SCERG
Sustainable and Clean Energy Research Group

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SIMULATION MODEL AND SENSITIVITY ANALYSIS TO ASSESS ANAEROBIC DIGESTION AND/OR COMPOSTING PROCESS OF BIOPLASTICS AND ORGANIC WASTE

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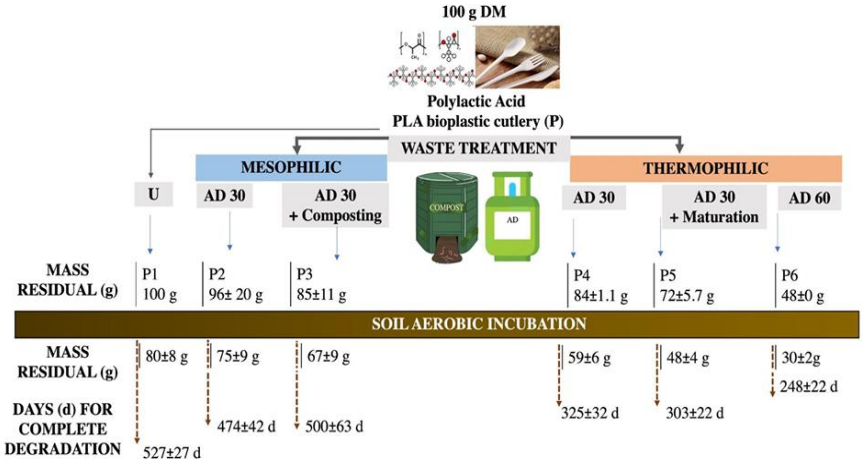
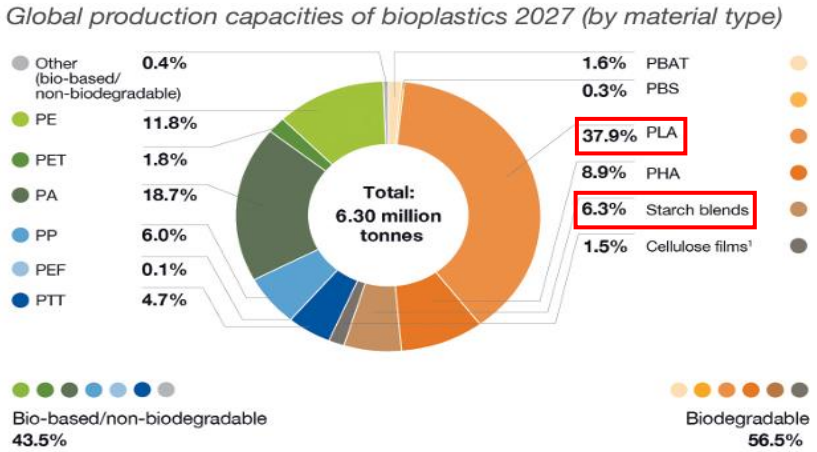
Outline

- Aim of the work
- Bioplastics vs OFMSW
- Modeling
- Procesess Design on Aspen Plus
- Results and Discussion
- Conclusion

Introduction





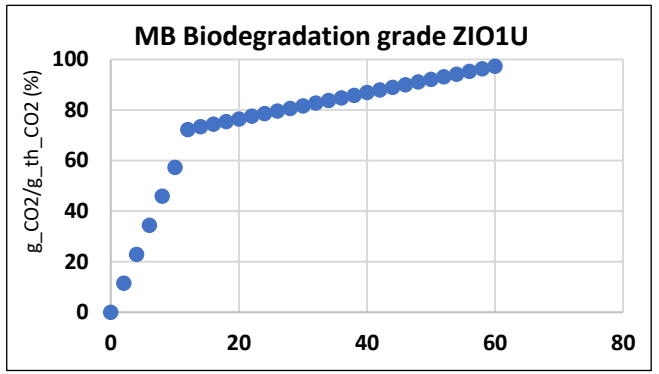
Plant operating parameters are **different** from those of the certification standards

