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Composting trial with BioFoam® products in a full scale commercial composting facility

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Colophon

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Executive summary

Synbra Technology bv (Etten-Leur, NL) commissioned Wageningen UR Food & Biobased Research (Wageningen, NL) to organise and coordinate a demonstration trial showing the biodegradation/disintegration of BioFoam® in a full scale industrial composting facility.

The main objective of the trial was to be able to judge whether BioFoam® material degrades at sufficient rate to be composted together with regular source separated municipal solid biowaste in a full scale industrial composting facility.

Three different materials were tested in the biological waste treatment facility operated by Attero, located in Venlo:

- BioFoam® substrate foam, (recovered from a horticulture trial, including residual roots),
- BioFoam® insulation slabs, closed foam, sawn in pieces of 10x10x10 cm.
- Loose BioFoam® beads (obtained by shredding insulation slabs).

The following five trials were performed:

1) Test materials were composted (thermophilic, aerobic) for 13 days.
2) Test materials recovered from Trial 1 were composted in a second run (13 days).
3) Test materials recovered from Trial 1 were placed in the compost maturation storage depot and periodically evaluated.
4) Test materials were exposed to a pre-treatment step (mesophilic, anaerobic) for 8 days.
5) Test materials recovered from Trial 4 were composted for 13 days (i.e. representing a customary full cycle).

Substantial polymer degradation (chain scission), complete loss of mechanical properties, and severe disintegration of BioFoam® pieces up to 15 cm were observed in a single composting run of 13 days (i.e. 3 days at 65°C and the remaining composting time at 50-55°C). All three tested BioFoam® materials were completely disintegrated after a second composting cycle. As source separated municipal solid biowaste ('GFT') generally takes several composting cycles to disintegrate sufficiently to pass the 15 mm sieve, it is concluded that BioFoam® disintegrates at least as fast. A mesophilic anaerobic pre-treatment step did not hinder, nor accelerate the degradation and disintegration of BioFoam® products during composting. Furthermore it was found that the degradation of small BioFoam® particles continued during the maturation of the compost, implying that composted BioFoam® particles passing through the 15 mm sieve will not negatively affect the quality of the final compost due to so called visual pollution.

From these trials it is concluded that BioFoam® products biodegrade and disintegrate at sufficient rate to be composted together with source separated solid biowaste in a full scale industrial composting facility.

Content

1 Introduction

BioFoam®, a product produced by Synbra Technology bv (Etten-Leur, NL), is certified according to EN 13432 *"Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging"* implying that has been demonstrated that it fulfils the requirements for compostable products. Laboratory tests performed by OWS (Gent, BE) show that the material biodegrades and disintegrates rapidly under composting conditions. Nevertheless, customers of Synbra Technology have questions regarding the biodegradability of BioFoam® products, in particular with respect to the willingness of composting companies to accept BioFoam® products in their compostable waste.

In order to address these questions, Synbra Technology would like to demonstrate the biodegradability and disintegration of BioFoam® in a full scale trial at a commercially operated industrial composting facility. Synbra Technology commissioned Wageningen UR Food & Biobased Research (Wageningen, NL) to organise and coordinate such a demonstration trial.

The main objective is to be able to judge whether BioFoam® material degrades at sufficient rate to be composted together with regular source separated municipal solid biowaste in a full scale industrial composting facility.

This report describes the activities performed to achieve this objective, summarises the results obtained with the various experiments performed in a selected industrial composting facility, and draws conclusions from the findings.

2 Methods

2.1 Test materials

All test materials were received from Synbra Technology bv (Etten-Leur, NL) on 22 October 2014. The following materials were composted in the demonstration trials:

- BioFoam® substrate foam, (recovered from a horticulture trial, including residual roots), pieces varying in size up to approx. 15x15x15 cm.
  coded: **X**

- BioFoam® insulation slabs, closed foam, sawn in pieces of 10x10x10 cm.
  coded: **Y**

- Loose BioFoam® beads (obtained by shredding insulation slabs).
  coded: **Z**

2.2 Composting facility

The trial was executed at the biological waste treatment facility operated by Attero, location Venlo (James Cookweg 10, Venlo, The Netherlands). The process for biowaste treatment and compost production is schematically presented in Figure 1.

