SHENZHEN HENGCHANGTAI TECHNOLOGY CO., LTD.
ROOM 1209-10, ZHAOFENGXIANG BUSINESS BUILDING, DONGFANG LIYE ROAD, SONGGANG SUBDISTRICT, BAOAN DISTRICT, SHENZHEN

Sample Description	:	BPP (BIODEGRADATION PP)
Material Type	:	PP
Material Composition	:	PP
Style No.	:	JJ2100(+)

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Sample Receiving Date	:	JUN. 01, 2023
Testing Period	:	JUN. 01, 2023 TO JUL. 14, 2023

Test Items	PAS 9017 Requirement	Sample	Conclusion
Polyolefin Product Category	Annex B	PP+BA	/
Carbonyl Index	>1	1.16	PASS
Number Average Molecular Weight (Mn)	<5000 Da	2907	PASS
Higher Weight Average Molecular Weight (Mz)	<30000 Da	21430	PASS
% Loss of Weight Average Molecular Weight (Mw)	>90%	98%	PASS
Seedling Emergence and Seedling Growth Test[1]	OECD 208	-	VALID
Daphnia magna Reproduction Test[1]	OECD 211	-	VALID
Earthworm Reproduction Test[1]	OECD 222	-	VALID
Soil Biodegradation Testing[2]	>90%	99.4%	PASS

Remark:

1. *Results are in accordance with the eco-toxicity requirements of OECD 208, 222, and 211 standards and were carried out at the Research Centre for Toxic Compounds in the Environment (RECETOX) which can be found in the Ecotoxicity Statement provided and in line with the requirements specifies in PAS9017.*
2. *Results are in accordance with the requirements in PAS9017 and were carried out at AIMPLAS in line with ISO 17556, to which the test sample achieved 99.4% biodegradation in 278 days. The data can be found in "AIMPLAS report AST-21-097-06"*
3. *GB/T 22047-2008 is equivalent to ISO 17556-2003 "Plastics--Determination of the ultimate aerobic biodegradability in soil by measuring the oxygen demand in a respirometer or the amount of carbon dioxide evolved", the technical content is exactly the same.*

Signed for and on behalf of
SGS-CSTC Standards Technical Services (Shanghai) Co., Ltd.

Scan to see the report
SHHL2308039050SD-3
Verification:
check.sgsonline.com.cn

Melody Zhang
Authorized Signatory

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Check details as below:

TEST ITEM	REPORT NO.	ISSUED DATE	LAB	STANDARD	RESULT
Soil Biodegradation Testing	AST-21-097-06	07/02/2023	AIMPLAS	ISO 17556	VALID

Testing Procedure:
The parameters followed should be in accordance with the specifications stated in PAS 9017: 2020 accordance with ASTM D2565-16 / BS EN ISO 4892-2.

Test Condition:
Irradiance: (0.35±0.02) W/(m²•nm) @340nm
Light: 8h, black label temperature (73±2)℃, box temperature (60±2)℃, relative humidity (50±5)%
Dark: 16h, box temperature (60±2) ℃, relative humidity (50±5)%
Filter: Daylight-B/B
Total test time of Exposure duration: 672h

Sample Frequency:
The sample frequency has been stated in hours which relate to the elapsed test time of the apparatus. See table below.

At each sample interval, one sample of each material needs to be removed from the apparatus and placed in a bag, analysis is carried out where stated. The bags containing the samples should be labelled with the material ID and time interval removed ready to send to Polymateria.

Frequency (time = hours)	Material
	PP
0	IR & GPC
168	IR
336	IR
504	IR
672	IR & GPC

Sample Analysis:

1.FTIR

A Thermo Nicolet IS10 FTIR, equipped with an Attenuated Total Reflectance (ATR) attachment was used for the infrared analysis of the specimens.

ATR is a sampling technique used in conjunction with infrared spectroscopy which enables samples to be examined directly in the solid or liquid state without further preparation. Specimens were tested without any previous preparation straight after conditioning. The FTIR is annually calibrated, serviced and maintained by Thermo fisher engineers.
In total three specimens per material per conditioning time were tested using FTIR. The FTIR testing parameters used were as follows:

- Wavenumber range: 550 cm^{-1} to 4000 cm^{-1}
- Scanning resolution: 4 cm^{-1}
- Number of scans: 32 scans
- Number of background scans: 32 scans, before every sample.

