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OPA Comments on Plymouth Study

by Napper & Thompson

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Oxo-biodegradable plastic technology is intended to deal with plastic litter on the surface of land and sea which can lie or float around for decades. It does this by including a catalyst in the polymer which accelerates oxidation, which in turn causes a reduction in molecular weight and renders the material biodegradable, much more quickly than ordinary plastic, and does not leave microplastics to persist in the environment.

The process is described by Professor Ignacy Jakubowicz of the SP Technical Research Institute of Sweden, as follows:

> "The degradation process is not only a fragmentation, but is an entire change of the material from a high molecular weight polymer, to monomeric and oligomeric fragments, and from hydrocarbon molecules to oxygen-containing molecules which can be bioassimilated."

The researchers at Plymouth tested two types of carrier-bag said to have been made from oxo-biodegradable plastic, which they labelled Oxobio1 (bearing Symphony's d_2w logo), and Oxobio2 (bearing the EPI logo). They did not investigate or record the chemical composition of the bags, so it is not known whether they had been correctly made, with the right balance between their prodegradant and anti-oxidant components.

The researchers also tested a compostable bag, a conventional bag, and a bag said to be "bio-renewable" whose chemical composition is unclear.

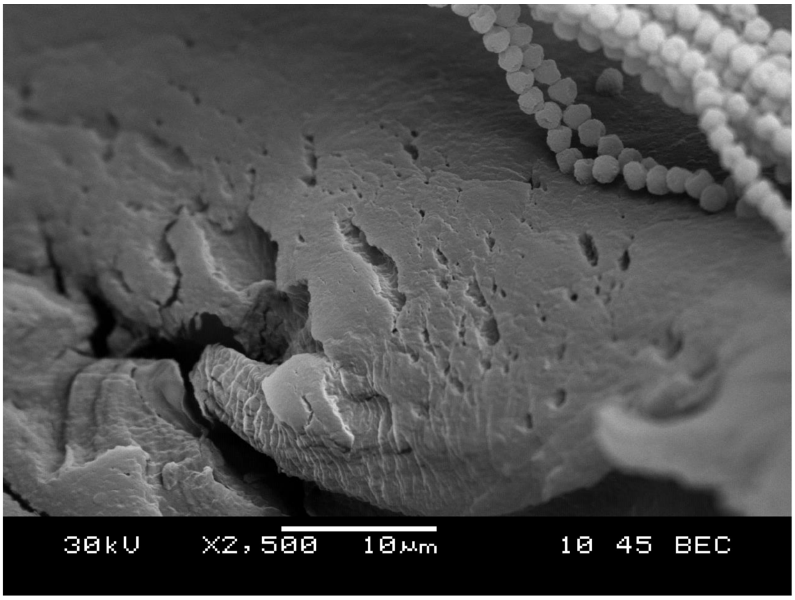
They exposed the bags in the open air in Plymouth UK, and found that Oxobio1 lost strength at a significantly faster rate than the other bags - between 0–9 months ($p = < 0.01$). Indeed they found that Oxobio1 had the greatest loss in tensile stress over 27 months for all environments in which bags were tested. Conventional plastic had the least reduction in tensile stress.

> **Throughout the 27 months of this experiment, Symphony's Oxobio1 was the only bag type to lose tensile stress significantly faster compared to biodegradable, conventional and Oxobio2 bag types.**

This is what we would expect, and in parallel with loss of tensile strength we would expect the molecular-weight of the polymer to have reduced significantly, and the polymer to become substantially biodegradable. However, the researchers, who are marine biologists not polymer scientists, do not seem to be aware of the fundamental principles of polymer degradation as explained in ASTM D6954, which is the industry-standard for testing oxo-biodegradable plastic. They did not therefore measure the molecular weight, which is a crucial indicator of biodegradability. They did however find changes in chemical composition by FT–IR analysis which were indicative of oxidation.