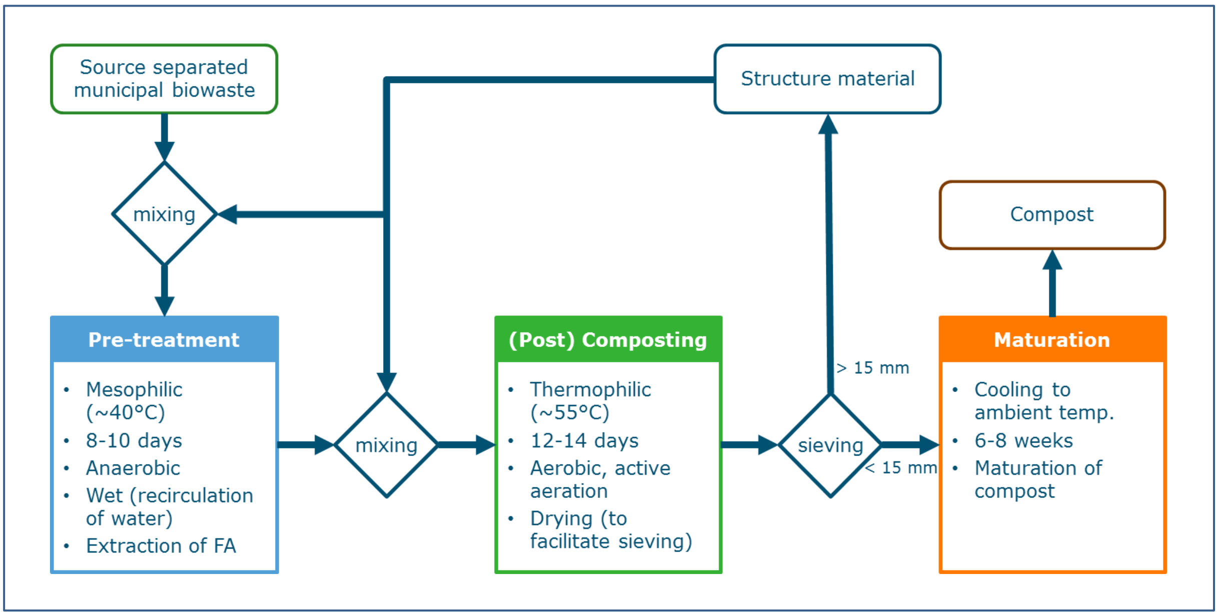


Figure 1 *Schematic presentation of the composting process at the Attero facility - location Venlo.*

This composting facility was chosen because:

- the facility processes annually 90,000 tons of source separated municipal (and analogue) solid biowaste (in the Netherlands so called GFT, i.e. household kitchen/vegetable/fruit and garden waste). The biowaste input is therefore representative for that of other source separated municipal solid biowaste treatment facilities in the Netherlands.
- the facility runs a batch process (in well controlled "tunnels" of 650 m^3, net processing volume about 450 m^3), which is large enough to be representative of commercial composting, and at the same time practical for placing and recovering test samples.
- the regular process comprises an anaerobic hydrolytic pre-treatment step which offers the possibility to separately evaluate the anaerobic degradation behaviour of test materials.
- the staff of the facility has previous experience with composting trials with compostable materials.

2.3 Composting trials

The test materials were mixed with recently delivered source separated municipal solid biowaste (from which large plastic impurities were removed manually) and put in mesh bags (approx. 50 l, mesh 2 mm). Depending on the type of test material, the following amounts were mixed with approx. 25-35 litre of biowaste:

Material X (chunks of substrate foam): 5 pieces, in total 5-8 litre (180-260 gram) per mesh bag.

Material Y (cubes of insulation foam): 5 cubes, in total 5 litre (140 gram) per mesh bag.

Material Z (loose foamed beads): approx. 15 litre (540 gram) per mash bag.

During the customary loading of the composting tunnel, the filled mesh bags were placed at different representative positions amongst the regular biowaste. The tunnels were operated according to the usual practice. The bags were recovered when the tunnels were unloaded at the end of the customary processing time.

The following trials were performed:

Trial 1 Test materials were composted (thermophilic, aerobic) for 13 days.

Trial 2 Test materials recovered from Trial 1 were composted in a second run (13 days).

Trial 3 Test materials recovered from Trial 1 were placed in the compost maturation storage depot and periodically evaluated.

Trial 4 Test materials were exposed to a hydrolytic pre-treatment step (mesophilic, anaerobic) for 8 days.

Trial 5 Test materials recovered from Trial 4 were composted for 14 days (i.e. representing a customary full cycle).

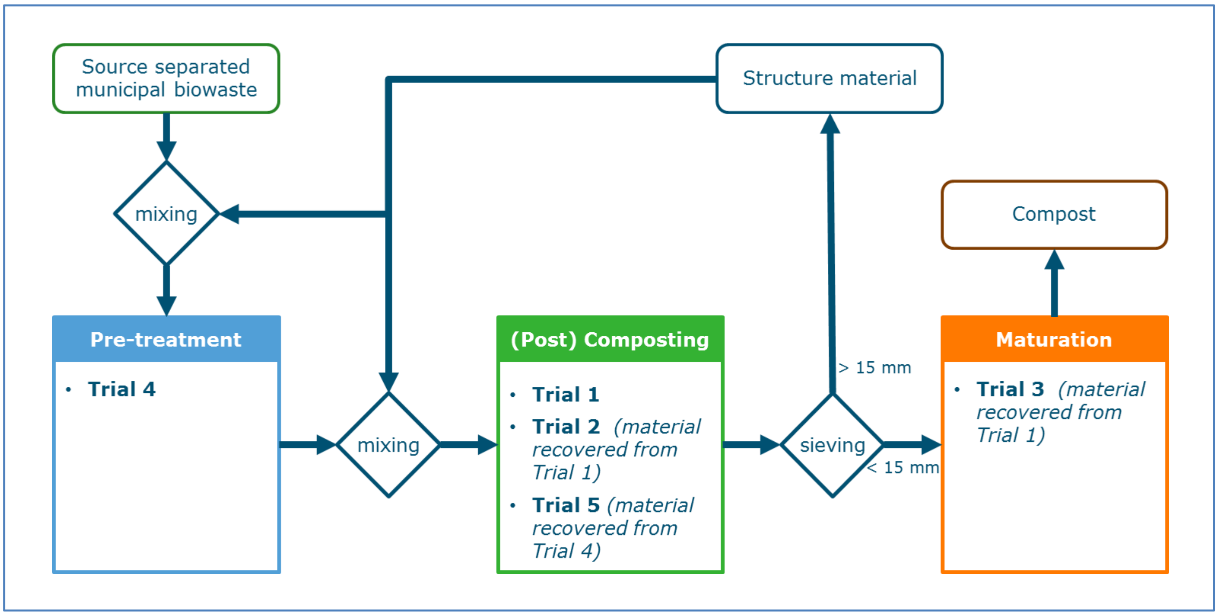


Figure 2 *Schematic presentation of the different composting trials performed at the Attero facility - location Venlo.*

Figure 3
Preparation of the fresh biowaste for mixing with test materials.