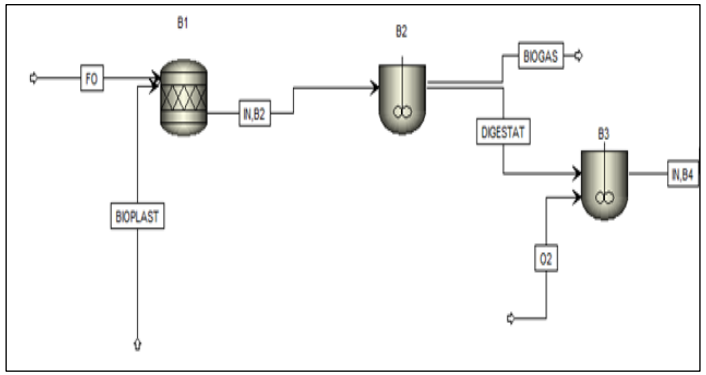
The amount of bioplastics globally will nearly **triple** from 2022 to 2027

In this context, the need arises to assess the **effective biodegradability** of the biopolymers produced

Objective

Evaluation of the the real biodegradability of rigid and flexible bioplastics, and to examinate the compatibility with actual organic fraction waste menagement in order to give useful information to plant menager





Rigid PLA, flexible Mater-Bi and OFMSW

PLA

SBS (STARCH BLEND SHOPPER)

OFMSW

OFMSW component	chemical formula	component weight/weight t.q.
Glucose	C6H12O6	0.02
Cellulose	C6H10O5	0.04
Hemicellulose	C5H8O4	0.02
Protein	-	0.02
Diacylglycerol	C37H68O5	0.01
Glyceryl trioleate	C57H104O6	0.01
Tripalmitine	C51H98O6	0.01
Inert	-	0.02
Water	H2O	0.85
Total		1

Samples	C (% w.t.)	H (% w.t.)	N (% w.t.)	S (% w.t.)	O (% w.t.)	HHV (MJ/kg)
PLA	52.74 (0.37)	4.04 (0.13)	0.03 (0.02)	0.02 (0.01)	43.17	15.89
SBS	59.53 (1.92)	5.12 (0.28)	0.03 (0.01)	0.48 (0.36)	34.81	21.28

