Advancing the evaluation of compostable plastics: fast-track methodologies for biodegradation and disintegration under industrial composting conditions

Framework Conditions – 10th of September 2025

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(3) Prime Biopolymers, Bioplastics company, Spain

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What is AIMPLAS?

A **technology centre** with more than 30 years' experience in the plastic sector.

More than **12,000 m^2** of cutting-edge facilities

Pilot plants (6,500 m^2)

Laboratories (4,500 m^2)

Training (1,000 m^2)

BIODEGRADABILITY & COMPOSTABILITY LABORATORY

28%
Specialist Technicians

43
PhDs

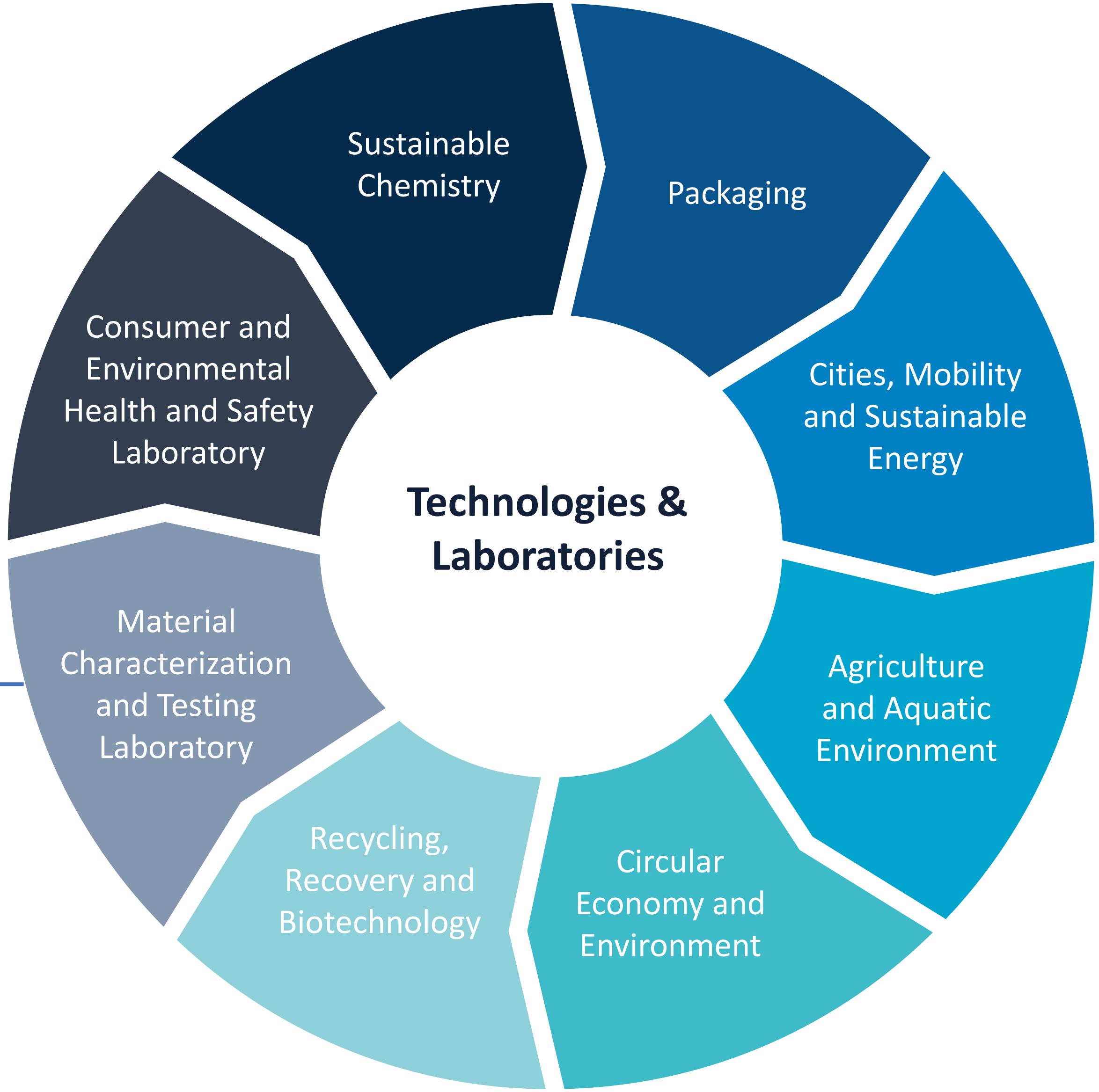
72%
University graduates

37 years
Average age

55% women

44% men

More than **260 professionals**



Biodegradability & Compostability Laboratory

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Biodegradability and Compostability studies:

- Compostability under industrial and home compost conditions (EN 13432).
- Biodegradability under controlled composting conditions (ISO 14855), soil (ISO 17556), aqueous media (ISO 14851 and 14852), and marine water (ASTM D6691 and ISO 22404).
- Disintegration at pilot (ISO 16929) and laboratory scale (ISO 20200).
- Ecotoxicity in higher plants (OECD 208, EN 13432).

❖ We provide technical assistance during the product development and support during the certification process.

Accreditations and Certifications:

✓ Laboratory accredited by ENAC.

✓ Laboratory recognised by TÜV Austria, DIN CERTCO and BPI:

OK Compost INDUSTRIAL

OK Compost HOME

OK Biodegradable SOIL

SEEDLING

✓ Ability to carry out the schemes of ASTM D6400, ISO 17088, ISO 18606, EN 14995 and EN17033.

ENAC Entidad Nacional de Acreditación

TÜV AUSTRIA

DIN CERTCO

BPI

Why bioplastics?

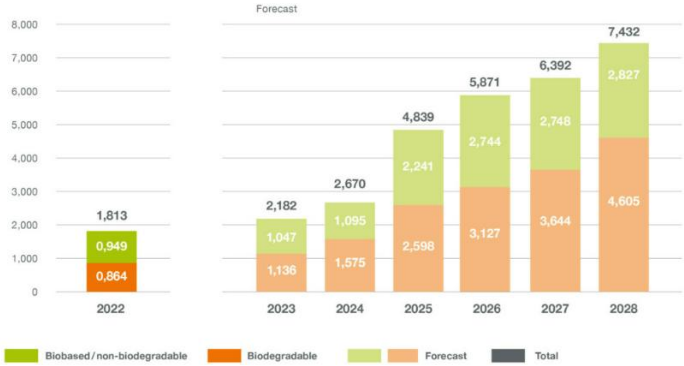
Resource scarcity

Plastic pollution

Environmental awareness

Global production capacities of bioplastics

in 1,000 tonnes



Bioplastic Properties

- Biodegradability
- Nontoxicity
- Sustainability

Key factors for market growth

FoB:Plast by Ceresana Future of Bio Plastics

Industrial compostability

Chemical characterization

Identification of the sample (**FTIR**)
Volatile solids **>50%**
Heavy metals and fluorine content

Biodegradability (ISO 14855)

90% biodegradation after maximum **6 months**

Disintegration quantitative and/or qualitative

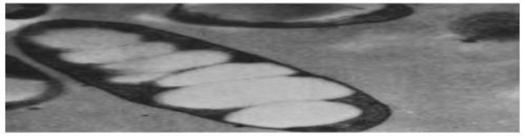
90% after **3 months**

Ecotoxicity

Physical-chemical analysis of the final compost.
90% germination and biomass yield in higher plants.