Figure 4
Mixing fresh biowaste with 15 l test material Z.

Figure 5
Mesh bag filled with 15 l test material Z and approx. 35 l biowaste.

Figure 6
Loading of a composting tunnel: mixing fresh biowaste with structure material.

Figure 7
Loading of a composting tunnel with the mixed biowaste.

Figure 8
Loading of a composting tunnel: filling it with 450 m^3 of mixed biowaste (length 30 m; width 5 m; height 3 m).

Figure 9
Mesh bags filled with test materials mixed with biowaste (Trial 1).

Figure 10
Placing the mesh bags in the composting tunnel (Trial 1).

Figure 11
Position of the mesh bags in the composting tunnel (Trial 5).

3 Results and discussion

3.1 Trial 1

In the first trial, the three different test materials were placed in a (post) composting tunnel, filled with biowaste that had previously undergone 8 days of anaerobic pre-treatment. The samples were positioned at 3 locations in the tunnel, coded A, B and C at resp. ¼, at ½ and at ¾ of the length of the composting tunnel (i.e. approx. 7 m, 15 m and 22 m in the tunnel). Although no significant differences in temperature and/or aerobic conditions were expected, care was taken to have samples of the three test materials evenly divided over the three positions in the tunnel, as well as evenly distributed over the bottom, middle and top layer of the composting pile, and over the width of the tunnel (see Figure 12).

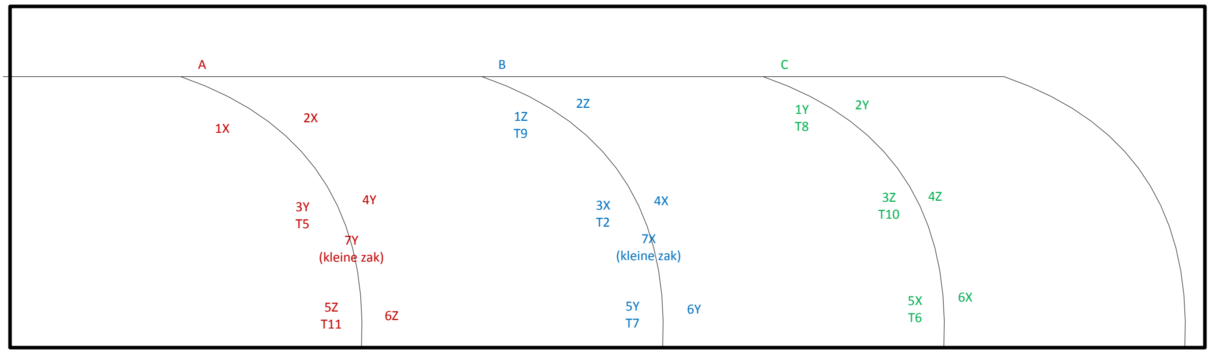


Figure 12 *Distribution of samples of test materials X, Y and Z in the composting tunnel of Trial 1*

The tunnel was operated according to the usual practice, i.e. composting for 13 days with active aeration from below, thus regulating the temperature to be 65°C for 3 consecutive days and 50°C for the remaining composting period. Technical parameters of this trial are presented in Annex 1.

When the content of the tunnel was ready to be sieved, it was carefully unloaded and the mesh bags were recovered. In this first trial, all bags in the locations A and C were recovered, but two bags of location B were lost (i.e. B3X and B4X). Initially, the bags B5Y and B6Y were also lost but they were recovered later from the sieve overflow. All recovered bags were photographed, and emptied individually into a container for closer examination. Annex 2-3 contain a representative selection of pictures of recovered samples.

It was observed that in all bags, the different test materials had been significantly degraded, but some residues of the foamed products were still visible. This was independent of the location in the tunnel, as there were no noticeable differences between samples recovered from locations A, B or C, nor between those from the top, middle or bottom of the pile.

The chunks/blocks of material X and Y had lost their mechanical strength and had partly fallen apart, even though they had been subjected to little mechanical stress in the process. Remaining

BioFoam® lumps easily crumbled apart upon soft rubbing between fingers. The molar mass of the polymer in remaining lumps was determined and proved to be significantly lower than that of the foamed products before the composting trial (e.g. an Mw of approx. 15 kDa whereas the Mw of starting materials X and Y were resp. 66 and 82 kDa). This means that the degradation of mechanical properties of the foamed products during the composting trial is associated with polymer degradation (chain scission).

If the test materials would have followed the regular route in the waste treatment process, it is expected based on the above, that any residual lumps would fully disintegrate in the sieving step due to the substantial mechanical sheer that is applied there. This means that most of the polymer fragments would end up in the <15 mm fraction, and be transported to the depot for final maturation of the compost. This would also be the case for the loose beads (test material Z). The content of the mesh bags with material Z still had a white appearance upon recovery after 13 days of composting. Due to the lack of shear in the mesh bags, and the extreme high concentration (~30 vol%), bead like structures were still visible. However, upon closer examination, these beads pulverised upon the slightest touch. The only concern according to the operator of the composting facility would be whether the white colour of the powder would cause visible contamination in the final compost.

An interesting aspect of test material X is that the pieces still contained plant roots that had penetrated the foam during its application in horticulture. For the recovered samples of test material X, it was observed that these roots were mostly intact after 13 days of composting. Although the foamed product did show disintegration, it can be expected that some of the polymer (kept together by the roots) will not pass through the 15 mm sieve and end up as 'structure material' and as such will re-enter the composting process.