PLA	$C_{1237}H_{1120}O_{752}N$
SBS	$C_{319}H_{318}O_{139}S$

Reaction modeling: Anaerobic digestion and composting

PLA

Anaerobic Digestion

$$C_aH_bO_cN_d + A\,H_2O \rightarrow B\,CO_2 + C\,CH_4 + D\,NH_3$$

	A	B	C	D
moli	582	667	570	1

Composting

$$C_aH_bO_cN_d + A\,O_2 \rightarrow B\,CO_2 + C\,H_2O + D\,NH_3$$

	A	B	C	D
moli	1140	1237	559	1

SBS

Anaerobic Digestion

$$C_aH_bO_cS_d + A\,H_2O \rightarrow B\,CO_2 + C\,CH_4 + D\,H_2S$$

	A	B	C	D
moli	170	155	164	1

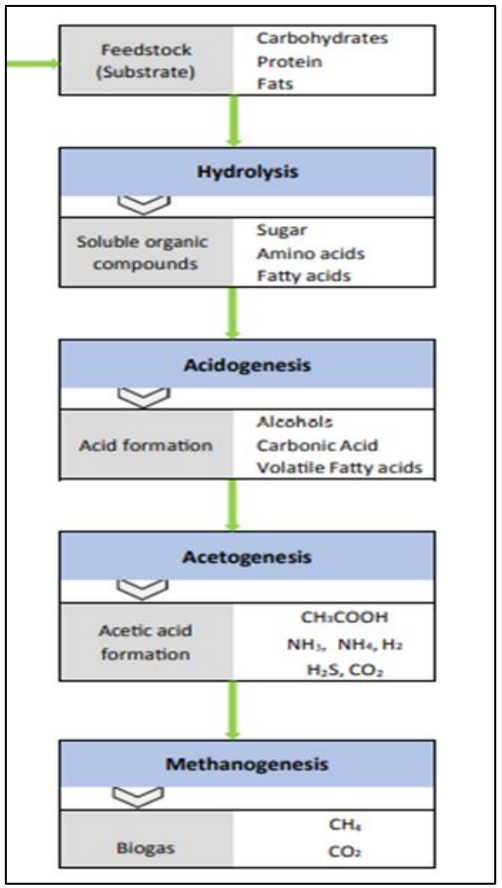
Composting