From the spectra collected in FTIR tests, the carbonyl peaks were identified and the carbonyl index, CI was calculated as follows:

$$CI = \frac{Peak\ area\ of\ the\ carbonyl\ peak\ around\ 1714 cm^{-1}}{Peak\ area\ of\ the\ CH_2\ scissoring\ peak\ around\ 1470 cm^{-1}}$$

When calculating the carbonyl index the following peak regions were used:

- For the carbonyl peak = 1650 cm^{-1} to 1850 cm^{-1}
- For the CH_2 peak = 1420 cm^{-1} to 1500 cm^{-1}

2.GPC

A single solution of each sample was prepared by adding 10 mL of solvent to 20 mg of sample. The sample solutions were heated and shaken at 160°C for 4 hours, or until dissolved. The vials were placed in an autosampler where injection of part of the contents of each vial was carried out automatically. All masses, volumes, times, and temperatures in this section are only approximate.

- Instrument: Agilent Technologies PL GPC220,
- Columns: PLgel Olexis
- µm,Solvent: 1, 2, 4 -trichlorobenzene with anti-oxidant,
- Flow-rate: 1.0 mL/minute (nominal),
- Temperature: 160°C (nominal),
- Detector: refractive index with differential pressure and light scattering.

Data capture and subsequent data handling was carried out using Agilent Technologies 'Cirrus' software.

The GPC system used for this work was calibrated using a series of Agilent/Polymer Laboratories EasiVial PS-H polystyrene calibrants with known molecular weights but a mathematical correction, making use of Mark-Houwink parameters has been applied to express the results as for linear polyethylene or polypropylene homopolymer (the Mark Houwink parameters used are identified in table below).

Mark Houwink Parameters	Polystyrene (calibrants)	PP
Alpha	0.65	0.725
K x 10^{-5} dL/g	19	19

The samples appeared to be completely soluble. There were no apparent problems with either the filtration or the chromatography of any of the solutions.

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Test Result:

1. Average Carbonyl Index (CI)

Sample	Average Carbonyl Index (CI) after Light Ageing Test-UV Exposure				
Exposure time	0h	168h	336h	504h	672h
Sample	0.01	0.60	1.36	1.31	1.16
STDVA	0.01	0.05	0.09	0.18	0.07

Note: Carbonyl Index (CI)= (Area under band 1850-1650 cm^{-1})/(Area under band 1500-1420 cm^{-1})

Appendix – FTIR data

	Run	Sample		
		Area under band 1850-1650 cm^{-1}	Area under band 1500-1420 cm^{-1}	Carbonyl Index (CI)
Original sample	1	0.02	2.01	0.01
	2	0.04	3.81	0.01
	3	0.00	2.25	0.00
	AVERAGE	**0.02**	**2.69**	**0.01**
	STDVA	**0.02**	**0.98**	**0.01**
UV Exposure 168h	1	2.16	3.84	0.56
	2	2.58	3.90	0.66
	3	2.13	3.67	0.58
	AVERAGE	**2.29**	**3.80**	**0.60**
	STDVA	**0.25**	**0.12**	**0.05**
UV Exposure 336h	1	2.10	1.68	1.25
	2	3.41	2.46	1.39
	3	3.72	2.60	1.43
	AVERAGE	**3.08**	**2.25**	**1.36**
	STDVA	**0.86**	**0.50**	**0.09**
UV Exposure 504h	1	4.17	3.06	1.36
	2	4.02	2.75	1.46
	3	2.36	2.13	1.11
	AVERAGE	**3.52**	**2.65**	**1.31**
	STDVA	**1.00**	**0.47**	**0.18**
UV Exposure 672h	1	3.70	3.07	1.21
	2	3.51	2.94	1.19
	3	1.85	1.72	1.08
	AVERAGE	**3.02**	**2.58**	**1.16**
	STDVA	**1.02**	**0.74**	**0.07**

2. Molecular weight analysis

	Mw original	Mw 672h	Mn original	Mn 672h	Mz original	Mz 672h	Mw loss (%)	Mw/Mn(PD) original	Mw/Mn(PD) 672h
Sample	258066	8198	72735	2907	597150	21430	98%	3.5480	2.8201
STDVA	5823	130	7780	155	24106	752	/	/	/

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Appendix – GPC data

Condition	Run	PP
Mw, No conditioning	1	261644
	2	261207
	3	251347
	AVERAGE	**258066**
	STDVA	5823
Mw,672h UV weathering	1	8344
	2	8095
	3	8154
	AVERAGE	**8198**
	STDVA	130
Mn, No conditioning	1	66722
	2	81521
	3	69961
	AVERAGE	**72735**
	STDVA	7780
Mn,672h UV weathering	1	3007
	2	2871
	3	2773
	AVERAGE	**2907**
	STDVA	155
Mz, No Conditioning	1	624380
	2	578537
	3	588533
	AVERAGE	**597150**
	STDVA	24106
Mz,672h UV weathering	1	21086
	2	20912
	3	22292
	AVERAGE	**21430**
	STDVA	752