HOME OK compost TÜV AUSTRIA HOME

HOME COMPOSTABLE DIN Geprüft



Home compostability

Chemical characterization

Identification of the sample (**FTIR**)
Volatile solids **>50%**
Heavy metals and fluorine content

Biodegradability (ISO 14855)

90% biodegradation after maximum **12 months**

Disintegration quantitative and/or qualitative

90% after **6 months**

Ecotoxicity

Physical-chemical analysis of the final compost.
90% germination and biomass yield in higher plants.

BIOFAST

BIOFAST

Biodegradation acceleration and improvement

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Objective: Develop a combined methodological protocol to improve the bioplastics biodegradation in composting

- **WP1**: Development of different bioplastics with different biodegradability in compost

- **WP2**: Enrichment of compost with agricultural waste to promote biodegradability

- **WP3:** Evaluation of physical degradation techniques to promote bioplastic biodegradation in compost

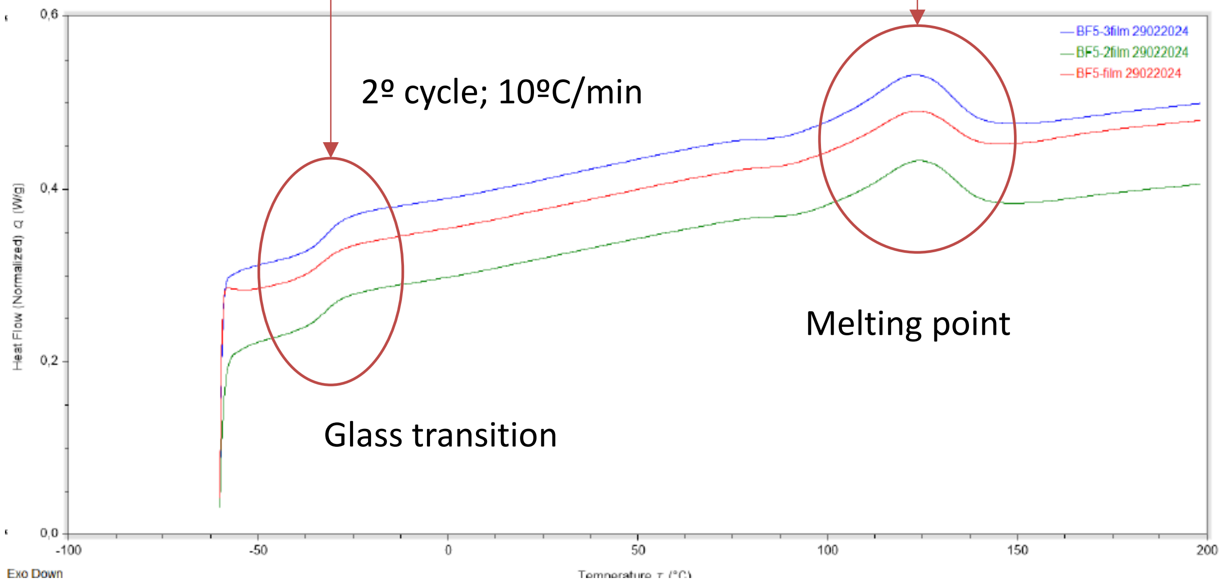
- **WP4**: Development of a combined methodology to promote bioplastic biodegradation in compost

WP1: Development of different bioplastics with different biodegradability in compost

FoB:Plast by Ceresana – Future of Bio Plastics

Polymeric matrix	% Additive	Elastic modulus (Mpa)	Tensión yield (Mpa)	Elongation at break (%)	MFI 190ºC (g/10 min)	Tg (ºC)	Tm (ºC)	Hm ()
PBAT:TPS	37	268	11.5	105	2.64	-34	123	7.7
PBAT:TPS	27	201	9.3	264	3.96	-32	124	8.8
PBAT:TPS	17	158	15.0	360	3.86	-32	122	10.6

Based on starch



FoB:Plast by Ceresana
Future of Bio Plastics

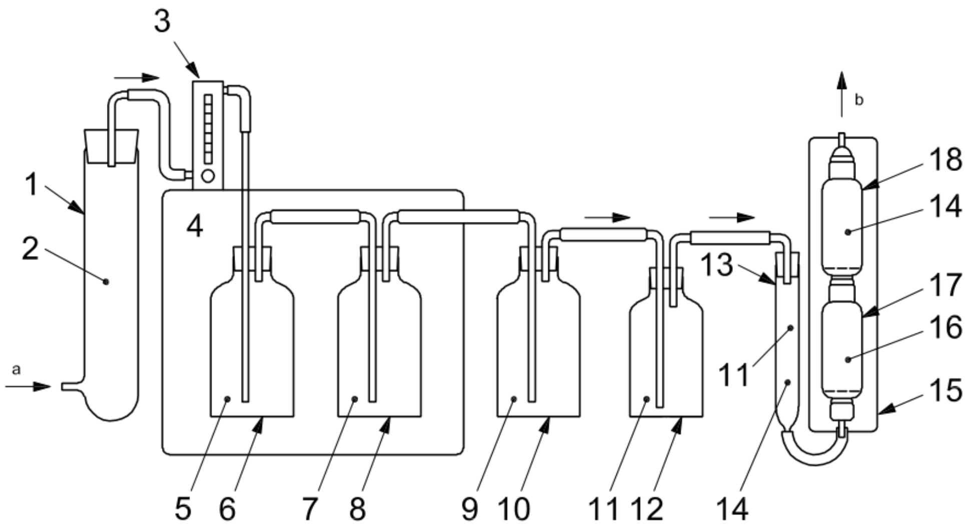
- ISO 14855 "*Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions — Method by analysis of evolved carbon dioxide*"

- The CO_2 produced is measured in test and blank vessels to determine the cumulative CO_2 production.

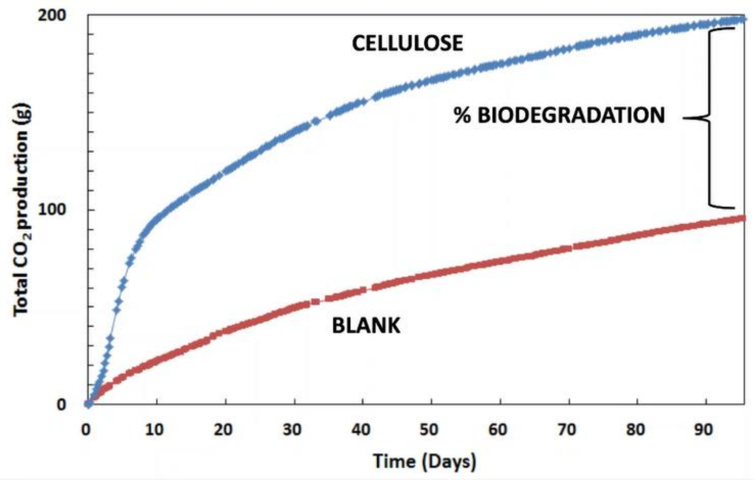
- Percentage of biodegradation (%B)= ratio of the CO_2 produced from the test material to the maximum theoretical amount of CO_2 produced from the test material (obtained from the total organic carbon of the sample.