Based on these results, it was decided to perform some additional trials:

- A trial resembling the test material to be looped into a second composting cycle before it goes to the maturation phase.
- A trial to verify whether disintegrated foam material (but still visible as white powder) will degrade further during the maturation of the compost thus limiting the risk of visual contamination of the final compost.
- A trial to investigate whether the anaerobic pre-treatment step (which is normally performed at the Attero facility in Venlo prior to composting) affects the rate and/or degree of degradation of the test materials during the composting cycle.

3.2 Trial 2

This trial was set up to see whether test materials continue to degrade in a second composting run, resembling the situation that it turns up in the fraction > 15 mm (i.e. structure material) and is subsequently looped into a another composting cycle (see also Figure 1).

In real practice, the fraction >15 mm coming out of a composting run is further processed to remove for example stones, metals, and plastic film, before it becomes ‘structure material’. This structure material is then mixed with freshly delivered bio-waste, the ratio depending on many factors, including the composition of the biowaste and the operational management of the plant at the time. In this trial, however, the total content of each mesh bag recovered from Trial 1, was thoroughly hustled, and in its entirety transferred to another mesh bag (without additional fresh biowaste). These mesh bags were then evenly positioned during the loading of the next composting tunnel (see Figure 13).

Figure 13 *Distribution of samples of test materials X, Y and Z recovered from Trial 1 in the composting tunnel of Trial 2*

The tunnel was operated according to the usual practice, i.e. similar to Trial 1 (composting for 13 days with active aeration from below, thus regulating the temperature to be 65°C for 3 consecutive days and 55°C for the remaining composting period). Technical parameters of this trial are presented in Annex 1.

When the content of the tunnel was ready to be sieved, it was carefully unloaded and the mesh bags were recovered. All bags were recovered and emptied individually into a container for closer examination. Annex 2-3 contain a representative selection of pictures of recovered samples.

Generally speaking, no BioFoam® residues could be identified any of the recovered samples. In a few individual cases, a light whitish haze was observed on remaining twigs and leaves. This could possibly be residual pigment particles (titanium oxide) from the BioFoam®, but could just as well be a haze caused by moulds/fungi (as also observed in surrounding composted biowaste).

On this basis it is concluded that, possibly just one, but certainly two composting cycles are sufficient to reach complete disintegration of BioFoam® pieces up to 15 cm in size.

3.3 Trial 3

This trial was set up to verify whether BioFoam® material which had been disintegrated in a composting cycle (but was still visible as white powder) will degrade further during the maturation of the compost.

In real practice, the fraction <15 mm coming out of a composting run is transported via a conveyor belt to a depot where it is stored for 6-8 weeks for the compost to mature (Figure 14). For this trial, however, the total content of selected bags with test material Z recovered from Trial 1, was photographed, thoroughly hustled, and in its entirety transferred to another mesh bag. These mesh bags were then buried (20-50 cm deep) in a pile of freshly produced compost, i.e. most recently sieved (Figure 15).

Figure 14
Storage of freshly produced compost (fraction < 15 mm) for maturation.

Figure 15
Burying mesh bags with test material Z recovered from Trial 1 into freshly produced compost stored for maturation (Trial 3).

The bags were recovered after 2 weeks of storage, photographed and buried again in the same pile of maturing compost. After 4 weeks of storage, the bags were recovered again, and emptied individually into a container for closer examination. Annex 2-3 contain a representative selection of pictures of recovered samples.

After 2 weeks of maturation, there were still white particles visible in the mesh bags. Due to the low moisture level of the content of the bags, these particles fell easily through the 2 mm mesh of the bags when the bags were shaken lightly(together with sand and other small particles). After 4 weeks of maturation, there was still a light haze visible on remaining twigs and leaves. nevertheless, it was not recognisable as polymer anymore, and acceptable according to the operator of the composting plant. When sieved over 2 mm, a greyish powder was obtained. This powder was analysed by GPC but no BioFoam® polymer could be detected.

From the observations described above, it was concluded that the degradation process of BioFoam® particles continues during the maturing of the compost. And that the visible BioFoam® particles ending up in the compost fraction (< 15 mm) after 1 cycle (13 days) of composting, will disappear during the 6-8 weeks that the compost is stored prior to application. Therefore it is concluded that composted BioFoam® particles passing through the 15 mm sieve will not negatively affect the quality of the final compost.

3.4 Trial 4

This trial was set up to investigate whether the anaerobic pre-treatment step (which is normally performed at the Attero facility in Venlo prior to composting) affects the rate and/or degree of degradation of the test materials during the composting cycle. In this trial, the three different test materials were placed on top of the biowaste in a hydrolytic pre-treatment tunnel. This was done to facilitate the recovery of the mesh bags at the end of the pre-treatment step, which is from practical point of view more difficult than after the composting step (due to the higher moisture content of the biowaste matter, and the subsequent clinging). Furthermore, no significant differences in temperature, anaerobic conditions, and/or biological activity were expected throughout the tunnel, because the percolate is continuously recirculated by spraying it onto the top layer of the tunnel content. Samples of the three test materials were evenly divided over two positions in the tunnel (see Figure 16).

The tunnel was operated according to the usual practice, i.e. under anaerobic conditions for 8 days, maintaining the temperature at 36-40°C. Technical parameters of this trial are presented in Annex 1.

Figure 16 *Distribution of samples of test materials X, Y and Z in the anaerobic hydrolytic pre-treatment tunnel of Trial 4.*

When the content of the tunnel was ready to be composted, it was carefully unloaded and the mesh bags were recovered. All bags could be recovered and were examined (without opening them) and photographed. Annex 4 contains a representative selection of pictures of recovered samples. After residing for 8 days in the pre-treatment tunnel, the plant matter in the mesh bags appeared to be more moist, and in a further stage of decay than at the start of the trial. However, the BioFoam® products appeared unchanged after these 8 days, still having their original shape and mechanical properties (evaluated without opening the bags, based on e.g. squeezing by hand). This appeared to be the case for all three types of BioFoam® products. Based on these observations it is concluded that BioFoam® products are not very susceptible for biodegradation under mesophilic anaerobic conditions. Or at least the process is too slow to notice effects within 8 days.