By contrast, researchers at Queen Mary University London https://doi.org/10.1101/719476 did measure the molecular weight of oxo-biodegradable plastic . Their study showed that:

- Molecular-weight reduction is a critical factor in rate and extent of biodegradability
- The use of a prodegradant catalyst caused rapid molecular-weight reduction;
- The degraded polymer was then biodegraded by bacteria commonly found in soil and marine environments
- Oxo-Biodegradable plastic demonstrated up to 90 times more mineralisation than ordinary plastic
- There is similar biodegradation whether the polymer is degraded in the laboratory or under real-life conditions



Bacteria anchored to the plastic and evidence of pitting from biotic degradation of the plastic. The holes in the plastic are roughly the same diameter as a single bacteria (1μM).

The researchers at Plymouth would have known that oxo-biodegradable plastic products are intended to degrade under conditions in which plastic litter is likely to be found in the open environment, namely on the surface of land and sea where there is abundant oxygen and where the process is likely to be accelerated by sunlight and heat.

Nevertheless they also buried the bags in soil, and it is not therefore surprising that they found that degradation proceeded much more slowly. Because the researchers are not polymer scientists they seem to have been unaware that oxo-biodegradable plastic products contain stabilisers which delay the onset of degradation so as to give them a reasonable service life, during which time they can be re-used and recycled.

The stabilisers are rapidly deactivated by sunlight, but the burial in soil at Plymouth did not allow for this mechanism to operate as it would if the bags had been littered. Even buried oxo-biodegradable bags which had first been exposed to sunlight would likely show much more degradation than was observed at Plymouth. If there is no exposure to sunlight at all, the stabilisers will deactive anyway but more slowly.

Similarly, they immersed the bags in seawater at a depth of approx. 1 metre under a pontoon with little or no sunlight, and again it is not surprising that degradation proceeded much more slowly than one would expect if the bags had been littered. It is notable that this was the only one of the Plymouth tests selected by the BBC for a broadcast on 19th July 2018, and which therefore gave a false impression of the experiments.

The polymers in which oxo-biodegradable technology is used have a specific gravity less than 1, so they will float on the surface where oxygen, sunlight, and bacteria are available. Oxygen is ubiquitous, and most of the plastic litter is found lying or floating around with free access to oxygen in the air and in the sea, but it is possible to imagine a piece of plastic in anaerobic conditions where abiotic degradation cannot proceed. However if this is in a landfill it does not matter, because the plastic has already been properly disposed of, and biodegradation in anaerobic conditions is not desirable – because it generates methane.

It is also possible for a piece of oxo-biodegradable plastic to find itself in anaerobic conditions outside a landfill but this would be very unusual and does not invalidate the general proposition. It is for example possible for plastic to be deprived of oxygen by being heavily bio-fouled in the ocean or buried in sediment, but this is unlikely to happen quickly enough to prevent sufficient exposure to sunlight and oxygen for abiotic degradation to occur. If it did, then that small proportion of the global burden of plastic litter would perform in the same way as ordinary plastic – no better and no worse.

CONCLUSION

In order to ascertain whether an oxo-biodegradable plastic bag would perform as intended if it became litter in the open environment, it is not sufficient to take a supermarket bag and make assumptions as to its chemical characteristics, expose it for a number of years, and then examine its physical characteristics. A competent scientist would carry out a properly designed and recorded experiment, which would start with a scientific characterisation of the specimen. He would in particular wish to know whether the molecular weight of the polymer had reduced during the experiment, as he would know that biodegradability depends on reduction of the molecular-weight.

'it is not sufficient to take a supermarket bag and make assumptions as to its characteristics'

The Plymouth researchers failed, before the experiment commenced, to ascertain and record in respect of the chosen specimens:

- whether the polymer film contained a prodegradant additive, and if so, the type and quantity of additive
- whether the film contained one or more anti-oxidants, and if so the type and quantity of anti-oxidants.
- the molecular weight of the film
- the carbonyl optical density of the film

They failed during the experiment

- to expose the polymer film on the surface of the water, with access to oxygen and sunlight.
- To measure the carbonyl optical density – at each time point

They failed at the end of the experiment to measure:

- the molecular weight
- whether the film still contained one or more anti-oxidants, and if so the type and quantity of anti-oxidants.

They failed to use a standard testing protocol appropriate for the material being tested ie ASTM D6954 for oxo-biodegradable material, and to record the data and produce the detailed report required by that protocol.