$$\%Biodegradation = \frac{CO_{2\,Test} - CO_{2\,Blank}}{Th\ CO_2}$$

$$Th\ CO_2 = M_{tot} \times TOC \times \frac{44}{12}$$

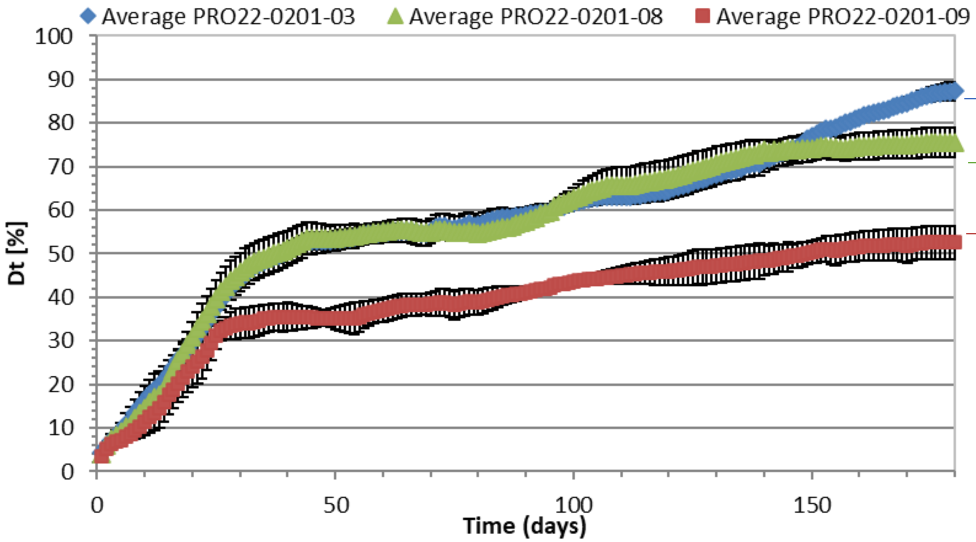


Key
1 carbon dioxide trap
2 soda lime
3 flow meter with controller
4 incubator with thermostat
5 water
6 humidifier
7 mixture of compost, test material and sea sand
8 composting vessel
9 1 M H_2SO_4 containing methyl orange indicator
10 ammonia trap
11 silica gel
12 dehumidifying trap 1
13 dehumidifying trap 2
14 anhydrous calcium chloride
15 trap for evolved carbon dioxide
16 mixture of soda lime and soda talc
17 carbon dioxide absorption column
18 water absorption column
[a] Compressed air in.
[b] Outlet.

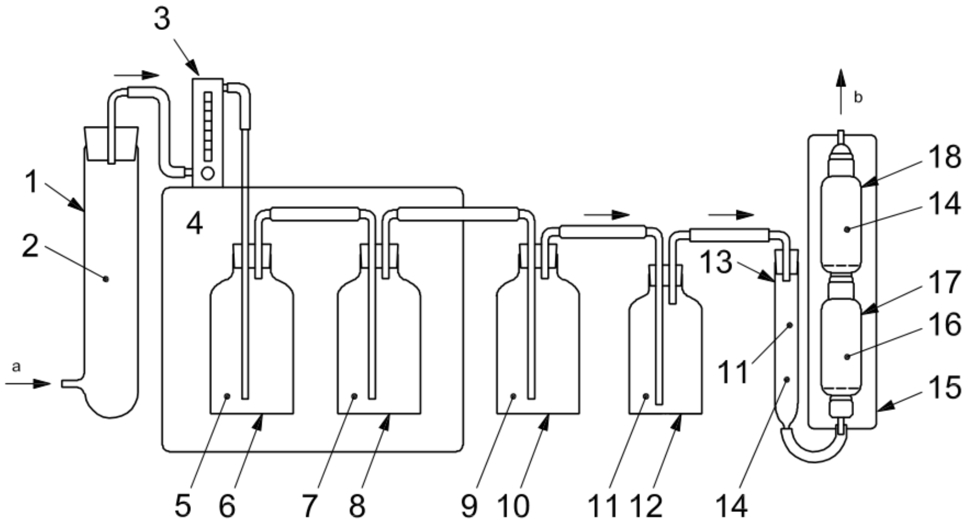


- ISO 14855 "*Determination of the ultimate aerobic biodegradability of plastic materials under controlled composting conditions — Method by analysis of evolved carbon dioxide*"

- Sample reveals a good biodegradability, which increase with the rising of the additive in the matrix



Polymeric matrix	% Additive
PBAT:TPS	37
PBAT:TPS	27
PBAT:TPS	17



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17 carbon dioxide absorption column
18 water absorption column

[a] Compressed air in.

[b] Outlet.

WP2: Enrichment of compost with agricultural waste to promote biodegradability

Rice straw
Coffee powder
Mineral salts

OECD 208 & Annex E of EN 13432: Ecotoxicity in higher plants

- The medium is mixed with the reference substrate at 25% (1: 3) and 50% (1: 1) (m / m).
- 2 plant species: Ray Grass (Lolium perenne) and Pea (Pisum sativum). 100 seeds for each specie.
- Total darkness until the germination process begins. After germination, alternation of light and day.
- Germination rate & Biomass production

