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ANAEROBIC DIGESTION OF BIO-PLASTICS: THE ISSUE OF BIODEGRADATION AND WEIGHT LOSS

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SESSION IV
Aerobic Treatment & Anaerobic Digestion I

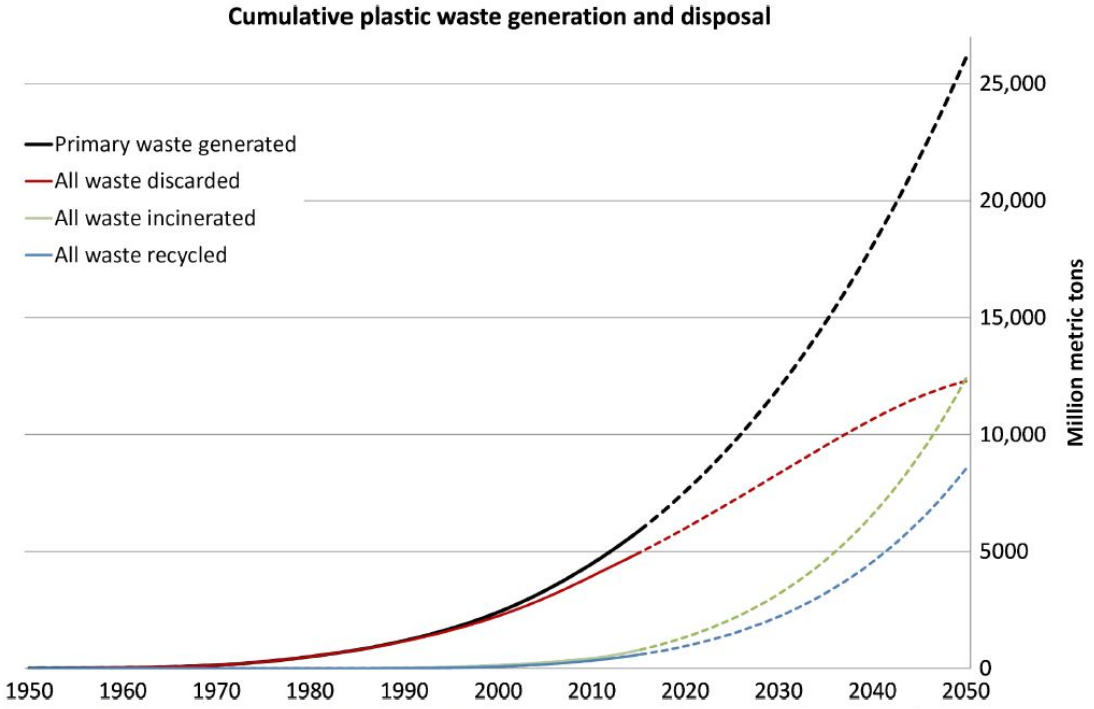
Monday, June 15, 2022

Framework

- Introduction and scope
- Materials and methods
- Bio-plastics samples
- Anaerobic digestion test
- Biodegradability
- Weight loss
- Kinetic analysis
- Results and discussion
- Methane production
- Biodegradability vs Weight loss
- Kinetic analysis
- Conclusions

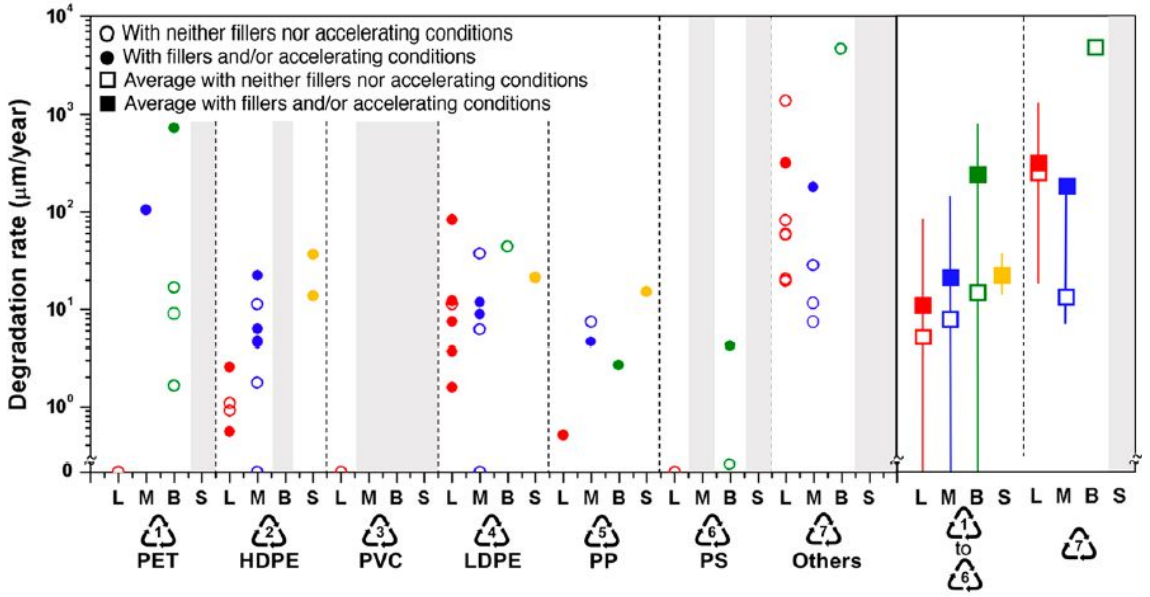
Introduction

Plastic waste: a problem for the environment



(Geyer et al., 2017)