3.5 Trial 5

According to the customary process, the content of the pre-treatment tunnel was unloaded and on the same day transferred to a composting tunnel. The mesh bags recovered from trial 4 were also transferred to the same composting tunnel. Based on the previous observations in trials 1 and 2 that the position in the tunnel did not influence the degradation behaviour, the bags were placed in the top layer only for easy recovery (see Figure 17).

The tunnel was operated according to the usual practice, i.e. similar to the Trials 1 and 2 (composting for 13 days with active aeration from below, thus regulating the temperature to be 65°C for 3 consecutive days and 55°C for the remaining composting period). Technical parameters of this trial are presented in Annex 1.

Figure 9 *Distribution of samples of test materials X, Y and Z in the composting tunnel of Trial 5*

When the content of the tunnel was ready to be sieved, it was carefully unloaded and the mesh bags were recovered. All bags were recovered and emptied individually into a container for closer examination. Annex 4 contains a representative selection of pictures of recovered samples.

The results of trial 5 were very similar to those of trial 1. In general there was a significant weight reduction of the biowaste, but twigs, leaves and larger plant matter could still be distinguished. Furthermore, the different BioFoam® test materials all had been severely degraded, but some residues of the foamed products were still visible. The chunks/cubes of material X and Y had lost their mechanical strength, had fallen apart, and pulverised easily upon soft rubbing between fingers. The molar mass of residual polymer lumps, however, could not be determined as large interfering monomeric peaks overlapped the peaks corresponding to oligomeric material.

Based on these observations, it is concluded that the mesophilic anaerobic pre-treatment step does not hinder nor accelerate the degradation and disintegration of BioFoam® products during composting.

3.6 Overall findings

Considering that:

a) all three tested BioFoam® materials had been severely degraded after a single composting run, and
b) the degradation was independent of the location in the tunnel, and
c) the observed disintegration and degradation of mechanical properties is associated with polymer degradation (chain scission), and
d) source separated municipal solid biowaste ('GFT') generally takes several composting cycles to disintegrate sufficiently to pass the 15 mm sieve, and
e) all three tested BioFoam® materials were fully disintegrated after a second composting cycle, and
f) the degradation of small BioFoam® particles continues during the maturation of the compost, and

g) the visible BioFoam® particles in the fraction < 15 mm had disappeared in 4 weeks in the maturation phase, whereas the usual storage time is 6-8 weeks, and
h) the mesophilic anaerobic pre-treatment step does not hinder (nor accelerate) the degradation and disintegration of BioFoam® products during composting, and
i) BioFoam® products fulfil the requirements of the European Standard EN 13432 and are certified as 'compostable' by an accredited testing laboratory, and,
j) the operator of the biowaste treatment facility of Attero in Venlo, being involved in the trials, is willing to expand trials to full scale,

we find that BioFoam® products are amply degradable to be compatible with the commercially operated composting process in Venlo, and expect that this will be the case for most processes for commercial waste treatment treating source separated municipal solid biowaste[1].

[1] *In this respect it should be mentioned that some composting plants process incoming (waste) material first by pre-sieving in order to take out large materials (typically > 100~250 mm). This is done to reduce the amount of interfering and/or non-organic materials in the input material, but it has as a consequence that coarse compostable materials (> 100~250 mm such as the BioFoam® products described in this report) will not enter the composting process because they are filtered out beforehand.*

4 Conclusions

- A single composting run of 13 days (i.e. 3 days at 65°C and the remaining composting time at 50-55°C) is sufficient to achieve substantial polymer degradation (chain scission), complete loss of mechanical properties, and severe disintegration of BioFoam® pieces up to 15 cm.

- All three tested BioFoam® materials were completely disintegrated after a second composting cycle. As source separated municipal solid biowaste ('GFT') generally takes several composting cycles to disintegrate sufficiently to pass the 15 mm sieve, it is concluded that BioFoam® disintegrates at least as fast.

- A mesophilic anaerobic pre-treatment step does not hinder (nor accelerate) the degradation and disintegration of BioFoam® products during composting.

- As the degradation of small BioFoam® particles continues during the maturation of the compost, it is concluded that composted BioFoam® particles passing through the 15 mm sieve will not negatively affect the quality of the final compost due to, so called, visual pollution.