$$C_aH_bO_cS_d + A\,O_2 \rightarrow B\,CO_2 + C\,H_2O + D\,SO_2$$

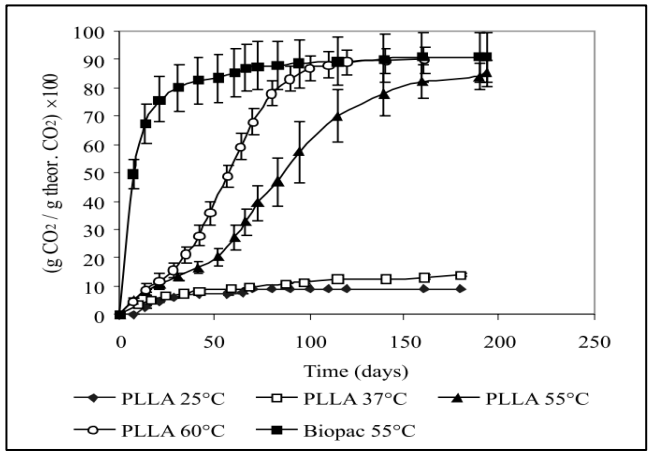
	A	B	C	D
moli	330	319	159	1

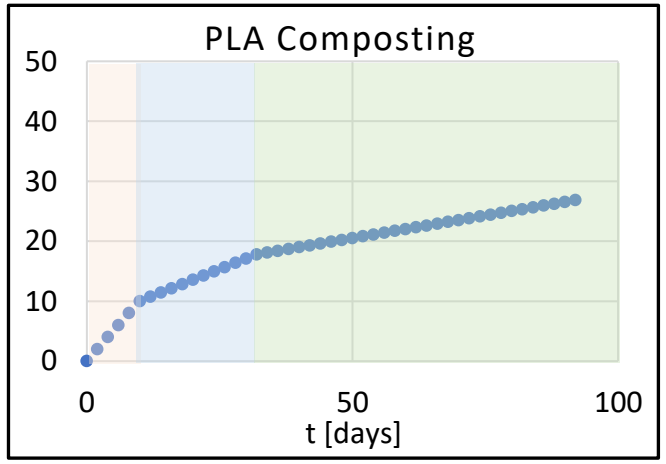
OFMSW

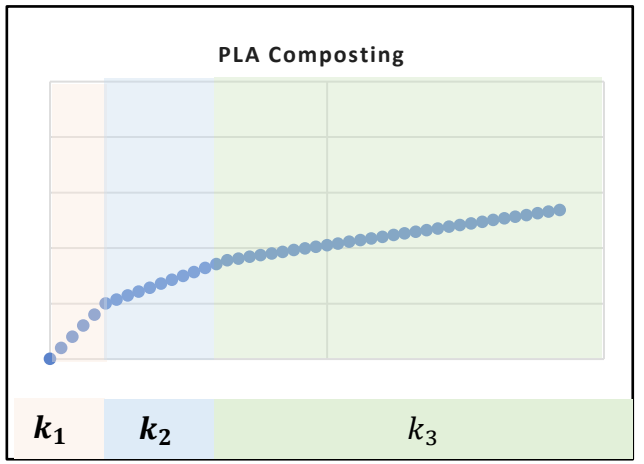
Anaerobic Digestion



Reaction modeling: Anaerobic digestion and composting



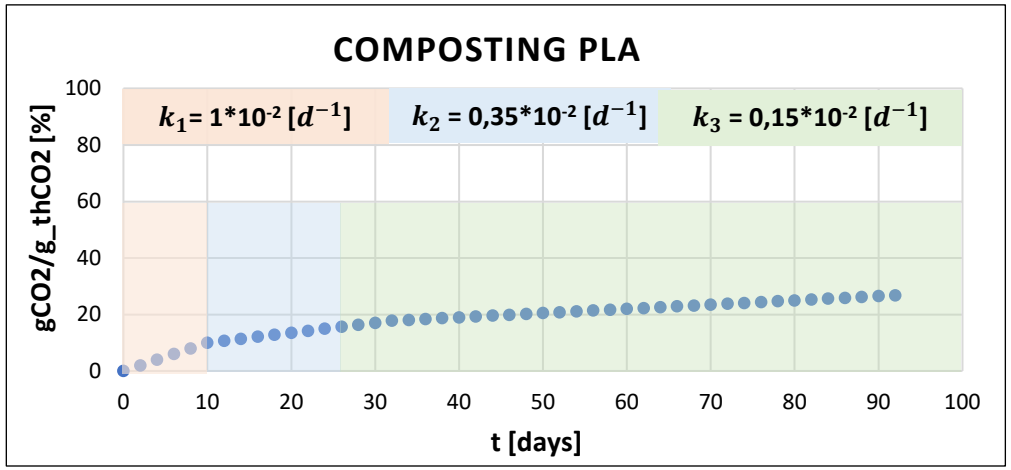




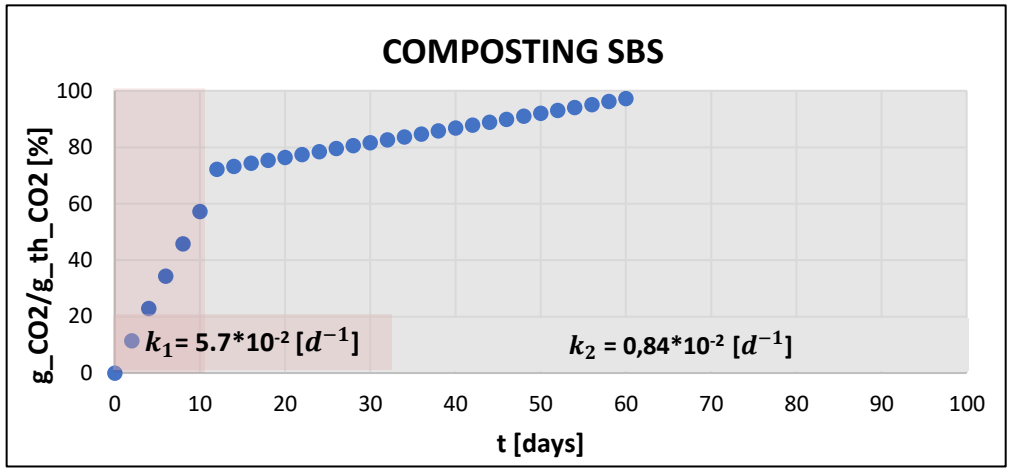
Biodegradation curves → Linear regression → Kinetics constant extrapolation

Reaction modeling: Anaerobic digestion and composting

PLA



SBS



k_3 =0,42*10-2 [d^{-1}]