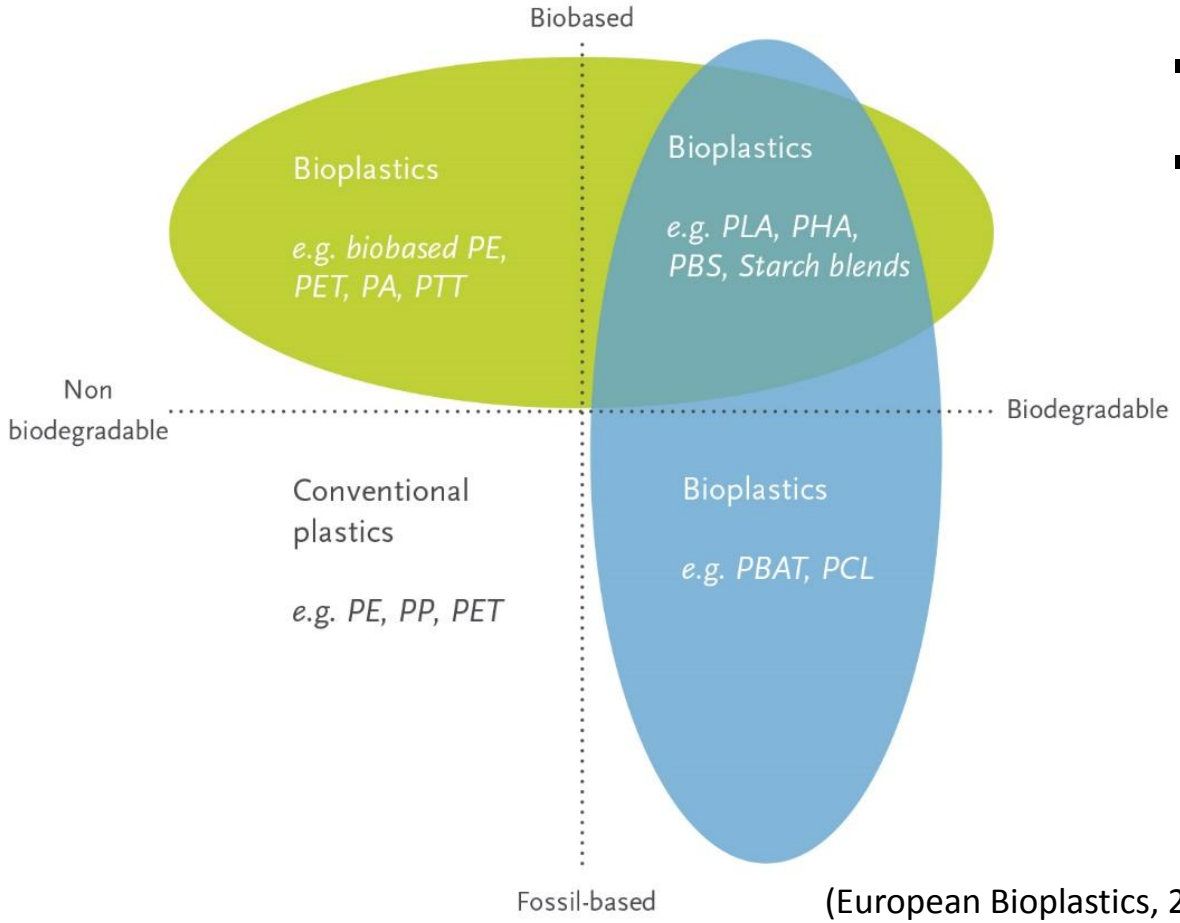
- The amount of plastic waste is increasing over time;
- Most of them are disposed in landfill;
- Due to the low degradation, plastic waste persists in the environment for long time.



(Chamas et al., 2020)