Note: the GPC test was subcontracted to GZ SPECIAL PRESSURE EQUIPMENT INSPECTION AND RESEARCH INSTITUTS

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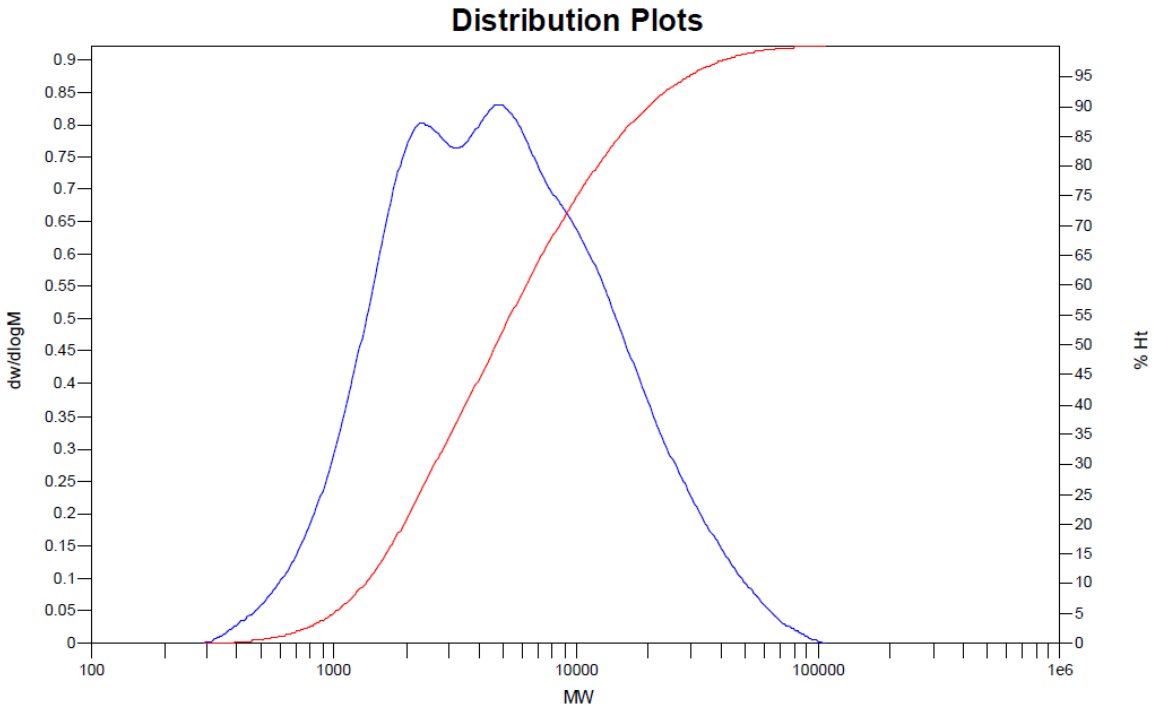
GPC distributions:



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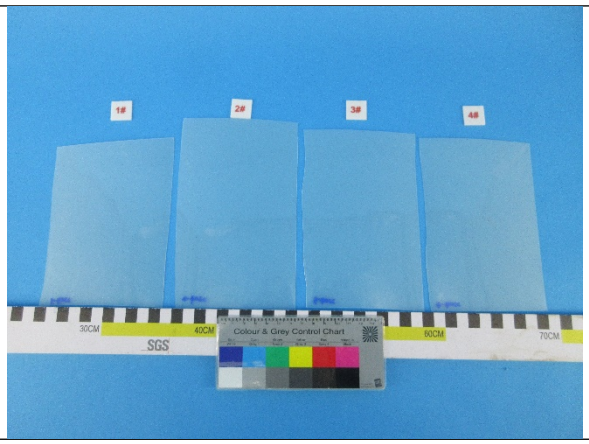
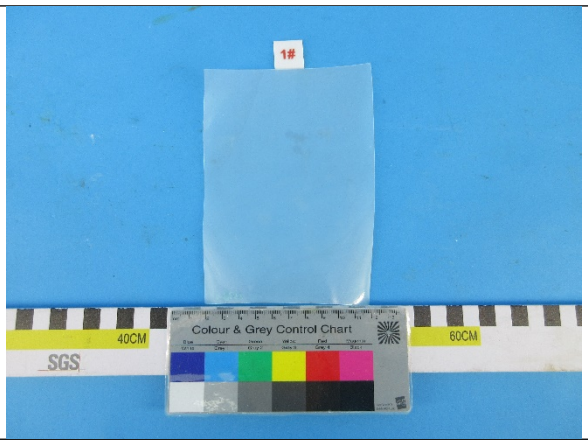
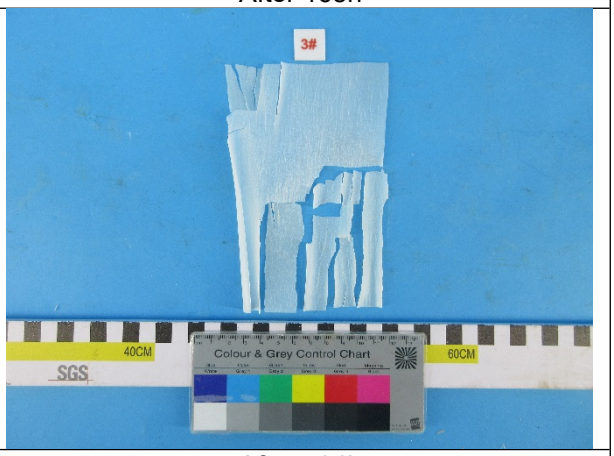
Sample Photo:

	
Before Test	After 168h
	
After 336h	After 504h
	/
After 672h	/

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Research Centre for Toxic Compounds in the Environment

1

Ecotoxicity Statement

This statement confirms that plastic products biotransformed by Polymateria's additive technologies, specified hereunder, have met all ecotoxicity criteria set out by BS PAS 9017:2020 for:

- **Freshwater aquatic and;**
- **Soil invertebrates and;**
- **Plant eco-toxicity**

And can thus be considered safe for contact in these environments.

The testing and reporting were conducted at RECETOX, a third-party laboratory ISO17025: 2005 accredited for chemical trace analysis and conducting the research, development and utilization of environmental eco-toxicity testing.

Persons responsible for the ecotoxicological testing and reporting – Mgr. Jana Vašíčková, Ph.D. & Mgr. Marek Šudoma, Ph.D.

Study dates: 22nd December 2020 - 20th February 2021

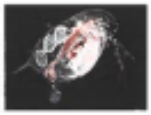
Place of study - Research Centre for Toxic Compound in the Environment (RECETOX), Faculty of Science, Masaryk University, Brno, Czech Republic.

Biotransformed products in study:

Sample ID	Description of the material tested	PAS 9017 Annex B category
Product 8	Plastic bottle (PP) containing Masterbatch formulation No. 1 of Cycle+	Polypropylene (+ BA)
Product 9	Plastic film (PE) containing Masterbatch formulation No. 1 of Cycle+	Polyethylene (+ BA)

Biotransformed products met criteria for:

- Chronic toxicity:

OECD 208	OECD 211	OECD 222
		
Terrestrial plants	*Daphnia* sp.	Earthworm

OECD 208: Terrestrial plant test (*Sinapis alba* and *Hordeum vulgare*): Terrestrial Plant Test: Seedling, Emergence and Seedling Growth Test
OECD 211: *Daphnia magna* Reproduction Test (freshwater aquatic eco-toxicity test).
OECD 222: Earthworm reproduction test (*Eisenia fetida*).

Conclusion: The trial concluded that the biotransformed plastic products (PP and PE) containing Polymateria's technologies (Cycle+) have met the criteria for all ecotoxicity tests required to reach BS PAS 9017 specfication and can thus be considered safe for contact in soil, plant and water environments.

Professor Luděk Bláha
Deputy Director of RECETOX

Signature.....