Anaerobic Digestion

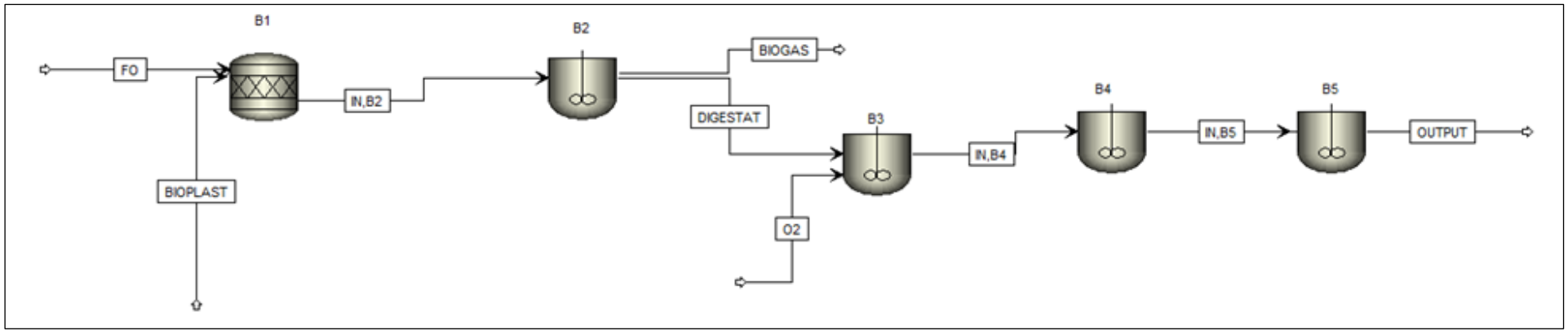
PLA

Condition	k [d^{-1}]
Mesophilic	1.2*10^{-3}
Termophilic	15*10^{-3}

SBS

Condition	k_1 [d^{-1}] (day 1-15)	k_2 [d^{-1}] (day 15-30)
Mesophilic	1.63	0.28
Termophilic	2.4	0.58