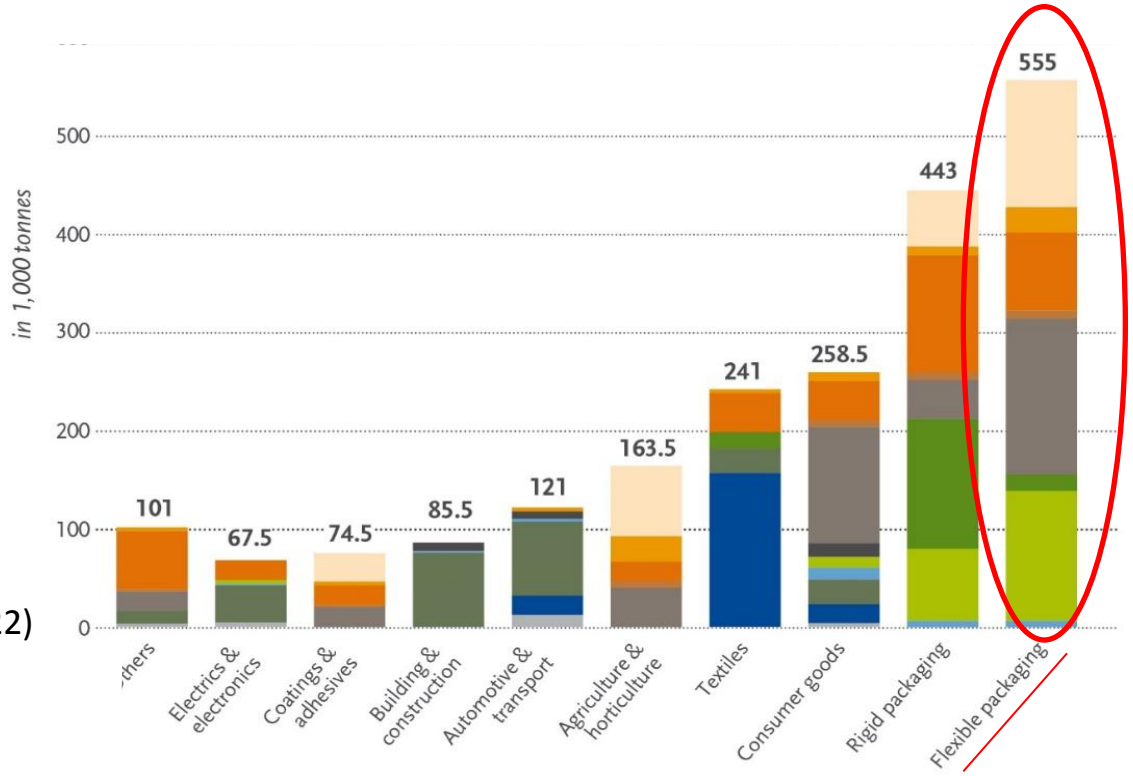
Introduction

Bio-plastics: a solution for the plastic pollution



(European Bioplastics, 2022)

- Bio-based: derived from natural or non-fossil source;
- Biodegradable: microorganisms can convert materials into natural substances.



Introduction

Bio-plastics waste management

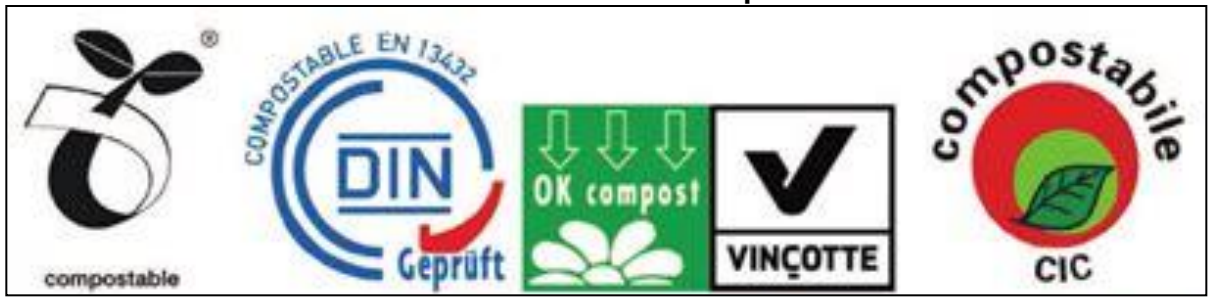
- If bio-plastics meet the compostability criteria, they can be treated with the organic fraction of MSW through industrial anaerobic digestion and composting;
- Actually, the anaerobic environment is not explored by this standard, which leads to a lack in knowledge about anaerobic digestion of bio-plastics;
- In addition, the difference between resindence time and temperature adopted in the experimental test and industrial plants lead to a incomplete degradation of bio-plastics. In order to avoid a contamination of the outputs, bio-plastics are sorted out from the process.