WP2: Enrichment of compost with agricultural waste to promote biodegradability

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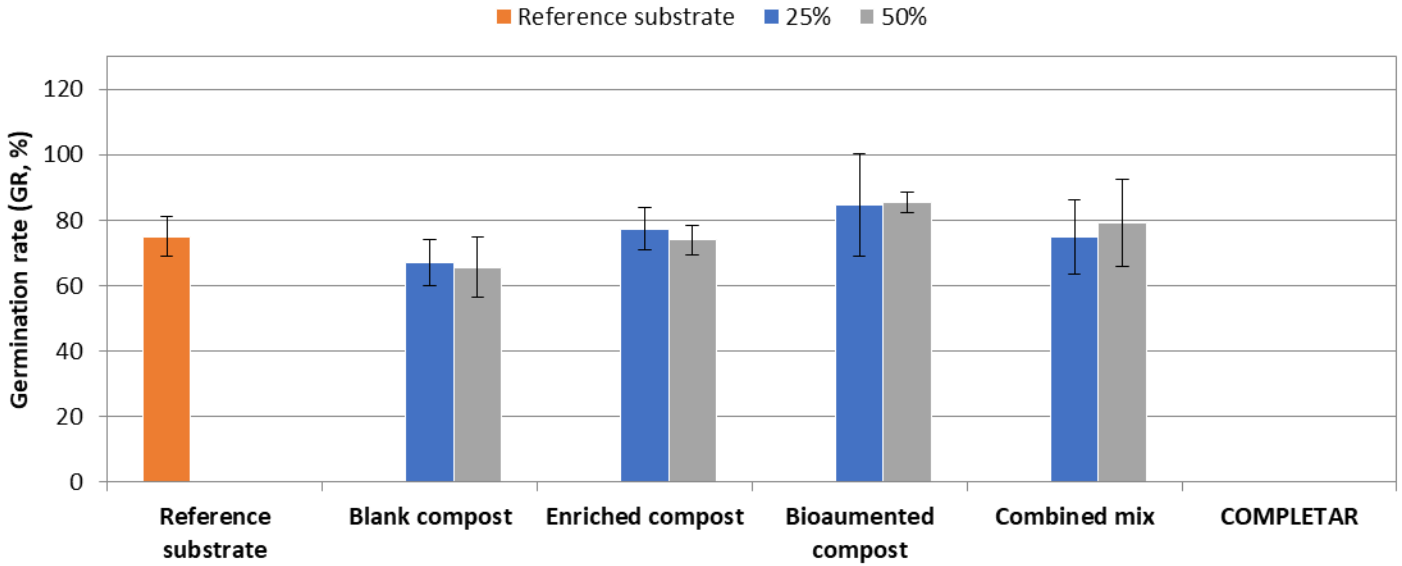
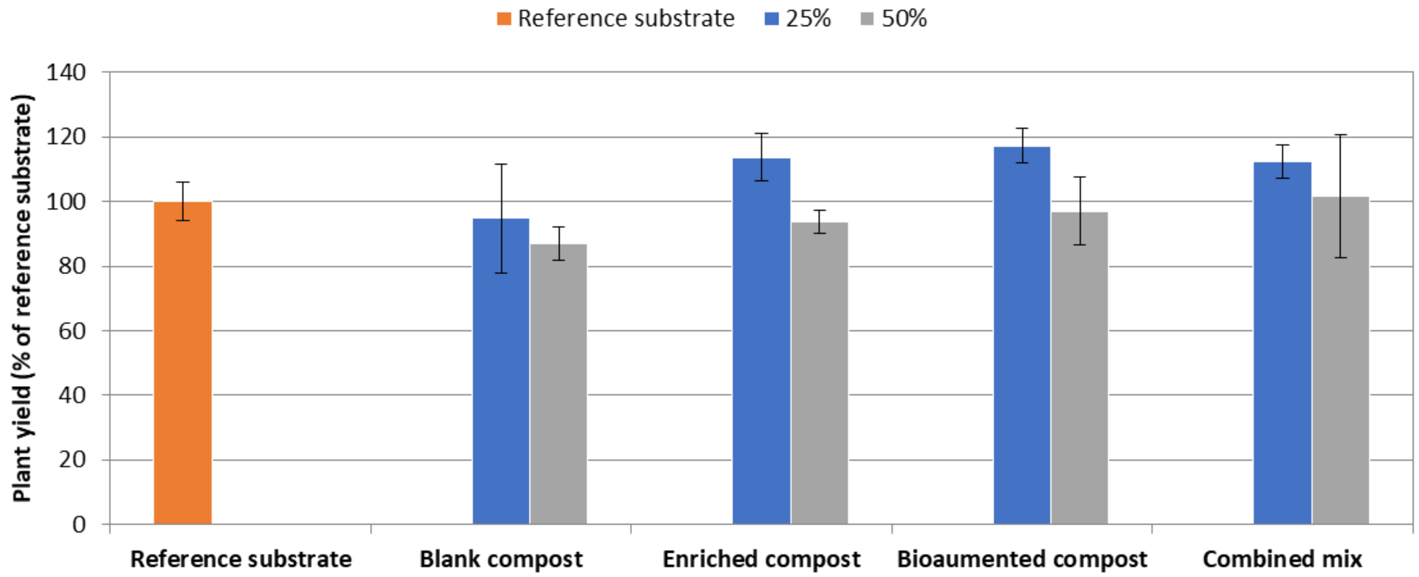
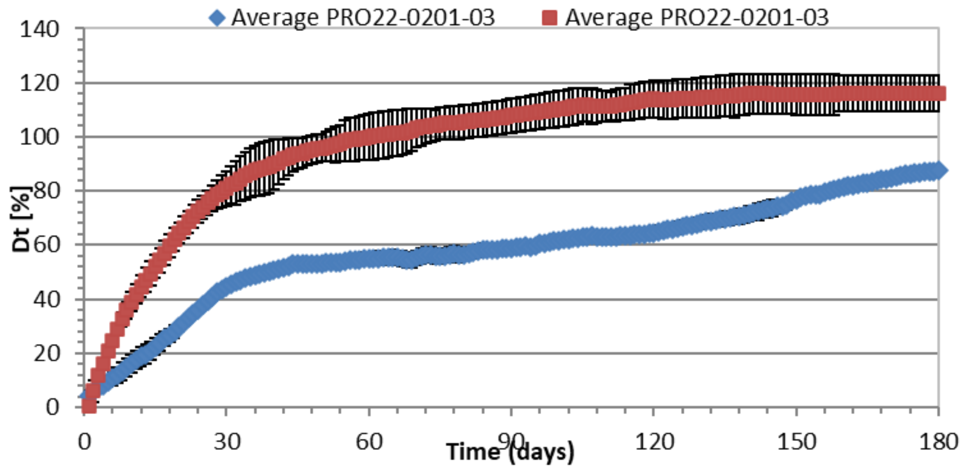




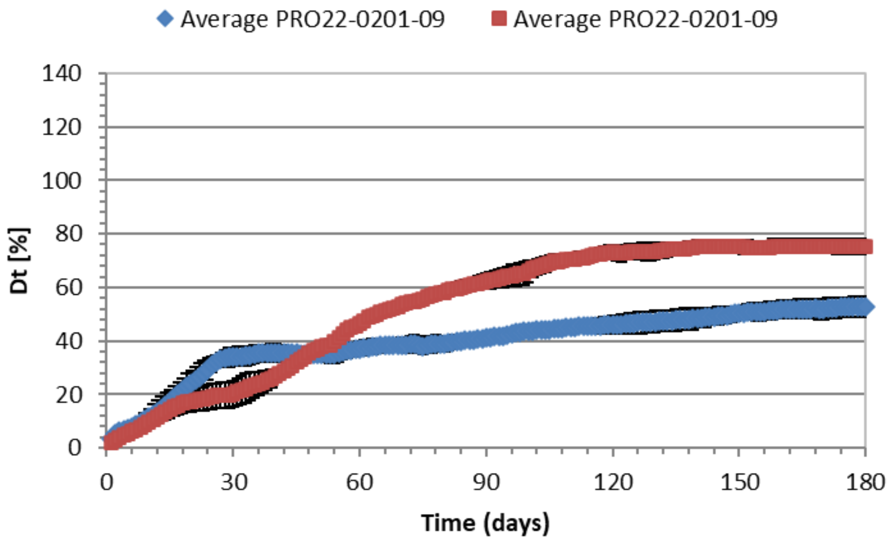
by Ceresana FoB:Plast Future of Bio Plastics

Sample	ISO 14855		Modified medium	
	%B	Std. dev	%B	Std. dev
Cellulose	91.6	3.9	104.9	4.9
PBAT:TPS + additive 37%	87.4	2.1	116.0	6.7
PBAT:TPS + additive 27%	75.5	3,4	81.0	9.9
PBAT:TPS + additive 17%	52.6	3,8	75.3	2.8

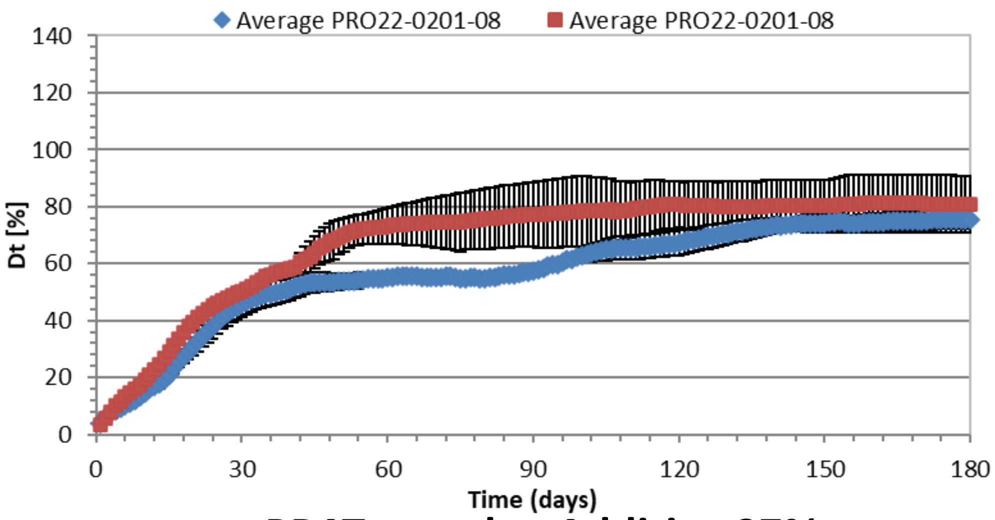
PBAT: starch + Additive 37%



- Significant improvement in biodegradation (after day 45)
- Not clearly detected in sample with 27% additive