In Brno, CZ, on date 30th April, 2021

Stamp:

MASARYKOVA UNIVERZITA
Přírodovědecká fakulta
Centrum pro výzkum
toxických látek v prostředí
Kotlářská 2, 611 37 Brno

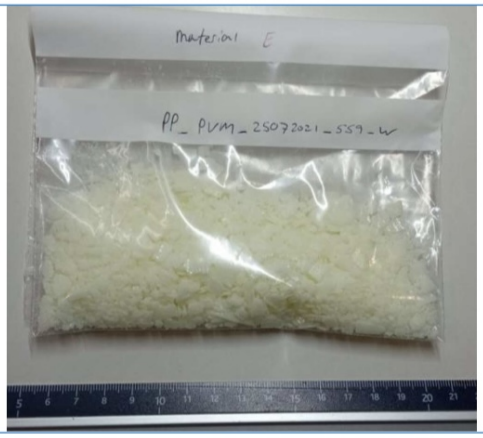
AIMPLAS
INSTITUTO TECNOLÓGICO
DEL PLÁSTICO

ilac-MRA ENAC
ENSAYO
ISO 17025
Nº56 / LE156

** The marked activities are not covered by the ENAC accreditation.*

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023
COMPANY	POLYMATERIA LTD Imperial College i-Hub White City Campus 80 Wood Lane W12OBZ LONDON UNITED KINGDOM
PETITIONER	Florence Huynh
PRODUCT NAME	PP_PVM_25072021_559_W *- Description: Polypropylene sample from a polypropylene product, containing Polymateria Technology at 2% loading rate (wt%), manufactured by* [redacted] *- Code: AST-21-097-06*
TESTS PERFORMED ACCORDING TO STANDARDS OR INTERNAL PROCEDURES	Determination of the ultimate aerobic biodegradability of plastic materials in soil under controlled soil conditions according to the UNE-EN ISO 17556:2019 standard.
RESULTS	According to reports: AST-21-097-6-EN/1

SAMPLE



Customer's reference
PP_PVM_25072021_559_W Polypropylene sample from a polypropylene product, containing Polymateria Technology at 2% loading rate (wt%), manufactured by [redacted]
AIMPLAS code
AST-21-097-06
Description
Yellowish crushed
Reception date
19/01/2022

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TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

Test method

Standard:	Determination of the ultimate aerobic biodegradability of plastic materials in soil under controlled soil conditions according to the UNE-EN ISO 17556:2019 standard.
Method:	The determination of the aerobic biodegradability of the plastic material samples has been carried out under controlled soil conditions. The test method used is based on the method reflected in the UNE-EN ISO 17556:2019 standard and is based on the measurement of carbon dioxide generated by gravimetry. In the present test, the soil used is a standardized soil and the material to be analyzed is tested in a size of 20x20 mm. 2500 mg (dry solids) of sample are mixed with 300 g (dry solids) in each 3-liter capacity reactor and intensively maintained under optimum oxygen conditions, temperature 25 ± 2 ° C and humidity (optimum water content between 40% and 60% of the total water holding capacity) for a test period of six months, extendable to 2 years under specific circumstances. Air was supplied into the vessels to ensure aerobic conditions throughout the test. Furthermore, the test vessels were subjected to stir twice a week in order that the air distribution was homogeneous throughout the vessel. The test vessels were distributed as follows: - Three reactors for the blank (compost). - Three reactors for reference material (cellulose). - Three reactors for each test material. During the aerobic biodegradation of the material, the amount of carbon dioxide generated in each of the reactor is continuously recorded and analyzed by an IR detector and the flow rate is determined by an on-line flowmeter. The percentage of biodegradation is calculated as the ratio of the carbon dioxide generated from the test material to the theoretical maximum amount of carbon dioxide in the test material ($ThCO_2$). The amount of carbon dioxide generated is absorbed in a column and measured at intervals of time by weighing the grams of CO_2 retained using a precision electronic scale. The percentage of biodegradation is calculated by the relationship between the carbon dioxide generated from the test material and the maximum theoretical amount of carbon dioxide ($ThCO_2$) that can be produced from the test material.
Standard:	Determination of Total Nitrogen (Nt)[c]
Method:	- Compost matrix: Internal procedure PI-LTL-6.038. - Plastic matrix: Internal procedures B-N211 and B-N214 according to ASTM D5291

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TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

	Test method D for matrices: Biomass (wood, pruning residues, sludge, manure, residues from the agricultural, wood and paper industries), solid biofuels and for Petroleum Products
Standard:	Determination of Total Organic Carbon (COT)[d]
Method:	- Compost matrix: Internal procedure PI-LTL-6.081 (Oxid. Dichromate) - Plastic matrix: Internal procedures B-N211 and B-N214 according to ASTM D5291 Test method D for matrices: Biomass (wood, pruning residues, sludge, manure, residues from the agricultural, wood and paper industries), solid biofuels and for Petroleum Products

[c] Subcontracted test covered by ENAC accreditation Nº 121/LE1782 in compost matrix.
[d] Subcontracted test covered by accreditation RvA Nº 135 in plastic matrix.