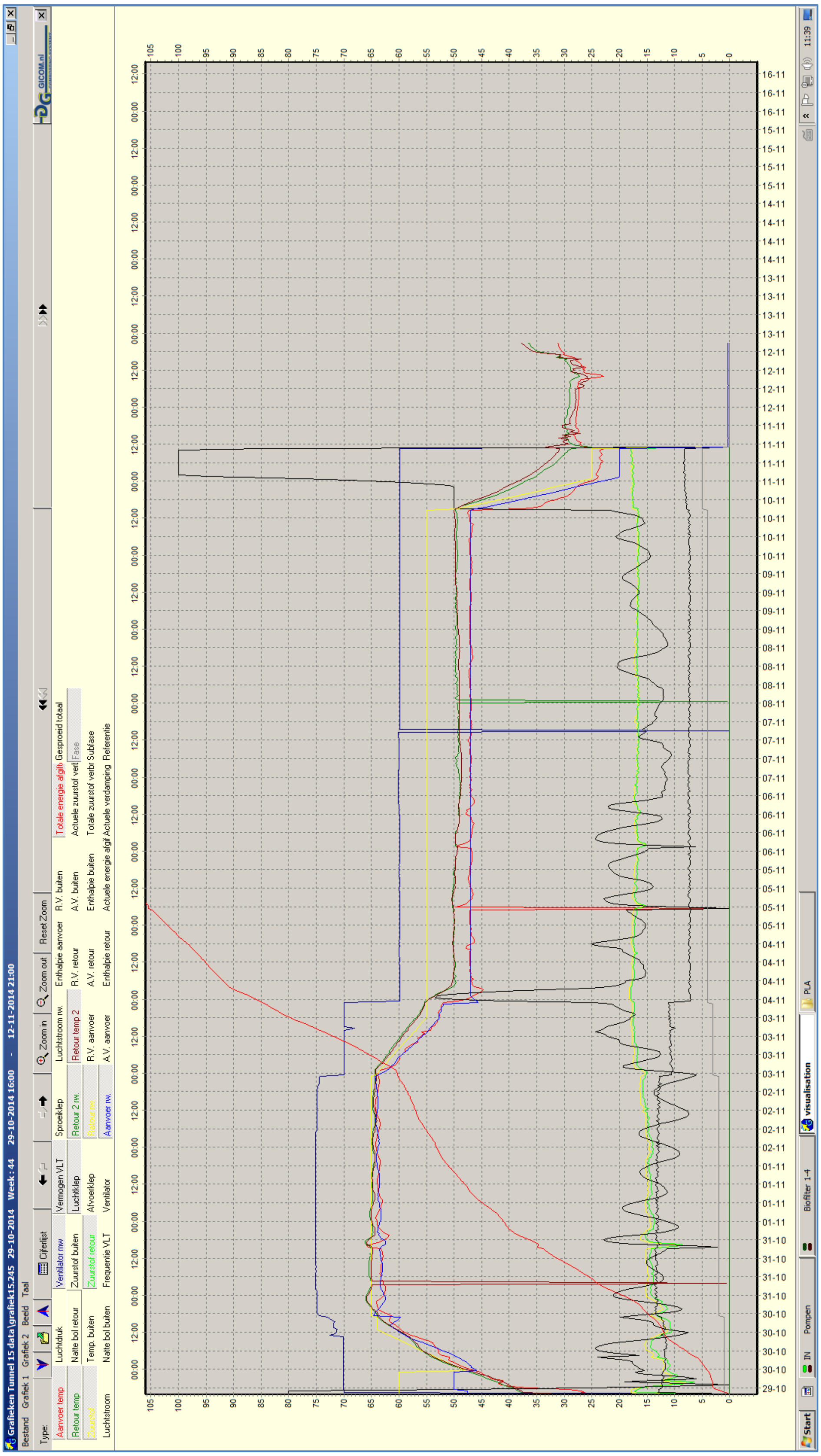
- BioFoam® products biodegrade and disintegrate at sufficient rate to be composted together with source separated solid biowaste in a full scale industrial composting facility.

Acknowledgements

The author greatly acknowledges the full cooperation of Attero and its staff of the composting facility located in Venlo with performing the composting trials. Special thanks go to their conversion technologist Marco Grosze-Holz for sharing his expertise in setting up the trials and his commitment and contribution to the experimental work.

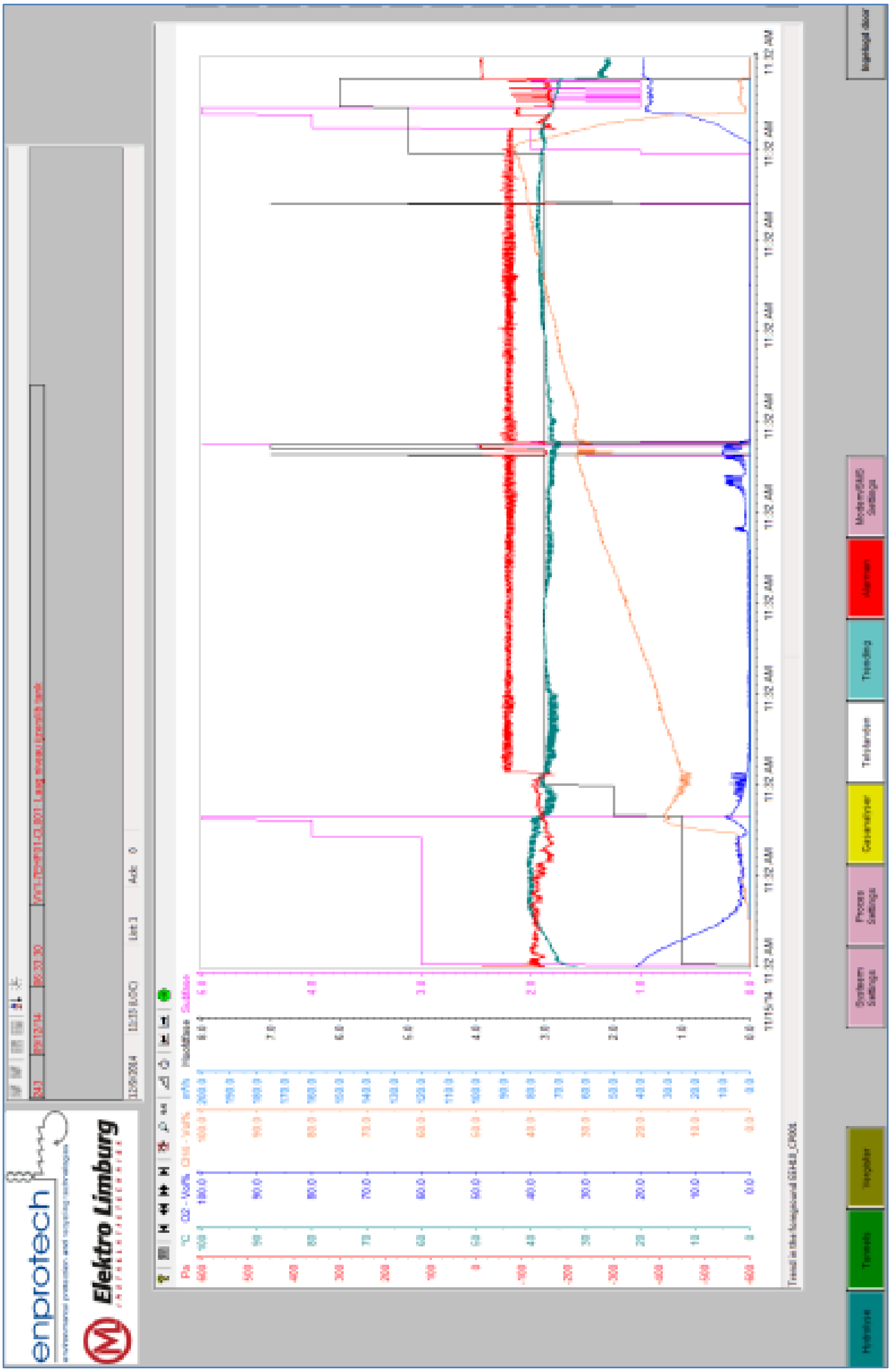
Annex 1 - Technical parameters of composting trials