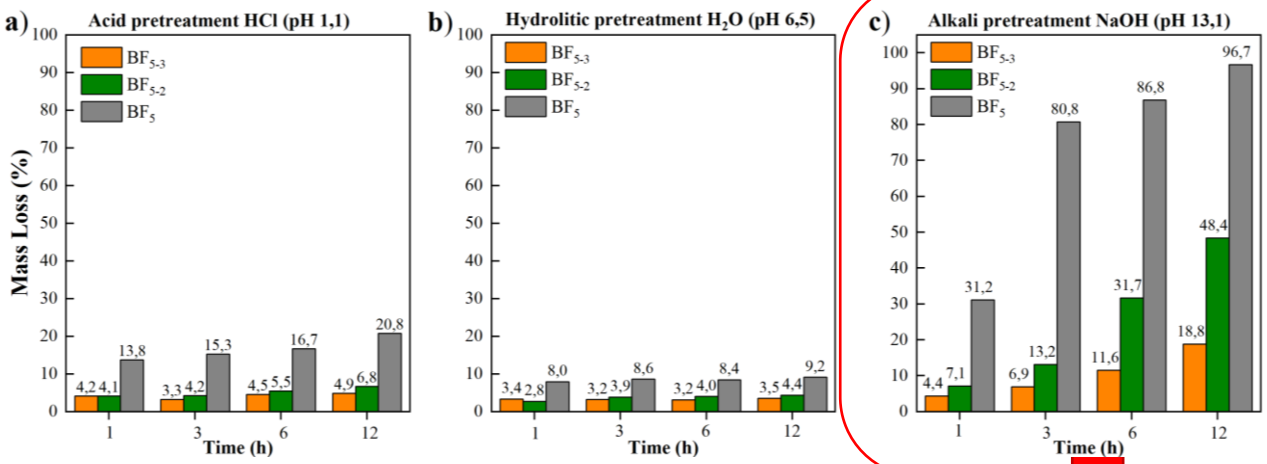
PBAT:starch + Additive 17%



PBAT :starch + Additive 27%

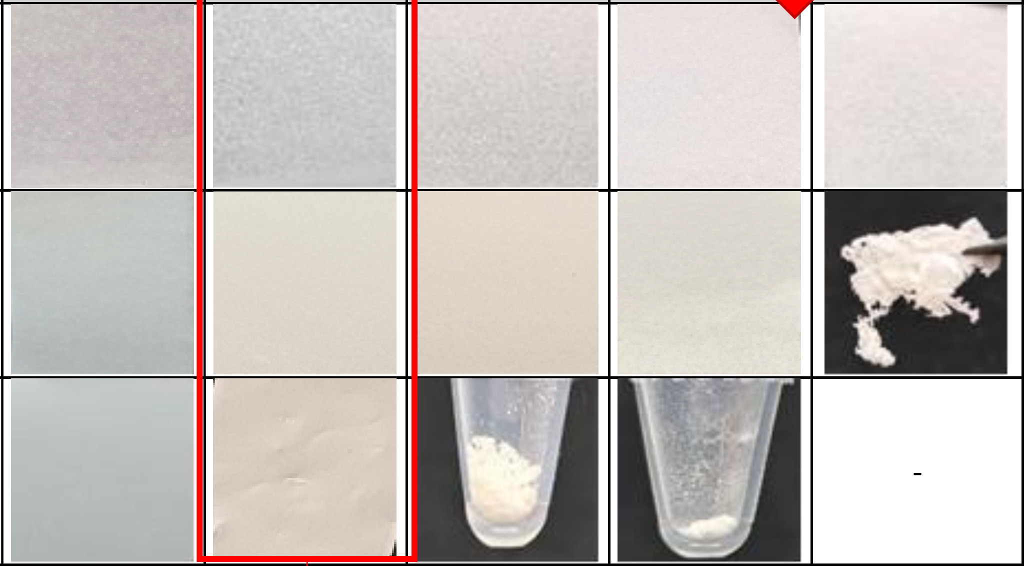
WP3: Evaluation of physical degradation techniques to promote biodegradation

Pretreatment	Factor	Levels
UV irradiation	UV irradiation type	1
	Time	4
	Humidity	2
	Distance from the source	2
Plasma treatment	Power	1
	Time	4
	Humidity	2
Corona treatment	Power	1
	Time	4
Hidro/chemical-thermal	Temperature	1
	Time	6
	Degradation media	3
	Sonification frequency	1



Samples	Thermal stability: Degradation temperature (°C)		Residue (%)	
	Start	Degraded	Start	Degraded
PBAT:TPS + Additive 37%	300	295	3,8	7,2
PBAT:TPS + Additive 27%	293	285	4	8,1
PBAT:TPS + Additive 17%	300	320	3,8	10

Hidro/chemical-thermal (NaOH 1 M; 58±2ºC)					
t (h)	0	1	3	12	24
PBAT/TPS+ Additive 17%					
PBAT/TPS+ Additive 27%					
PBAT/TPS+ Additive 37%					-



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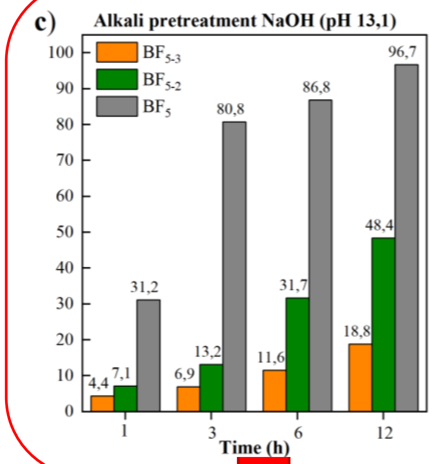
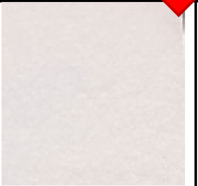
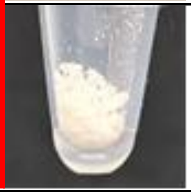
- Alkali treatment had a significant degradation in all sample: the degradability of the samples was coherent with their biodegradability;
- The pretreatments induced the lixiviation of TPS of the matrix, reducing the degradation temperature;
- This effect was not visible in sample with less additive due to the higher amount of PBAT in the matrix.