Results

Start date: 03/02/2022
Finish date: 09/11/2022

1) IDENTIFICATION AND CHARACTERIZATION OF PARAMETERS

- **Normalised soil composition**

Table 1

Normalised soil	Theoretical amount (g dry mass/reactor)
Amount of normalized soil/ reactor	200,000
Quartz sand	140,000
Clay	20,000
Natural soil	32,000
Compost	8,000
KH_2PO_4	0,040
$MgSO_4$	0,020
$NaNO_3$	0,024
Urea	0,012
NH_4Cl	0,024

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TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

2) TEST QUANTITIES

QUANTITY OF CARBON DIOXIDE AND CALCULATION OF THE PERCENT OF BIODEGRADABILITY

The following tables and figures show the evolution of CO_2 production and degree of biodegradation of the vessels containing the blank, the reference material and the test sample, respectively.

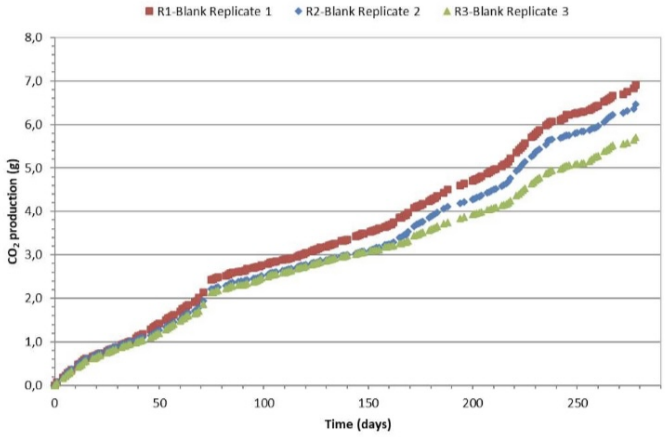

Figure 1. Evolution of CO_2 production (for each replica) of the blank

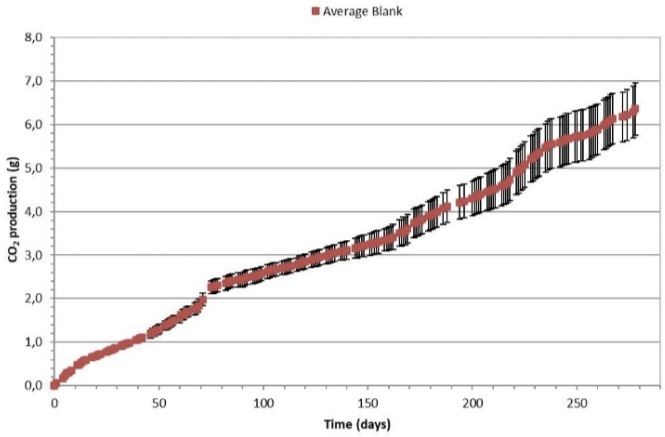

Figure 2. Evolution of CO_2 production (average value) of the blank

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

- **Reference (cellulose) results**

The graphical evolution of CO_2 production and the percentage of biodegradation (for each replica) and the average percentage of biodegradation of the reference material are shown below:

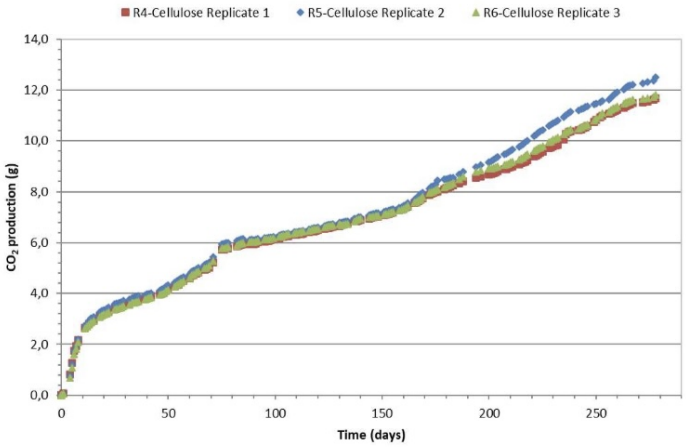

Figure 3. Evolution of CO_2 production (for each replica) of the reference material (cellulose)