Layout Design

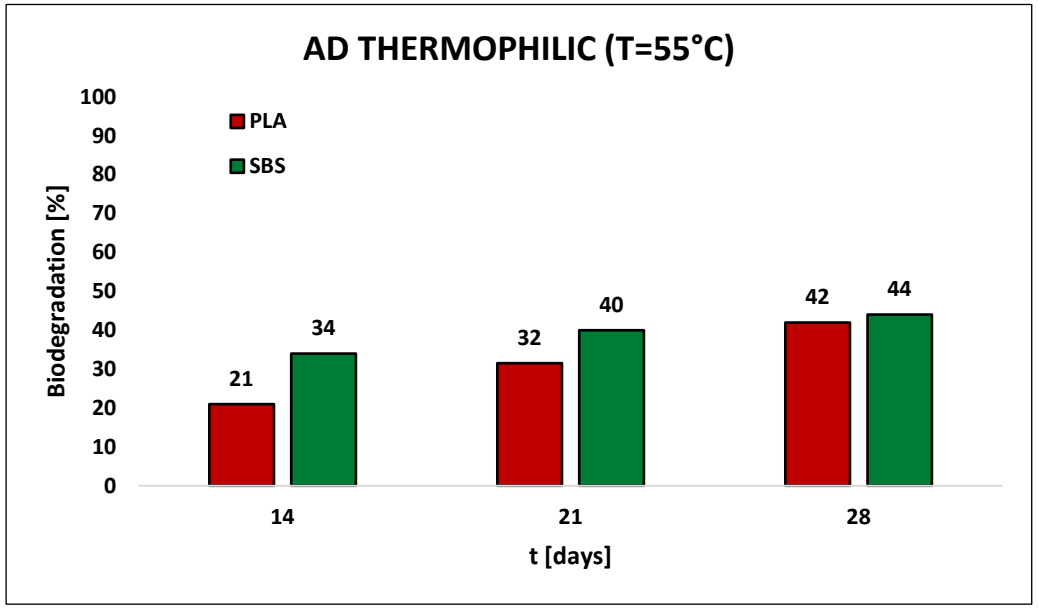


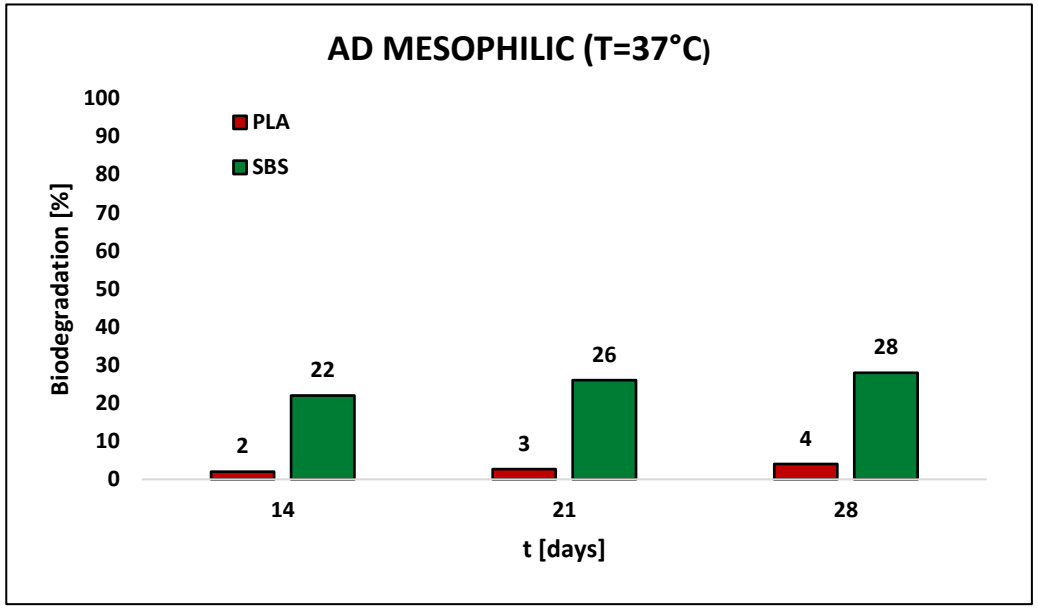
1. Feedstock goes to the first reactor with T=25°C and atmospheric pressure
2. 50% of PLA and 50% of SBS, bioplastics are made only of volatile matter
3. AD realized by semi-dry process
4. No interaction between bioplastics and OFMSW

Component	M_tot_in (kg/h)	Volatile Matter (kg_SV/kg_tq)	M_vol_in (Kg_SV/h)
Organic Fraction	97	12,75	12,3
Bioplastics	3	100	3