EN 13432:2002

Biodegradable

Disintegrable

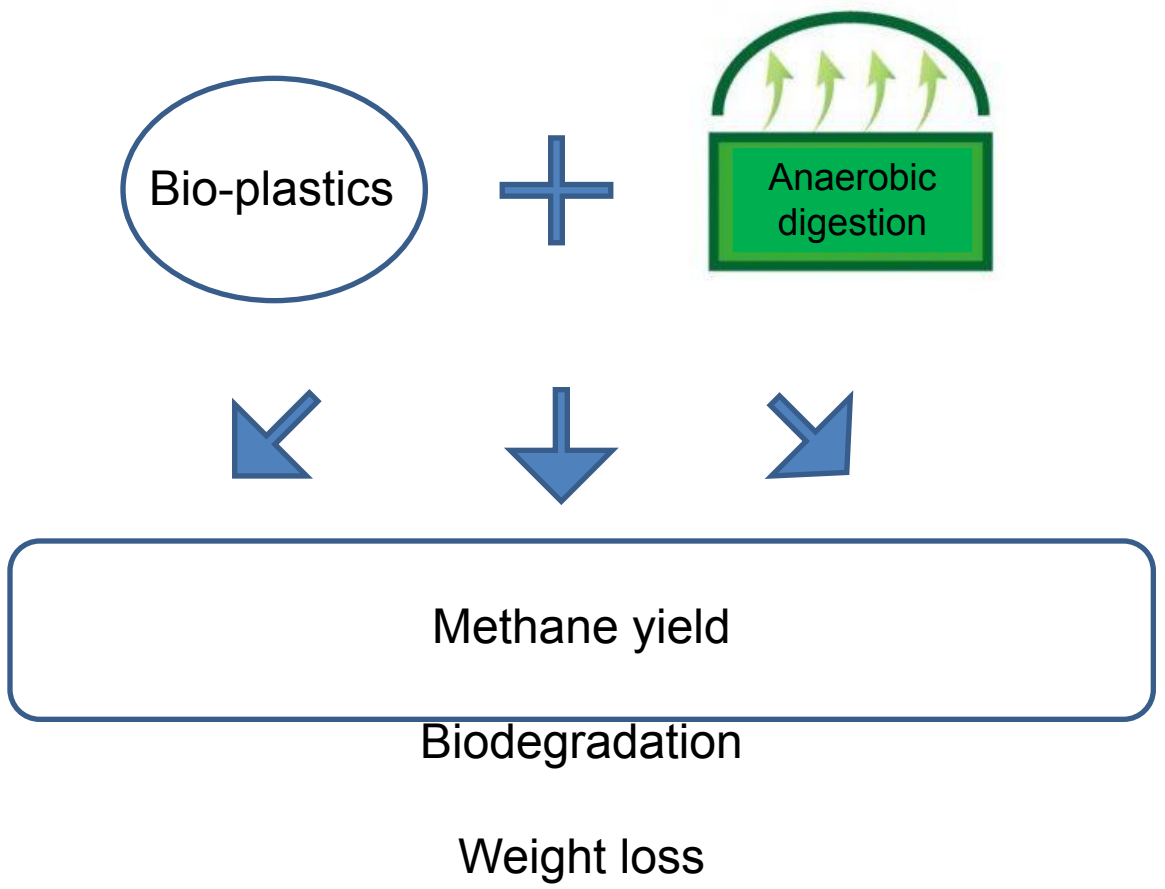
No effect on compost



Anaerobic digestion & composting

Scope of the study

- Thus, the aim of this study is to overcome the misinformation about anaerobic degradation of bio-plastics waste at industrial scale.
- For the scope, weight loss and biodegradation of different bio-plastics have been investigated in batch test;
- In order to assess the current residence time of anaerobic digester, batch test have been carried out for 32 days;
- Finally, the analysis of the anaerobic degradation kinetic have been carried out.



Materials and Methods

Bio-plastics samples

- Cellulose-based:
  - CA: blend of cellulose acetate and 30% of triacetine;
  - CA-LDH: blend of CA and 5% of inorganic filler composed of Layered Double hydroxide (LDH) organically modified with 20% of sorbate anion
- PLA film:
- PBS-gelatin blend:
  - PBSg: pellet of PBS blended with 20% of gelatin;
  - PBSp: pieces of PBS blended with 20% of gelatin;

CA

CA-LDH

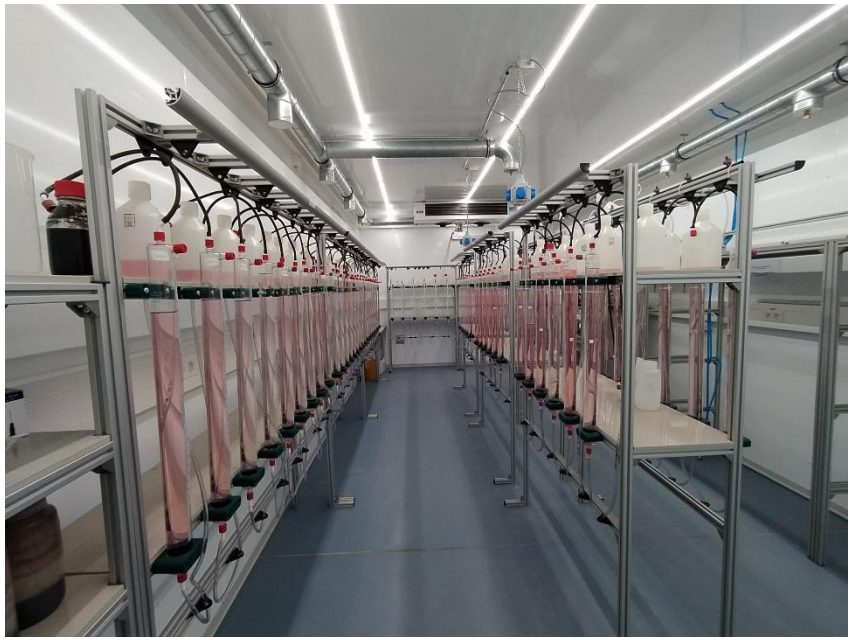
PBSg

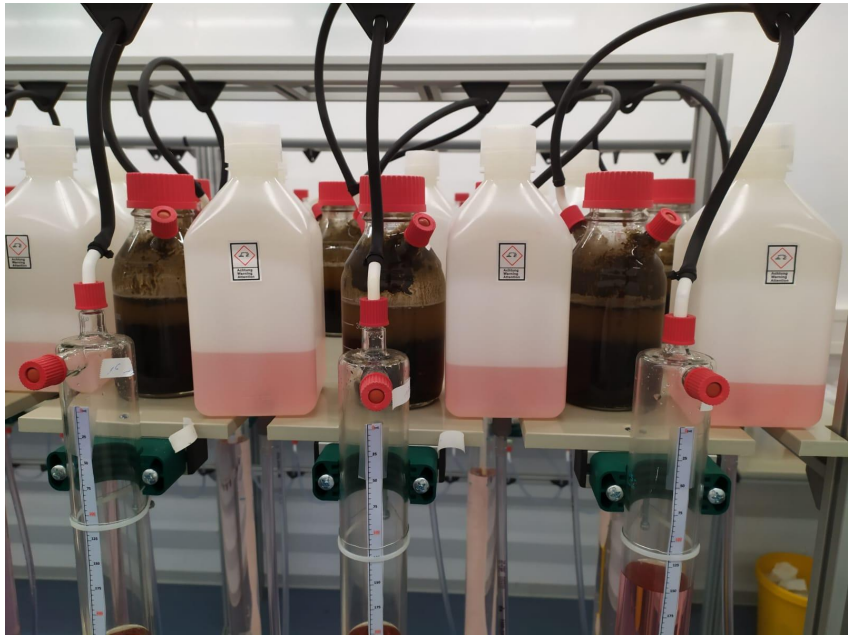
PBSp

Materials and Methods

Anaerobic digestion test

- Batch test at mesophilic temperature (37°C) and liquid-state condition (<10%TS) for 32 days;
- Triplicate of each bio-plastics (specimens of 25x25mm) + reference (microcrystalline cellulose) + blank (anaerobic sludge);
- ISR = 2 (VS basis)
- Biogas reading: volumetric system