Hidro/chemical-thermal (NaOH 1 M; 58±2ºC)					
t (h)	**0**	**1**	**3**	**12**	**24**
PBAT/TPS+ Additive 17%					
PBAT/TPS+ Additive 27%					
PBAT/TPS+ Additive 37%					-

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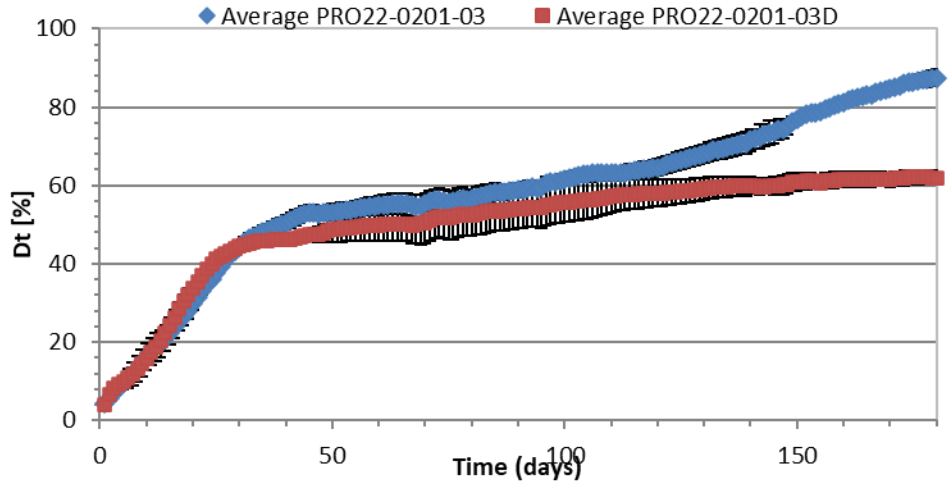
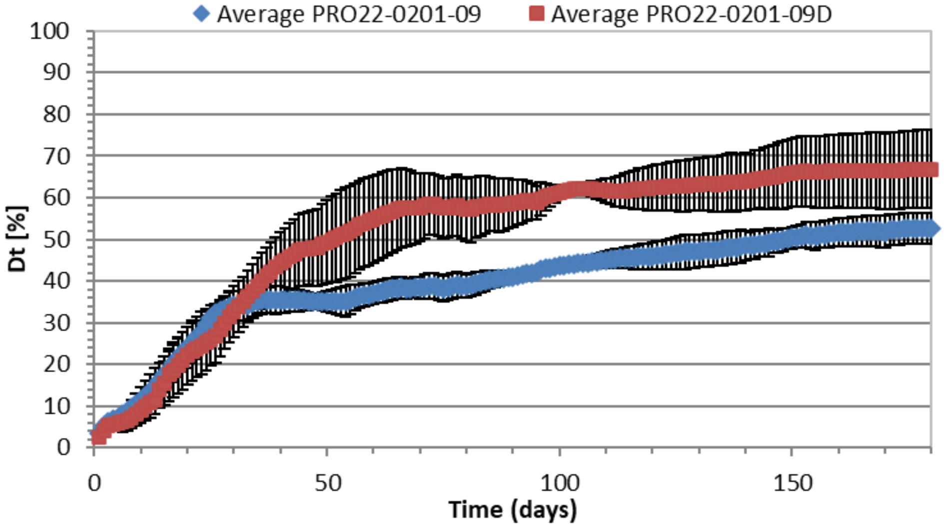
PBAT:TPS + Additive 17%	300	320	3,8	10

Sample	ISO 14855		Pretreatment	
	%B	Std. dev	%B	Std. dev
Cellulose	91.6	3.9	104.9	4.9
PBAT:TPS + additive 37%	87.4	2.1	62.0	1.8
PBAT:TPS + additive 27%	75.5	3,4	68.6	8.1
PBAT:TPS + additive 17%	52.6	3,8	66.8	9.4

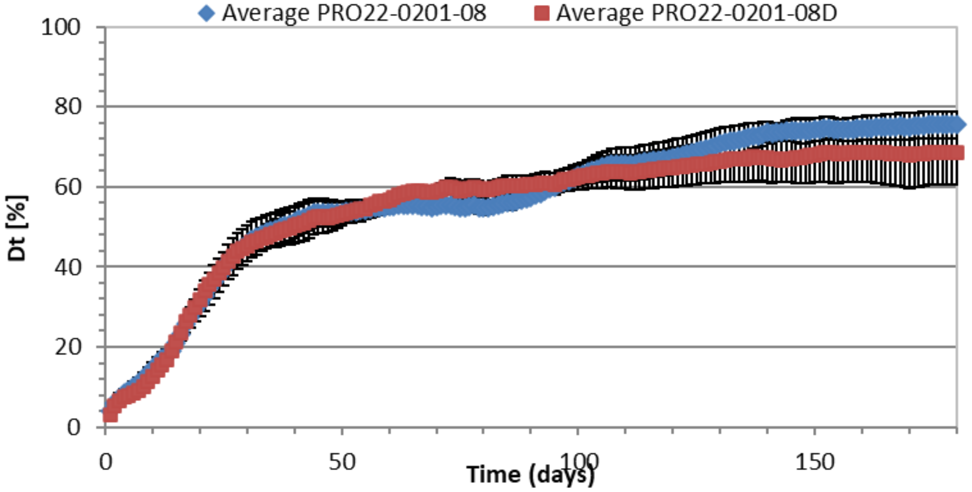
PBAT: starch + Additive 37%



- Pretreatment ineffective on the sample under investigation
- Lixiviation of TPS reduced the amount of more biodegradable polymer in the matrix



