, the organic materials cannot be described as having been 'home composted'.**

The implicit assumption made by the researchers in the BCE was that participants would continue to manage their home composting bins in their usual way and terminate the experiment at a point when they would harvest and use their compost. It was unclear whether the experimental length chosen by the participants reflected this in practice. **It is unlikely, therefore, that some participants in the Big Compost Experiment actually carried out 'home composting'.** This is supported by photographs on the BCE website gallery showing completed experiments where twigs and leaves were visible (i.e. they had not composted).

Should an experiment assess degradation before compost is produced, then adjectives such as 'partial', 'limited', 'incomplete' or 'interrupted' should have been used.

It thus seems unwise for the authors to have concluded that "*home composting is not an effective or environmentally beneficial waste processing method for biodegradable or compostable packaging in the UK*" given the experimental methods they employed.

The crux of the argument relates to how home composting is defined, understood and carried out in practice; a topic that is worthy of further research and has been the point of debate by CEN/TC 261/SC 4/WG 2 (Degradability and organic recovery of packaging and packaging materials) when developing the standard for home compostability of carrier bags (EN 17427:2022).

As Degli-Innocenti noted, the authors adopted a 'black box' approach to composting, which differed from what most people would expect the term 'home composting' to represent. **The paper would, perhaps, have been better called: ''The Big Citizen Science Experiment: Assessing citizens' interaction with home composting, home compostable products and gardening''**.

Labelling of products

The authors noted how confused participants appeared to be when identifying appropriate plastic products suitable for use in the experiment, as a variety of different products were used, many of which were unsuitable for the purposes of the experiment; an issue that is not by any means unique to the UK (European Commission, 2022). This uncertainty is exacerbated by generic claims of biodegradability on some products. In fact, there is ample evidence that many of the plastics placed by participants in their home composting units should never have been there in the first place - including products clearly made from oxo-degradable plastics that are not suitable for composting. **Certification bodies, manufacturers and suppliers of compostable products could all play a role in improving labelling and raising awareness.**

Standards and certification have a vital role to play in ensuring that products do not cause environmental/ecological harm and that they have an intrinsic level of biodegradability. Conformance to one or more compostability standards does not, however, necessarily indicate that the product would perform in real world conditions in a similar way to laboratory test conditions. Manufacturers need to ensure that their products perform in line with their intended purpose, as well as composting in either home or industrial systems at the end of their life. **A balance therefore needs to be struck between product functionality and biodegradability**; a balance that is sometimes difficult to achieve.

Ultimately, **the success or failure of home composting is largely about managing expectations**. It is an art that requires skill, knowledge, practice and patience: knowing what to do, how to do it and when the compost is ready takes time to learn. The results of the BCE could have been better used to encourage government, local authorities, gardening groups and individuals to promote and carry out home composting, rather than the confusion and adverse media reporting that ensued.

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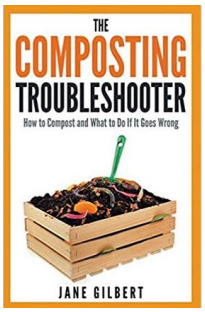
Biography

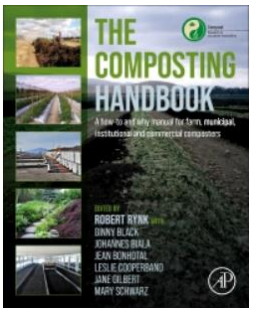
Dr Jane Gilbert trades as Carbon Clarity, providing consultancy, training and writing services. She holds a bachelor's degree in microbiology (BSc Hons, First Class), a doctorate (PhD) in biochemistry and a master's degree in Business Administration (MBA). She is a Fellow of the UK's professional body, the Chartered Institution of Wastes and Resources Management (FCIWM), a chartered environmentalist (CEnv) and is an ISWA International Waste Manager.

Jane has been involved in the organics recycling sector for over twenty-five years. She has experience in bio-waste recycling (composting and anaerobic digestion), standards and certification schemes, recycling organics to soil, compostable/biodegradable packaging, waste management qualifications, health and safety, end-of-life vehicles and clinical waste.

She is the former chief executive of the UK Composting Association, co-founder of the European Compost Network and the current Chair of the International Solid Waste Association's Biological Treatment Working Group.

Over the years, Jane has authored a number of technical publications on composting and the benefits of compost use. She is the author of *The Composting Troubleshooter: How to Compost and What to Do If It Goes Wrong* (2015) ISBN 978-0-9932017-0-7, and a co-editor of *The Composting Handbook* (2022) ISWA 9780323856027.





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Declaration

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