PLASTIC MICROBIAL ACCLIMATION AND OPTIMISATION OF COMPOSTING AND ANEROBIC DIGESTION PROCESSES MAY IMPROVE DEGRADATION TIMES

C.P.Boardman*, S.Summers**, K, Olsson-Francis***, T. Gladding*

** School of Engineering and Innovation, The Open University, Milton Keynes, MK7 6AA, United Kingdom*
*** School of Engineering and Physical Sciences, Heriot Watt University, Edinburgh, EH14 4AS, United Kingdom*
****School of Environment, Earth and Ecosystem Sciences, The Open University, Milton Keynes, MK7 6AA, United Kingdom*

Plastics are used for a wide range of purposes because they are inexpensive, lightweight, strong, durable and corrosion-resistant. Globally more than 320 million tonnes of plastic is produced each year, with *c*.50 million tonnes of plastics used in Europe within sectors that include; agriculture, electrical and electronic, automotive, building and construction, and packaging [1]. The packaging sector is the largest, representing 40% of the demand in Europe and dominated by the use of fossil fuel derived plastics such as polyethylene, polypropylene and polystyrene. Post-consumer plastics are ideally reused, repurposed or recycled at the end of their intended life, in-line with the waste management hierarchy, however *c*.30% of all plastic waste in Europe still goes into landfill. Disposal of plastic by landfill however is in decline, whilst energy recovery and recycling rates are increasing; a trend that should continue with plastic landfill bans becoming increasingly more prevalent [1].

The growing use of biodegradable and biobased plastic products has the potential to further divert plastics away from landfill. These types of plastics have been developed over the last 40 years to breakdown into their carbon and hydrogen components, and produce water, biomass and gas under prescribed conditions. Materials that can easily degrade and offer the same functionality as traditional plastics could, in theory, mitigate littering in the open environment, boost recycling and energy recovery, and contribute to the circular economy. Biodegradable plastics can be derived from fossil-fuels (e.g. polyvinyl alcohol) and from natural processes (biobased – e.g. polylactic acid), the latter offering an alternative in the future when fossil fuels may be prohibitively expensive to utilise.

Biodegradable and biobased plastics are used in a variety of different sectors, such as agriculture and packaging, and are increasingly being used at the householder level to store and transport food waste to biological waste treatment facilities. Theoretically, biodegradable plastics should be compatible with composting and anaerobic digestion processes, however, scientific research and industrial experience shows that degradation is polymer specific and influenced by operating conditions, such as temperature, treatment time and feedstock material [2-5]. Identifying which products are compatible with biological waste treatment is aided by harmonised international standards (e.g. EN 13432) and certification schemes, however these often do not reflect national composting practices or sufficiently cover the anaerobic digestion sector.

Biological waste treatment facilities currently remove the vast majority of plastic products from their feedstocks using shredders, filters and other specialist equipment. Even if a waste feedstock contained only certified biodegradable plastics, operators may still choose to remove them as they can physically interfere with machinery and/or do not degrade sufficiently within their process treatment time. Incompatible degradation times is compounded by current certification scheme criteria that use 90% loss of carbon within six months as the defining measure of degradation. With revenue often dictated by the volume processed (i.e. gate-fee driven), there are financial pressures to keep treatments times to a minimum, which effectively prevents the mass inclusion of biodegradable plastics into this treatment sector.

In response to the current situation, we explored the idea that a greater understanding of the microbiological processes within composting and anaerobic digestion could lead to an improvement in plastic degradation times. Specifically, the following hypotheses were tested:

- The introduction of ‘environmental’ microbes will decrease plastic degradations times in composting and anaerobic digestion

- Microbial acclimation to plastic presence will increase plastic degradation times in composting and anaerobic digestion