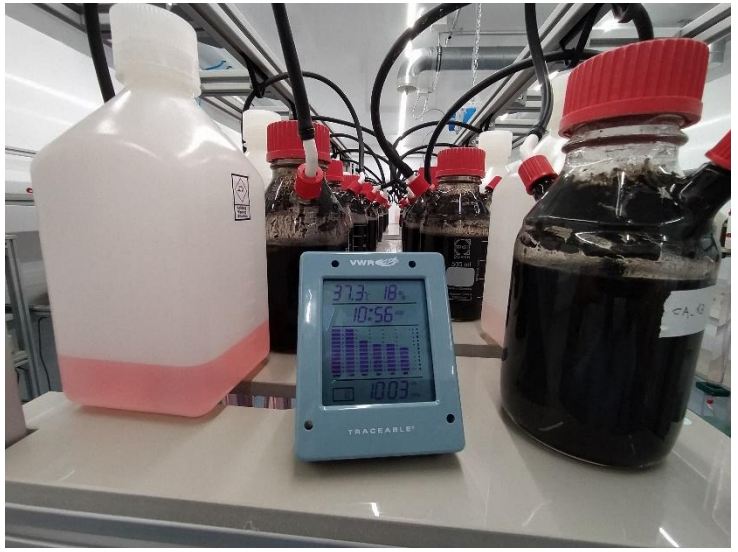




Materials and Methods

Parameters

- Methane yield (VDI, 2016):
  - From biogas to standardized biogas;
  - From standardized biogas to standardized methane;
  - From standardized methane to net standardized methane;
  - From net standardized methane to specific net standardized methane (NmlCH4/gVS).
- Biodegradation (ISO 14853):
  - Carbon produced in biogas;
  - Carbon dissolved in the liquid digestate.
- Weight loss (ISO 20200)



Materials and Methods

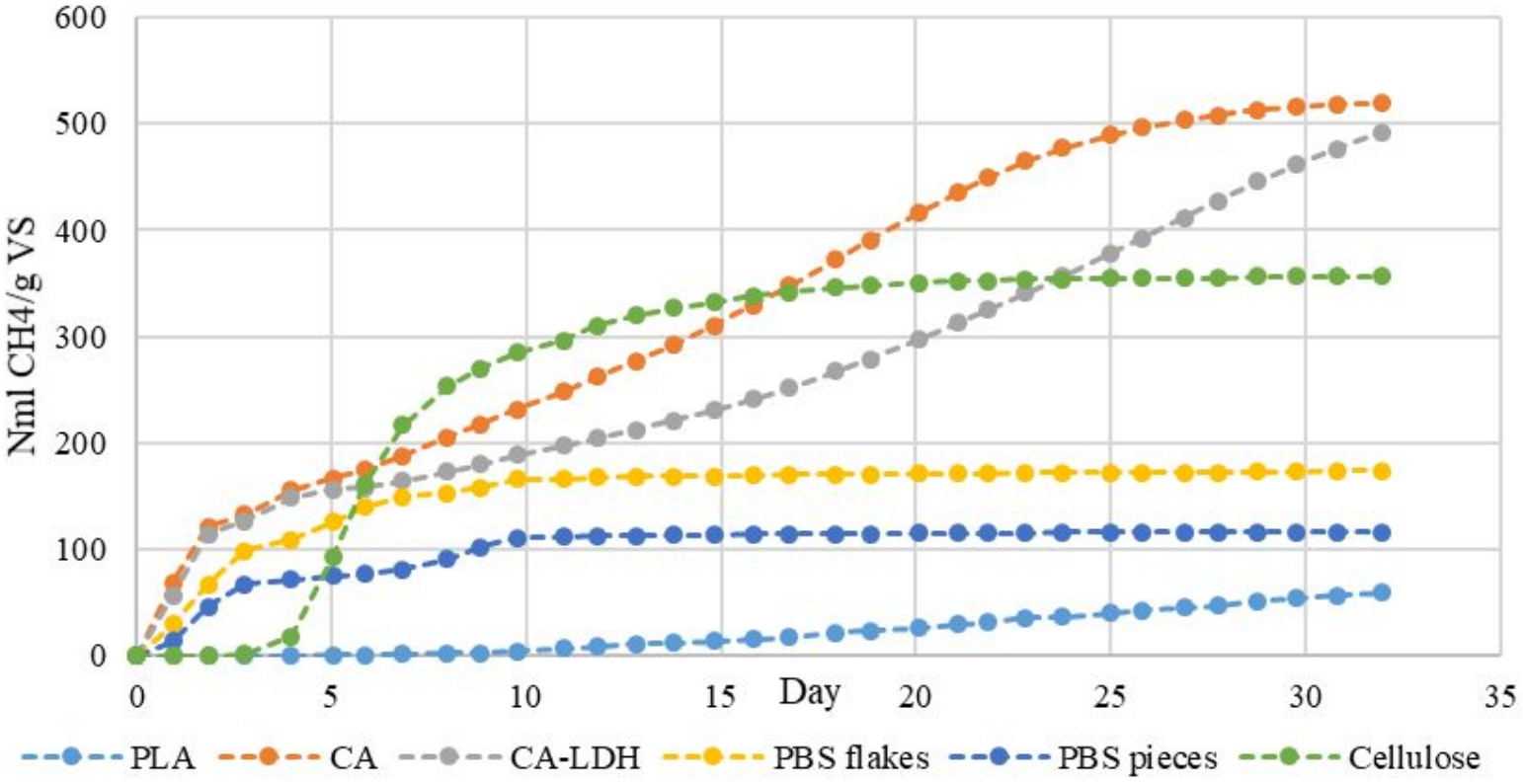
Kinetic analysis: Gompertz model

- $G_{(t)}$ = cumulative methane produced (mL/gVS),
- $G_{(0)}$ = the ultimate methane produced (mL/gVS),
- t = duration of digestion (d),
- R_{max} = maximum rate of methane production (mL/gVS/d),
- λ = lag phase (d),
- e = Euler's constant (2.71828). :

$$G_{(t)} = G_{(0)} \cdot exp\left\{-exp\left[\frac{R_{max} \cdot e}{G_{(0)}}(\lambda - t) + 1\right]\right\}$$