PBAT: starch + Additive 17%



PBAT: starch + Additive 27%

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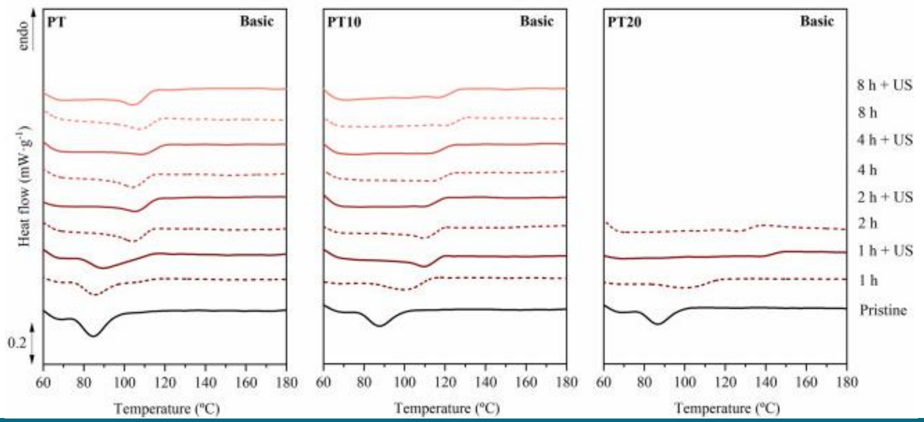
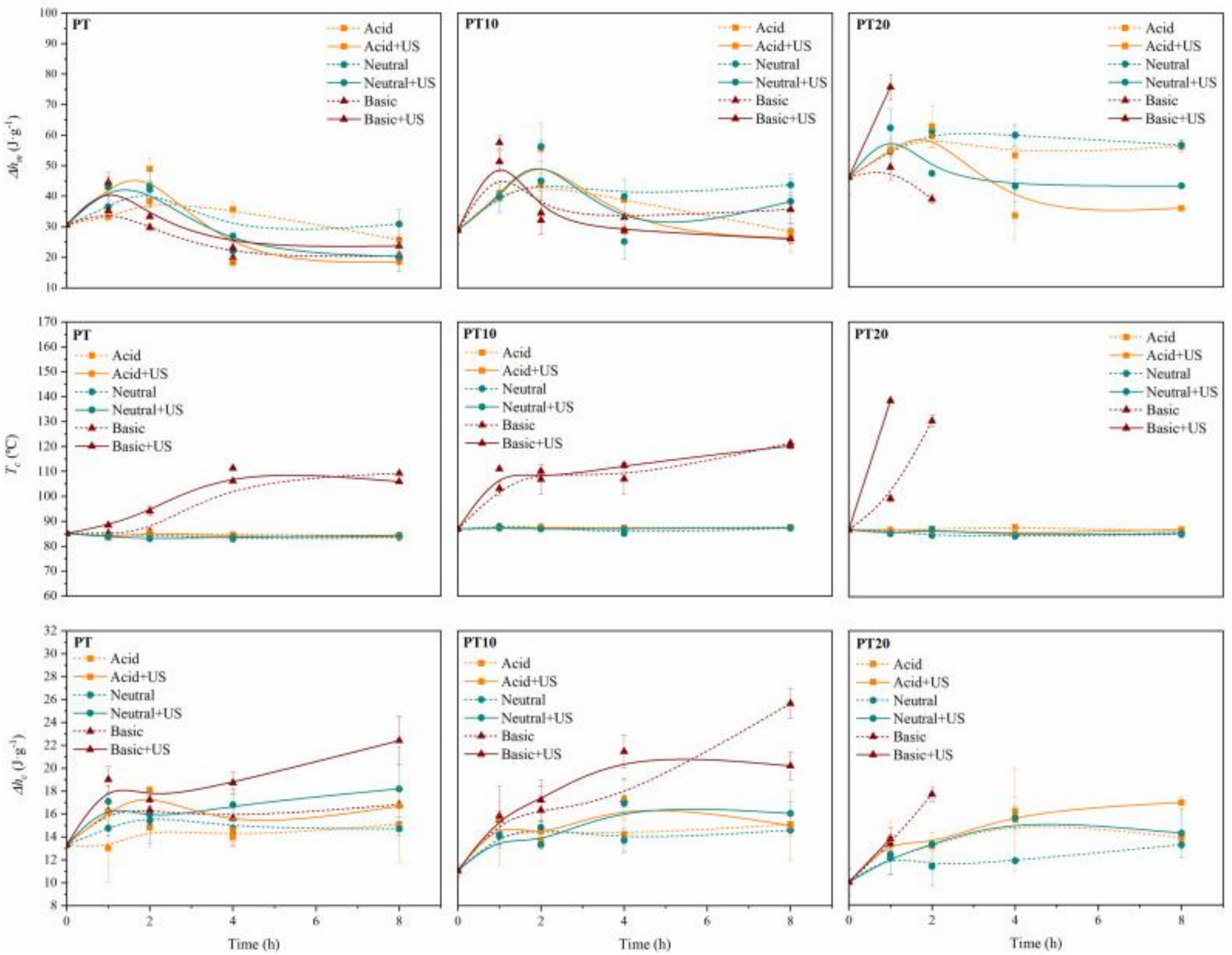
Pretreatment induces the formation of secondary crystalline structures: the material undergoes not only degradation but also structural reorganisation, where new crystalline regions are formed due to the breakdown of amorphous domains.

After 1 to 2 h of exposure the Δhm increases, indicating an initial phase of crystallization. However, as exposure time increases, the overall enthalpy begins to decline, suggesting that the material reaches a critical threshold.

During the cooling phase, the increase in Δhc and Tc indicates that shorter, hydrolysed chains can rapidly organise into crystalline domains.





PBAT:starch + Additive 17%

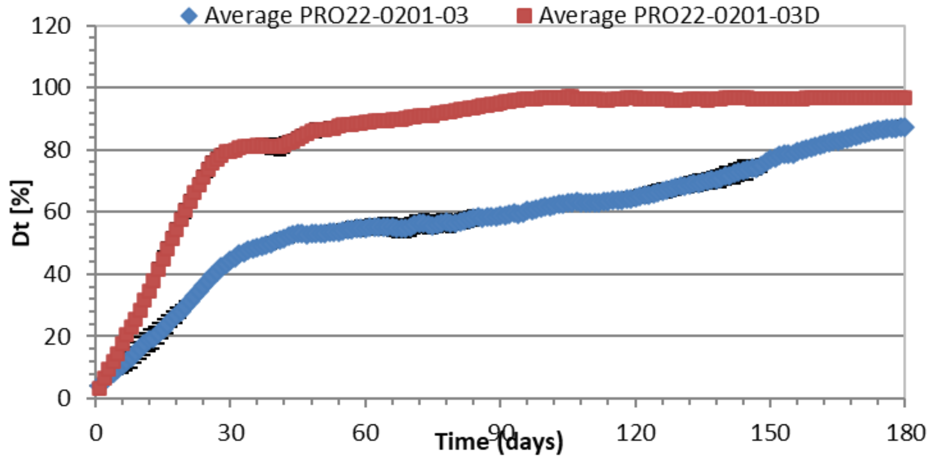
PBAT:starch + Additive 27%

PBAT:starch + Additive 37%

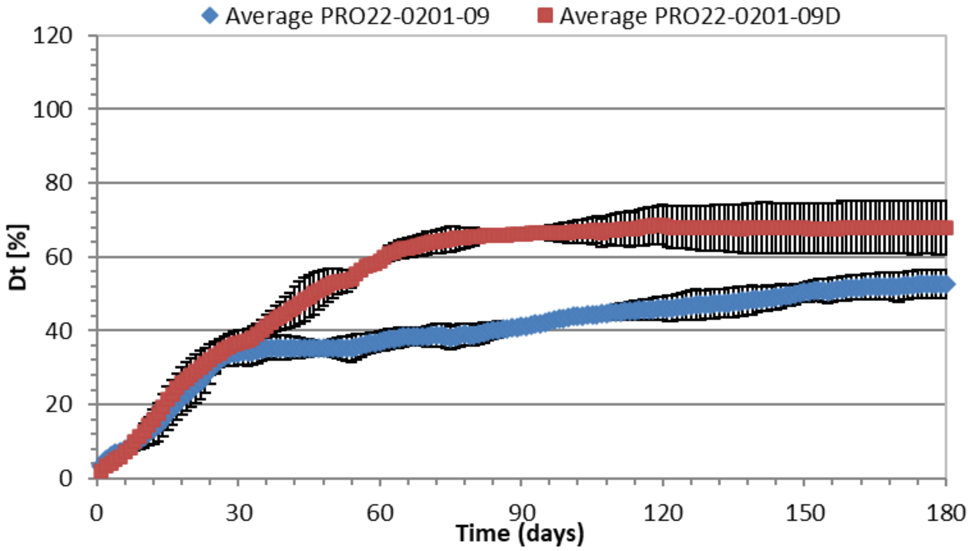
WP4: Development of a combined methodology to promote biodegradation in compost

Sample	ISO 14855		Combined strategy	
	%B	Std. dev	%B	Std. dev
Cellulose	91.6	3.9	104.9	4.9
PBAT:TPS + additive 37%	87.4	2.1	96.8	1.6
PBAT:TPS + additive 27%	75.5	3,4	89.1	3.1
PBAT:TPS + additive 17%	52.6	3,8	68.0	7.2