Trial 1 (Tunnel NC 15) 29 October – 11 November 2014



Trial 2 (Tunnel NC 15) 12 November – 25 November 2014

Trial 4 (Tunnel EEH-10) 15 November – 25 November 2014

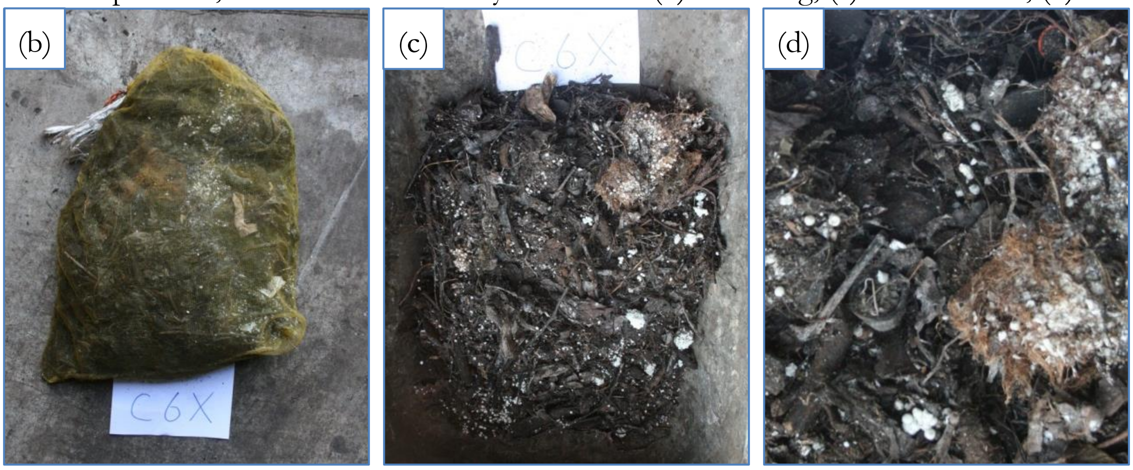


Trial 5 (Tunnel NC 8) 25 November – 9 December 2014

Annex 2 - Pictures of recovered samples [material X, Trial 1 and 2]

Test sample C6**X** at the start of Trial 1: (a) mesh bag.

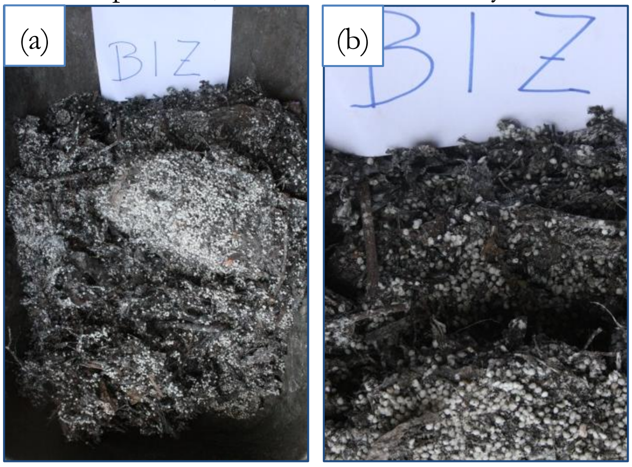
Test sample C6**X**, recovered after 13 days in Trial 1: (b) mesh bag, (c) total content, (d) close up.



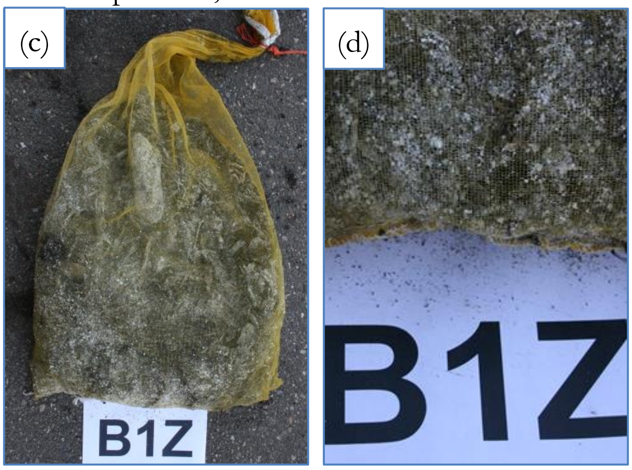
Test sample C6**X**, recovered after another 13 days in Trial 2: (e) total content, (f) close up.