Results

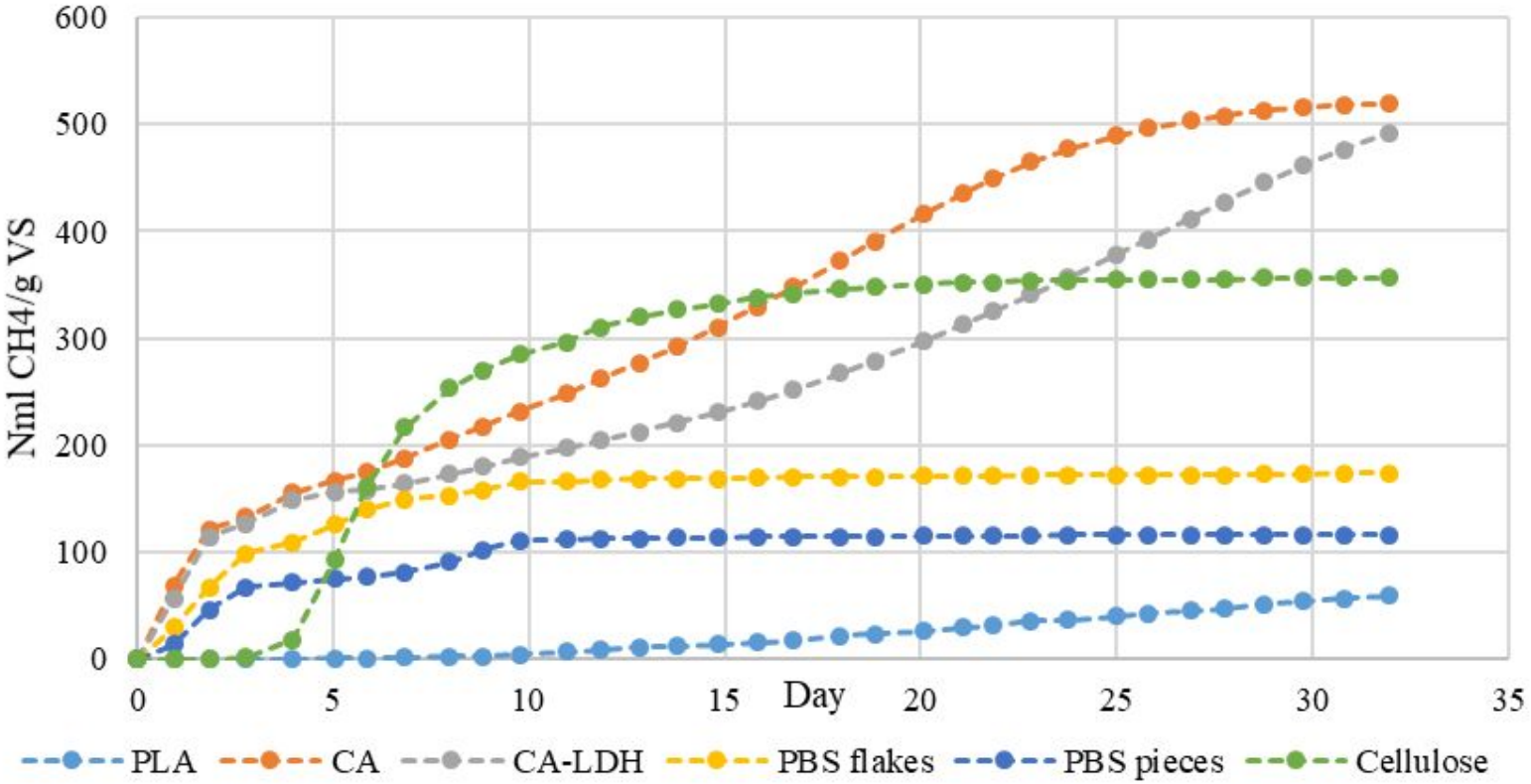
Methane yield



- Cellulose-based highest yield (comparable with food waste):
  - First 2 days triacetine degradation, which eliminate the lag phase of cellulose degradation;
  - At day 25 CA ended the degradation but CA-LDH could continue;
- PLA worst result:
  - Lag phase 10 days;
  - High crystallinity reduce the diffusion of microorganisms;