Results and discussion : Anaerobic Digestion

$$Biodegradation\ (\%) = (M_i - M_f)/M_i * 100$$

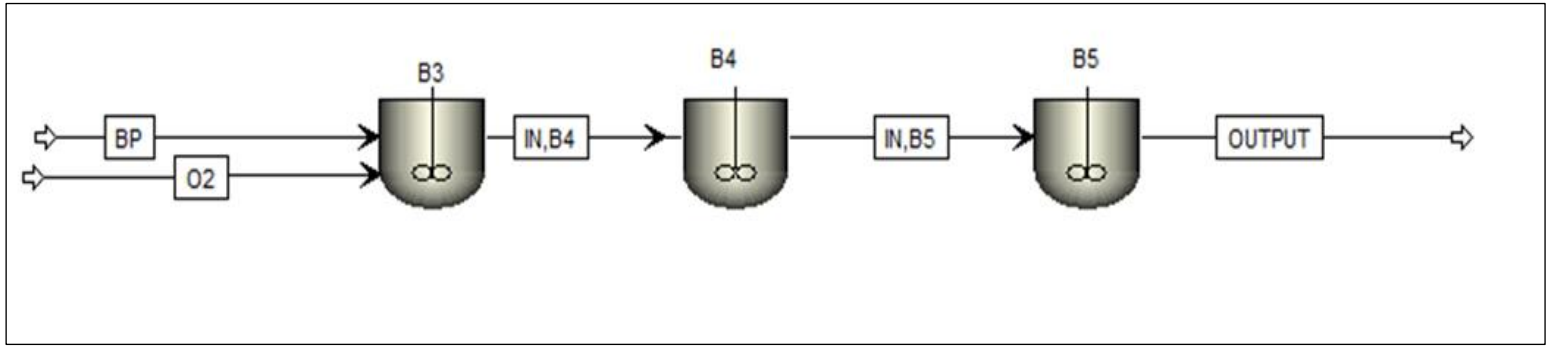


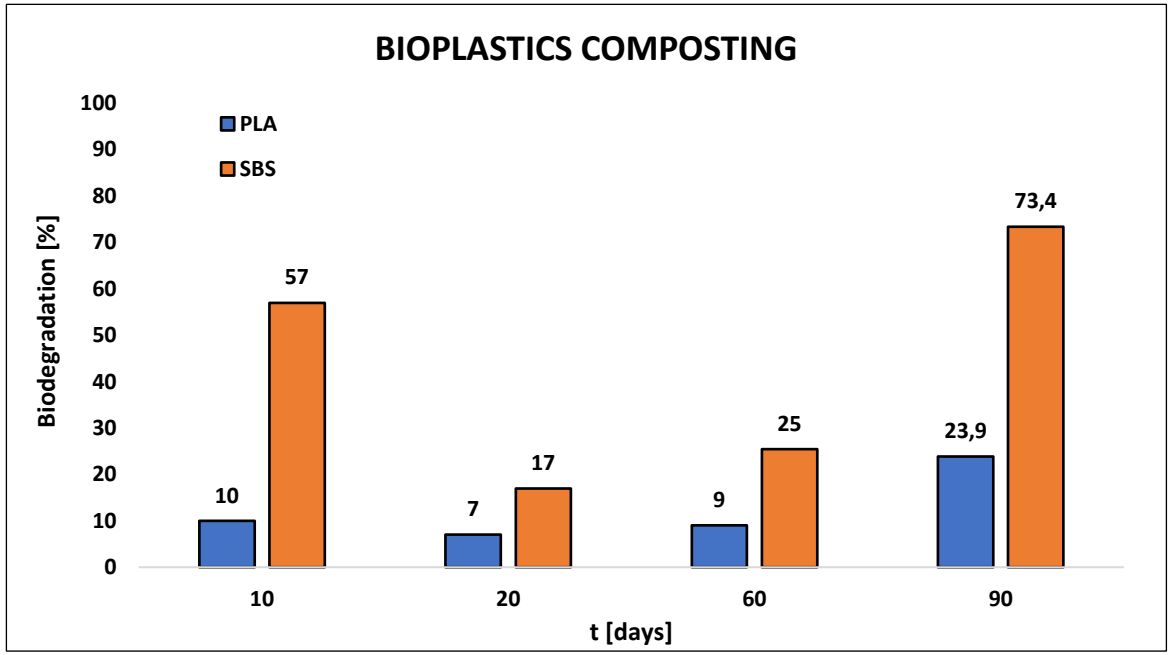


Thermophilic Condition	t (d)	NL_CH4 of OFMSW/kg_VS	PLA yield (NL_CH4/kg_VS)	MB yield (NL_CH4/kg_VS)
T=55 °C	14	195,4	77,7	123,7
	28	201,0	164,3	173,1

Mesophilic Condition	t (d)	NL_CH4 of OFMSW/kg_VS	PLA yield (NL_CH4/kg_VS)	MB yield (NL_CH4/kg_VS)
T=37 °C	14	148,7	8,8	53,0
	28	154,3	17,7	97,2

Results and discussion: Composting





SBS degradate better than PLA, especially in the first phase

Reaction kinetics for SBS in aerobic processes is higher than anaerobic kinetics, thus more akin to aerobic bacteria in contrast to what is observed for PLA

Observation:

Conclusions

SBS bioplastics

Suitable for integrated process with thermophilic and mesophilic AD with a maximum biodegradation found to be 85% with 28-day anaerobic digestion

suitable for composting processes with a biodegradation found to be 73.4%, while it is limited (44%) for AD-only processes (thermophilic for 28 days)

PLA

For integrated processes with AD in thermophilicity, maximum degradation found of 56%, with 28 days of working plant

Composting does not seem to be an appropriate route as the highest observed biodegradation is 23.9% while AD alone seems to be the process that most influences biodegradation (42%)

Fundamental to the success of these processes is the efficiency and effective management of the facilities in charge. In particular for PLA, other forms of recycling are to be evaluated, e.g., chemical, allowing the recovery of base precursors, lactide and lactic acid

Thank you for your attention!

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