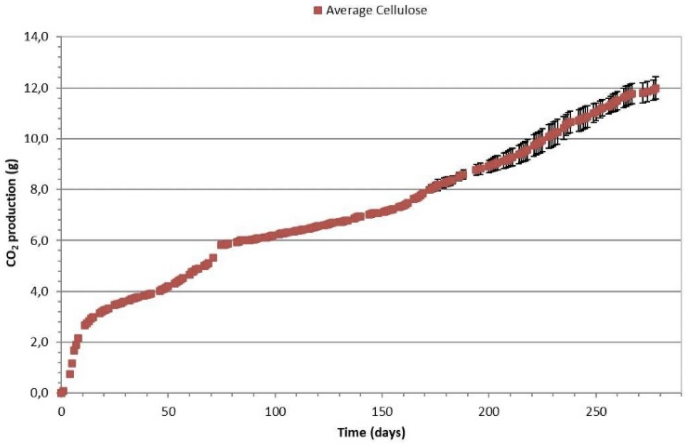

Figure 4. Evolution of CO_2 production (average value) of the reference material (cellulose)

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

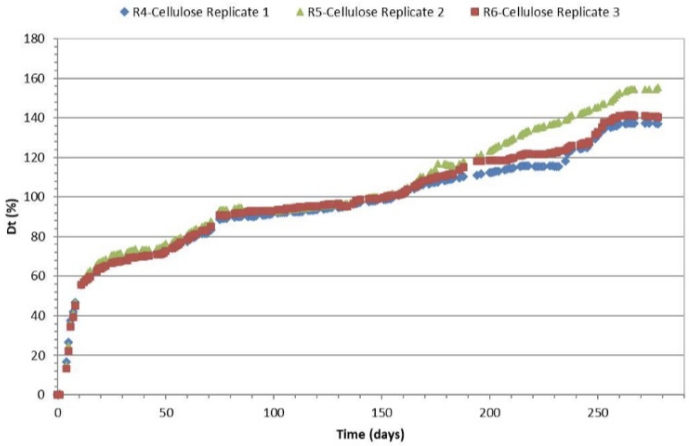

Figure 5. Evolution of the percentage of biodegradation (for each replica) of the reference material (cellulose)

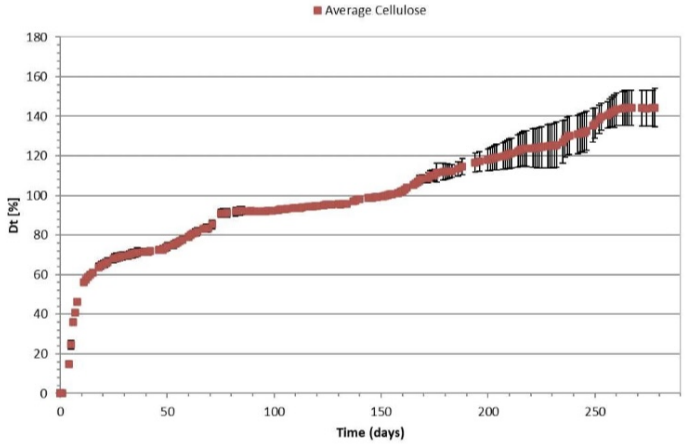

Figure 6. Evolution of the percentage of biodegradation (average value) of the reference material (cellulose)

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

- **Results sample AST-21-097-06**

The graphical evolution of CO_2 production and the percentage of biodegradation (for each replica) and the average percentage of biodegradation of the reference material are shown below:

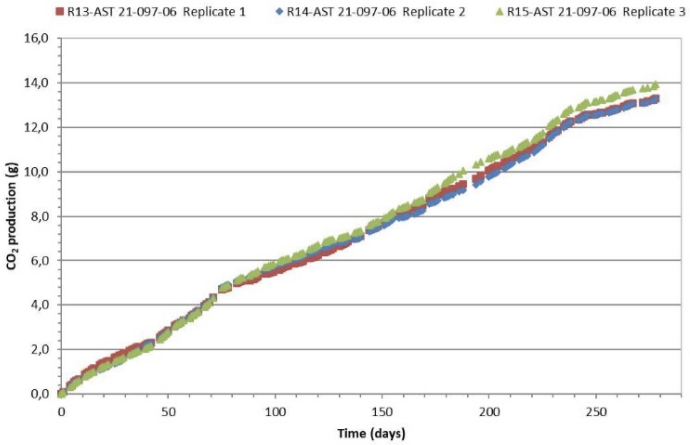

Figure 7. Evolution of CO_2 production (for each replica) of sample AST-21-097-06