Results

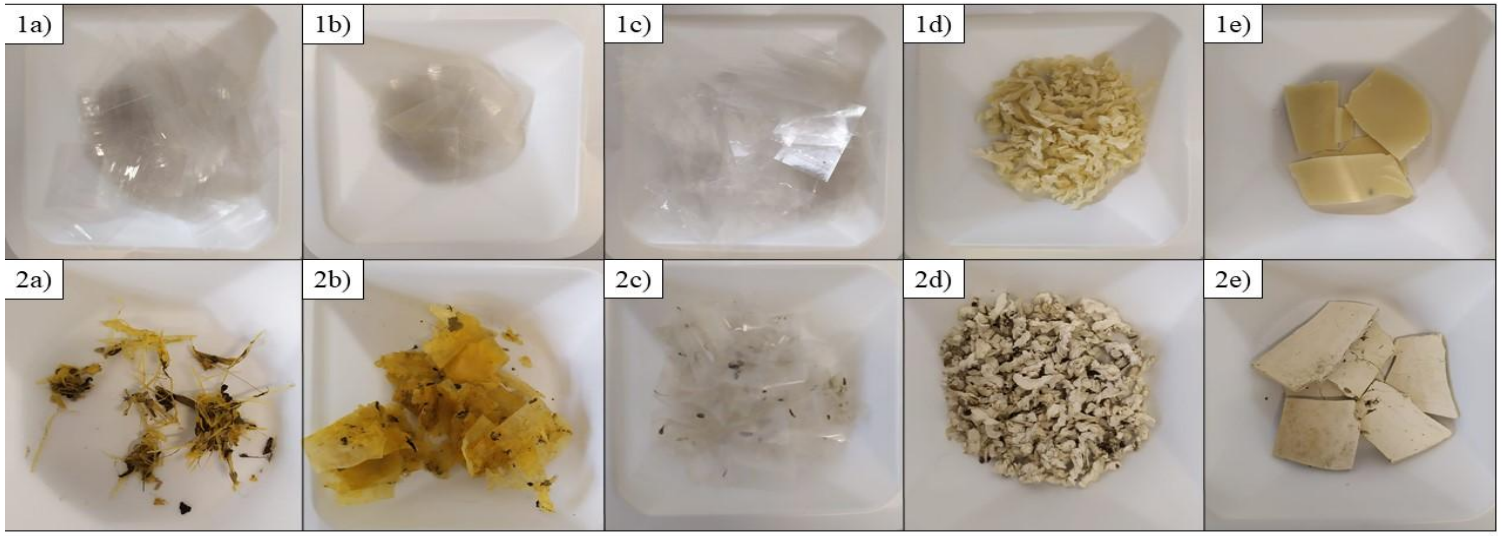
Methane yield

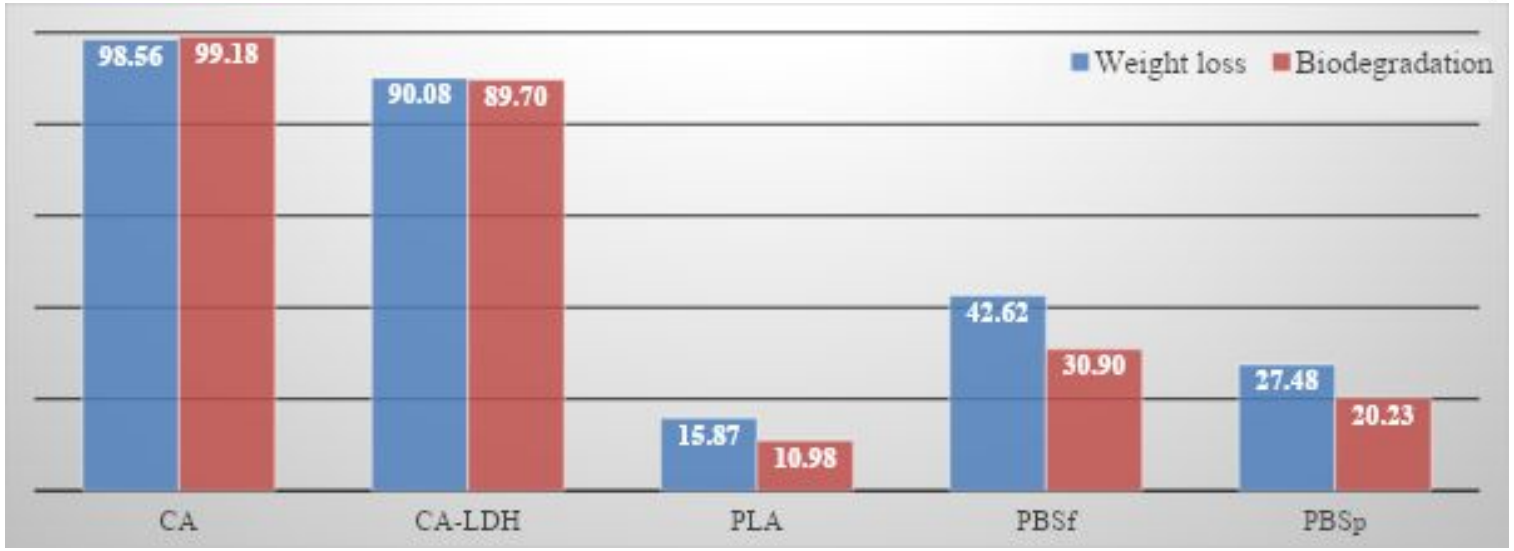


- PBS-gelatin:
  - Degradation occurred until day 10, for the conversion of gelatin to methane;
  - Addition of gelatin allow the production of methane from PBS, which is not anaerobically biodegradable;
  - Flakes degrade more than pieces due the smaller shape;
  - Pieces revealed a stepped trend
- Refernce was in the range of inoculum suitability.