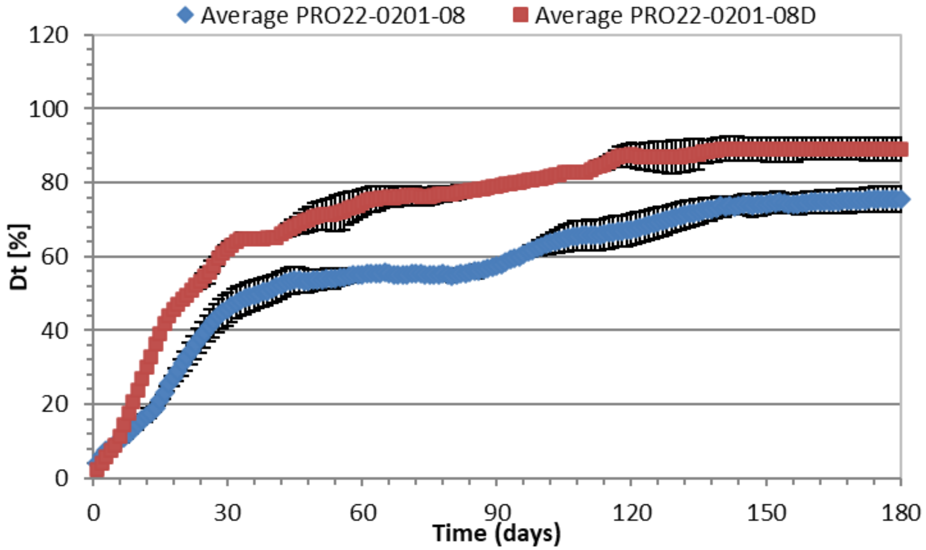
PBAT: starch + Additive 37%



- Results similar to the ones obtained from the enriched medium test
  - Lag phase of 45 days
  - 27% additive not clearly detected



PBAT: starch + Additive 17%



PBAT: starch + Additive 27%

$$D = \frac{m_i - m_r}{m_i} \times 100$$

where

m_i is the initial dry mass of the test material;

m_r is the dry mass of the residual test material recovered by sieving.

Accelerated method vs. standard disintegration test (ISO 20200)

- Assess the physical disintegration (not chemical biodegradation) of plastic materials under simulated composting conditions, specifically industrial composting, at laboratory scale.

- It is applicable to compostable final products, including packaging, films, and rigid plastics, to screen between several samples the one that better perform in terms of disintegration.

- Material under test is cut into specified shapes/sizes and mixed into the compost matrix.

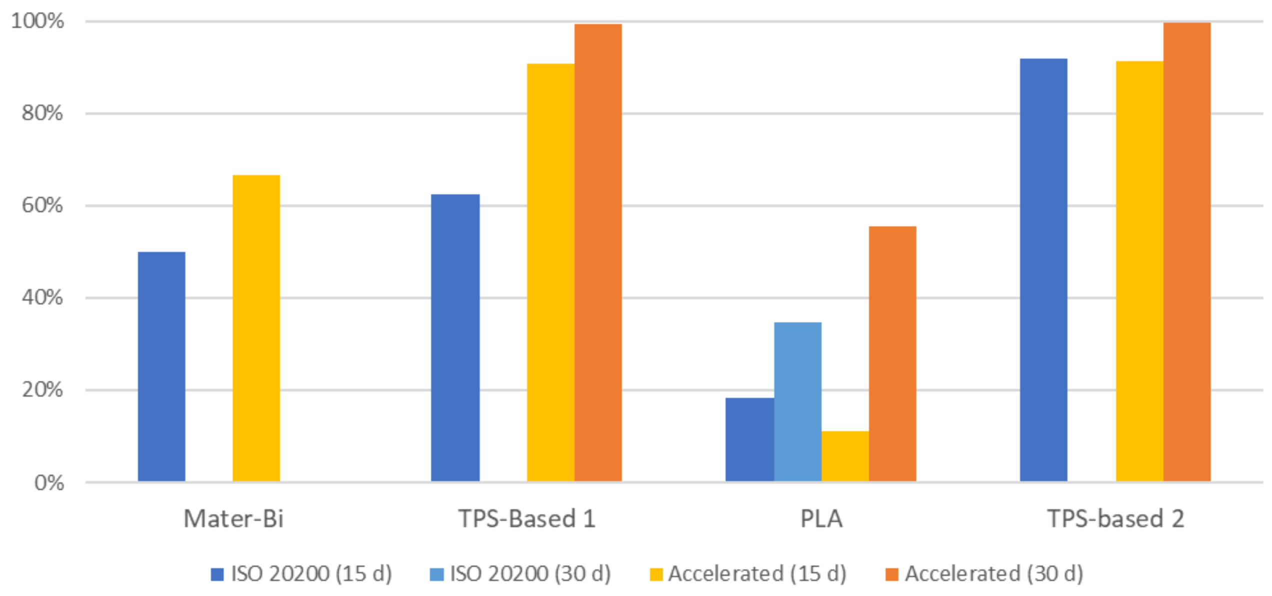
- Temperature 58 °C; Moisture content 50%; Test duration: 4 weeks.

- The degree of disintegration is determined by sieving the compost through a 2 mm mesh at the end of the test. The residual amount of material is collected, dried, and weighed. To be considered disintegrated, at least 90% of the original sample must break down into fragments smaller than 2 mm within 90 days.

Accelerated disintegration test

FoB:Plast by Ceresana — Future of Bio Plastics

Sample	ISO 20200		Modified medium	
	%D (15 d)	%D (30 d)	%D (15 d)	%D (30 d)
Mater-Bi	50.0%		66.7%	
TPS-Based 1	62.5%		90.6%	99.3%
PLA	18.3%	34.7%	11.1%	55.4%
TPS-based 2	91.8%		91.2%	99.5%



- Results showed improvement in several samples in both 15 and 30 days.
- In 30 days, the acceleration in disintegration is more visible.
- Other samples have been tested, confirming the full disintegration in 30 days or less.
- Accelerated disintegration has demonstrated to be applicable on a wide range of polymers (TPS; PLA; PCL etc.) as well as products (film; rigid plate; coffee capsule; pipes; etc.)

CONCLUSIONS

- Additive can directly affect the biodegradability of polymeric matrix;
- Indicators of termal degradation not always are related with improvement in biodegradation;
- Due to the higher cost and complexity of applying pretreatments, the combined strategy is not necessary to e adopted;
- Media modification can be evaluated for implementation at pilot and full-scale to improve the performance of compostable plastics treatment;
- It is necessary to extend the methodology to other compostable plastics in order to identify the suitability of such scheme to other polymers.

Sample	Standard ISO 14855	Modified médium	Pretreatment	Combined strategy
	% B	% B	% B	% B
PBAT:Starch + Additive 37%	87,4	115,98	62,02	96,81
PBAT:Starch + Additive 27%	75,51	80,96	68,63	89,08
PBAT:Starch + Additive 17%	52,56	75,34	66,75	67,98

FoB:Plast by Ceresana — Future of Bio Plastics

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MICROFAGO

Acceleration of biodegradation of bioplastics by modulation of the microbial population through the use of phages

DARWIN — Bioprospecting Excellence

WP1 Identification of new microorganisms and metabolic pathways for the biodegradation of bioplastics

Evolving THERAPEUTICS

WP2 Isolation and optimization of phages to modulate microbial populations in favor of bacteria beneficial for biodegradation

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WP3 Evaluation of the biodegradation of compostable bioplastic in different organic waste treatments

AIMPLAS PLASTICS TECHNOLOGY CENTRE

WP4 Determination of the optimal process for treating compostable bioplastic through microbiome modulation

girsa

WP5 Industrial-scale evaluation of the treatment process for compostable bioplastics in a modulated microbial environment

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