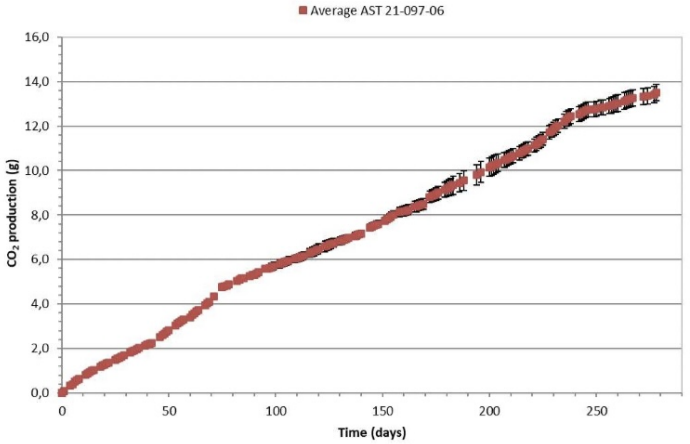

Figure 8. Evolution of CO_2 production (average value) of sample AST-21-097-06

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

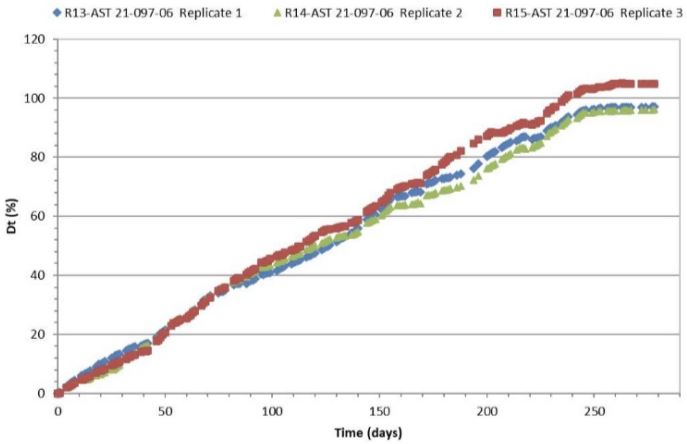

Figure 9. Evolution of the percentage of biodegradation (for each replica) of sample AST-21-097-06

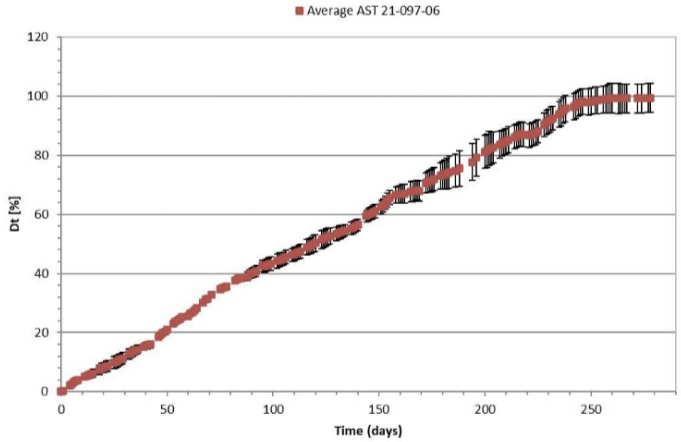

Figure 10. Evolution of the percentage of biodegradation (average value) of sample AST-21-097-06

TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

3) MAINTENANCE OPERATIONS CARRIED OUT DURING THE TEST AND AT THE END OF THE TEST

- **Temperature control during the test**
- **Humidity control and other maintenance operations during the test**

Water is added to each reactor during the stirring process to maintain the total weight of the reactors, and thus, to maintain the optimum humidity in the mixture.

- **pH control**

4) VALIDITY OF THE TEST

In accordance with the UNE-EN ISO 17556:2019 standard, the test is considered valid if the following criteria are met:

(a) The degree of biodegradation of the reference material is greater than 60% in the plateau phase or at the end of the test.

(b) The DBO or carbon dioxide in three blanks are at 20% in the plateau phase or at the end of the test.

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TEST CERTIFICATE	Number: AST-21-097-06 Date of tests: 03/02/2022-09/11/2022 Certificate issue: 07/02/2023

*CONCLUSIONS

Determination of the ultimate aerobic biodegradability of plastic materials in soil under controlled soil conditions according to the UNE-EN ISO 17556:2019 standard.

The percentage of biodegradation average value of the samples after 278 days of testing, is shown in the following table:

Sample	D_{tm} (%) 278 days
AST-21-097-06	99,40
Standard requirement	>90%

To demonstrate that a product is biodegradable under controlled soil conditions according to this standard, 90% biodegradation has to achieved within a minimum of 6 months and a maximum of 24 months.

Electronic signature of the authorized signatories:
NEUS|SORIANO|MARCO
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*** End of Report ***

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