Results

Biodegradation vs Weight loss

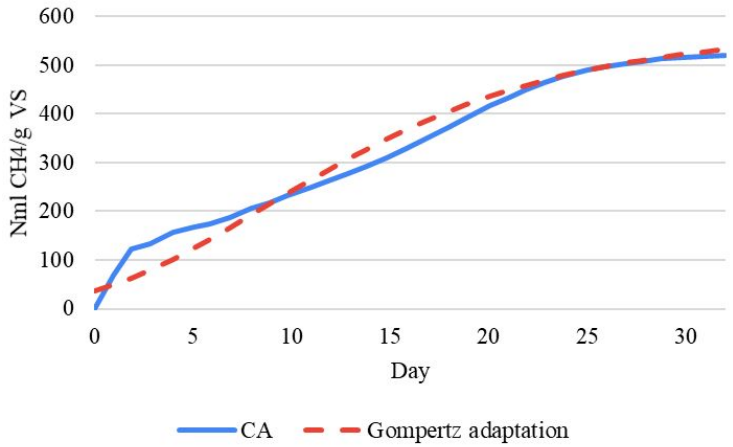


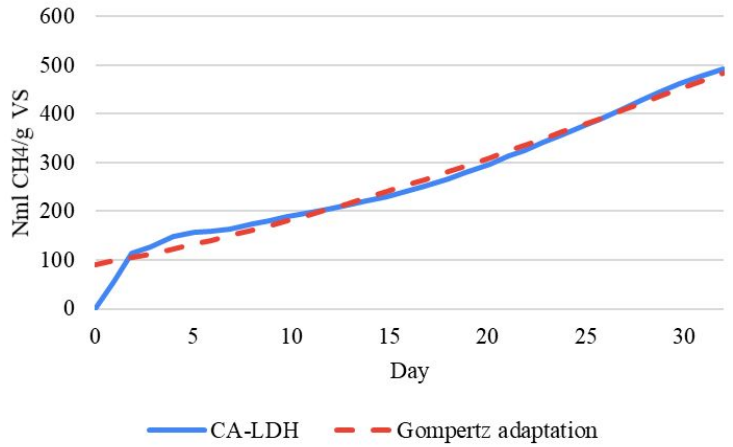


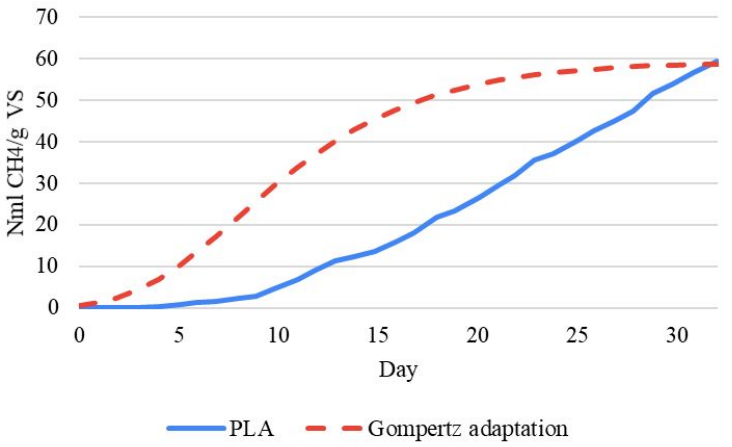
- CA achieved a full (bio)degradation, CA-LDH slight lower;
- PLA lowest weight loss and biodegradation (50% less than the first);
- PBS revealed high differences between weight loss and biodegradation (attributable to the gelatin);
- Dissolved C: null for cellulose-based, 7% of PLA, 25% for PBS

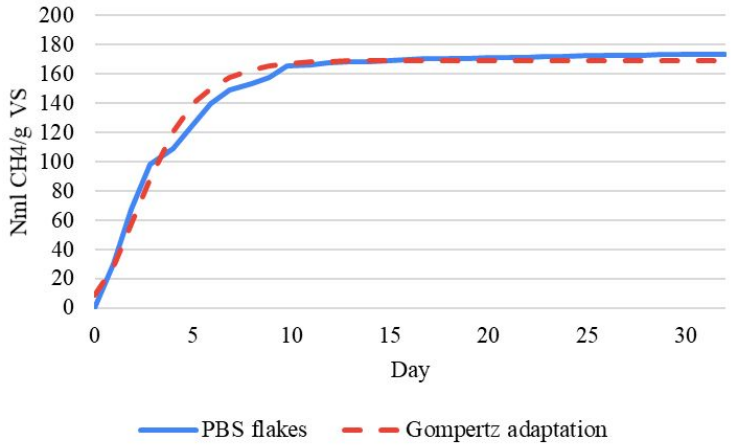
Results

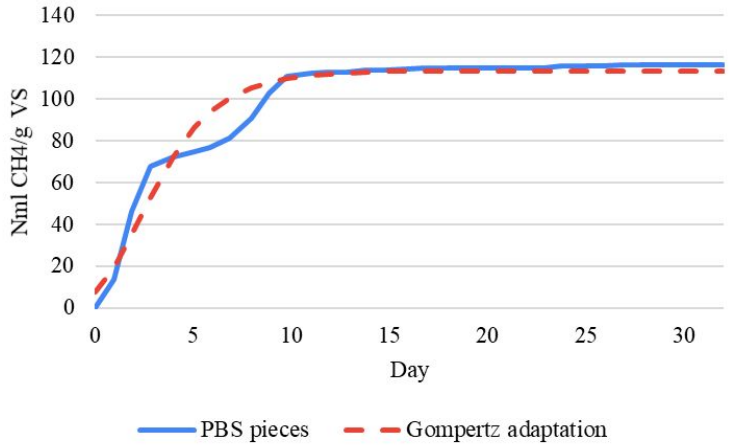
Kinetic analysis











- Stepped trend not represented by Gompertz model;
- Worst modelling for samples with an incomplete degradation

Conclusions

- The suitability of industrial anaerobic digestion has been evaluated in this work for different bio-plastics waste;
- Cellulose-based bio-plastics resulted in high methane yield and a full biodegradation and weight loss;
- Industrial anaerobic process, characterized by mesophilic and 30-day process do not allow the degradation of PLA as well as a significant methane production;
- The addition of gelatin generated methane from PBS samples, which remained undigested;
- High discrepancy between weight loss and biodegradation could be detected.
- Results revealed how not all bioplastics are suitable for the current anaerobic digestion process.
- In addition, the lower degradation of the bio-plastics could lead to clogging, reduction of working volume and other operational challenges in an industrial biogas plant.
- To avoid potential digestate contamination, technical adjustment should be implemented.

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Thank you for your attention!

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SESSION IV
Aerobic Treatment & Anaerobic Digestion I

Monday,
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