To quantify the level of ultimate biodegradation, microcosm experiments were carried out in optimised aerobic and anaerobic environments, as described in BS EN ISO 14855 and 14853, respectively. Aerobic experiments quantified degradation using infra-red gas analysers to measure respiration (e.g. Figure 1), whereas anaerobic experiments used cumulative biogas production. Polyvinyl alcohol (PVOH), low density polyethylene and certified biodegradable polylactic acid films were tested in our experiments, alongside standards (cellulose) and analytical blanks. Polymerase chain reaction amplification and sequencing was conducted by research and testing laboratory Ltd (Lubbock, Texas, USA) using primers 28f – 388r, amplifying the V1 and V2 hypervariable regions of the 16S rRNA gene. Sequence processing was conducted using the MiSeq SOP (accessed – Sept 2016) cited within the MOTHUR program [6]. Visualization of microbial community dissimilarity was conducted with the none-metric multi-dimensional scaling ordination (NMDS) (e.g. Figure 2). The results of these experiments will be further analysed and presented for the first time at this conference.

Figure 1

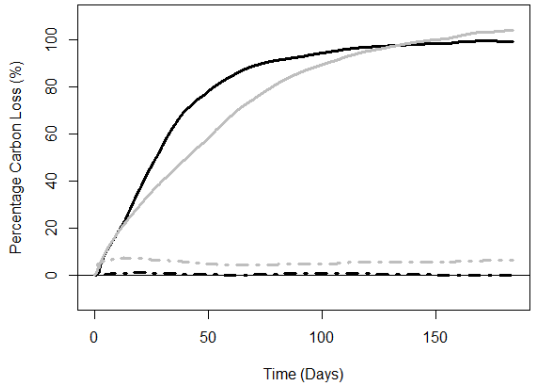

Figure 1. Percentage of estimated carbon dioxide that was evolved from each treatment plastic over a six-month incubation. Any treatment yielding >90% of estimated CO_2 was deemed to be biodegradable. Solid lines indicate Cellulose (black) and PLA (grey) while broken lines indicate PVOH (grey) and PE (black). (*n* = 6).

Figure 2

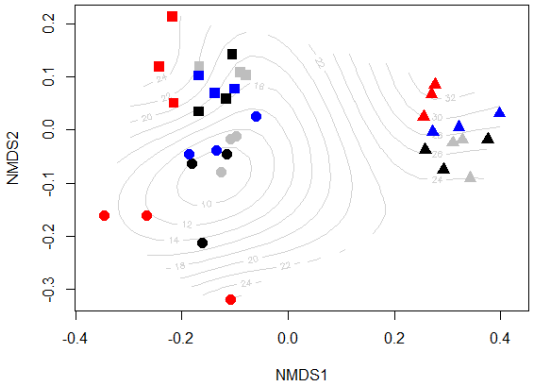

Figure 2. NMDS plot showing the similarity of bacterial communities between both treatments and time points measured. All points were overlaid onto an ordisurf plot of Shannon's diversity index (grey contours). Black symbols = Blanks, Grey symbols = PE, Red symbols = PLA and Blue symbols = PVOH; Circles are week 26, Squares are week 9 and Triangles are week 1. NMDS stress = 0.10

References

1. *Plastics - the facts 2016. An analysis of European plastic production, demand and waste data*. [cited 2017 01/03/17]; Available from: http://www.plasticseurope.org/Document/plastics---the-facts-2016-15787.aspx?FolID=2.
2. Hermann, B.G., et al., *To compost or not to compost: Carbon and energy footprints of biodegradable materials' waste treatment.* Polymer Degradation and Stability, 2011. **96**(6): p. 1159-1171.
3. Fontanella, S., et al., *Comparison of the biodegradability of various polyethylene films containing pro-oxidant additives.* Polymer Degradation and Stability, 2010. **95**(6): p. 1011-1021.
4. Mezzanotte, V., et al., *Influence of inocula on the results of biodegradation tests.* Polymer Degradation and Stability, 2005. **87**(1): p. 51-56.
5. Shah, A.A., et al., *Biological degradation of plastics: A comprehensive review.* Biotechnology Advances, 2008. **26**(3): p. 246-265.
6. Kozich, J.J., et al., *Development of a Dual-Index Sequencing Strategy and Curation Pipeline for Analyzing Amplicon Sequence Data on the MiSeq Illumina Sequencing Platform.* Applied and Environmental Microbiology, 2013. **79**: p. 5112-5120.