Annex 3 - Pictures of recovered samples [material Z, Trial 1 and 3]

Test sample B1**Z**, recovered after 13 days in Trial 1: (a) total content, (b) close up.



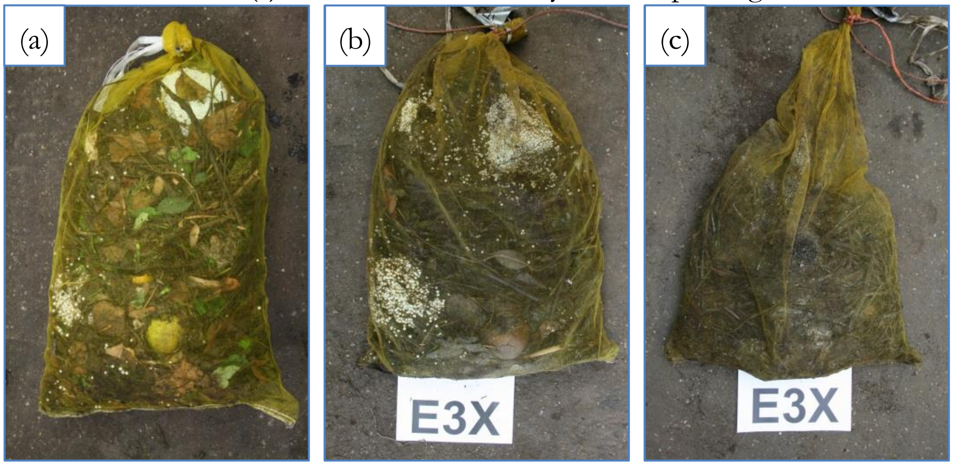
Test sample B1**Z**, recovered after 2 weeks in Trial 3: (c) mesh bag, (d) close up.



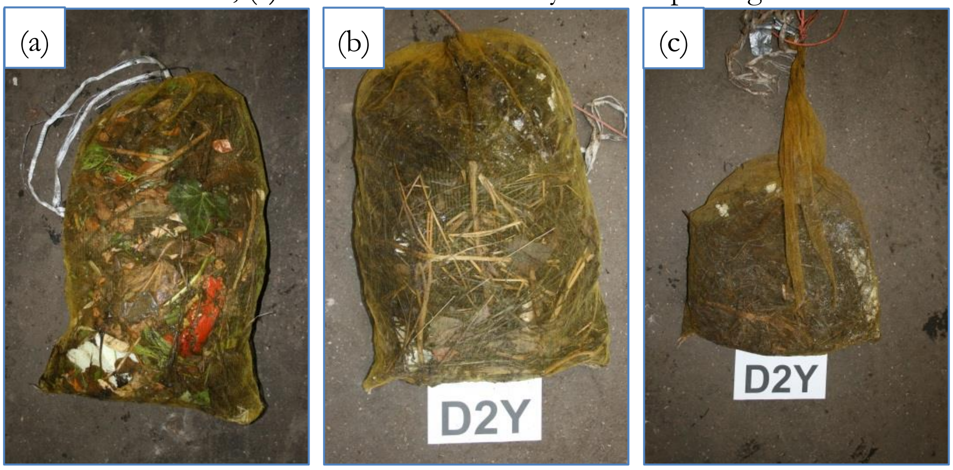
Test sample B1**Z**, recovered after 4 weeks in Trial 3: (e) total content, (f) close up.

Annex 4 - Pictures of recovered samples [Trials 4 and 5]

Test sample E3**X**: (a) at the start of Trial 4, (b) recovered after 8 days of hydrolytic pre-treatment and start of Trial 5, (c) recovered after 13 days of composting in Trial 5.



Test sample D2**Y**: (a) at the start of Trial 4, (b) recovered after 8 days of hydrolytic pre-treatment and start of Trial 5, (c) recovered after 13 days of composting in Trial 5.

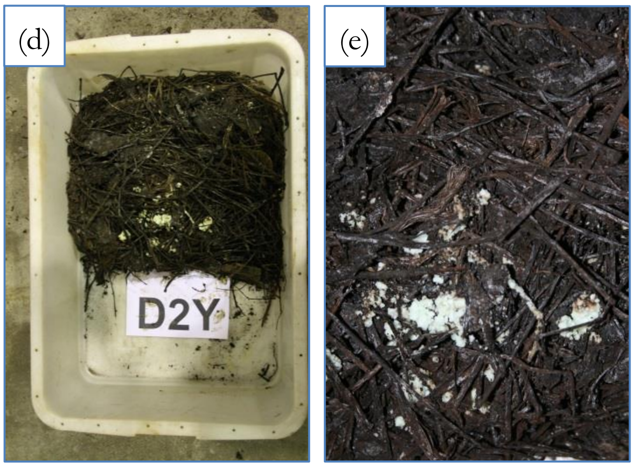


Test sample E2**Z**: (a) at the start of Trial 4, (b) recovered after 8 days of hydrolytic pre-treatment and start of Trial 5, (c) recovered after 13 days of composting in Trial 5.

Annex 4 – continued

Test sample E3**X**: (d) total content of the mesh bag recovered at the end of Trial 5, (e) close up of the content.

Test sample D2**Y**: (d) total content of the mesh bag recovered at the end of Trial 5, (e) close up of the content.



Test sample E2**Z**: (d) total content of the mesh bag recovered at the end of Trial 5, (e) close up of the content.