Single-phase anaerobic digestion of the Organic Fraction of Municipal Solid Waste without dilution: reactor stability and process performance for small size and decentralized plants

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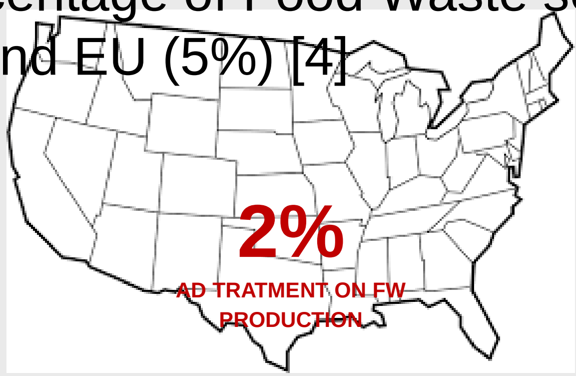
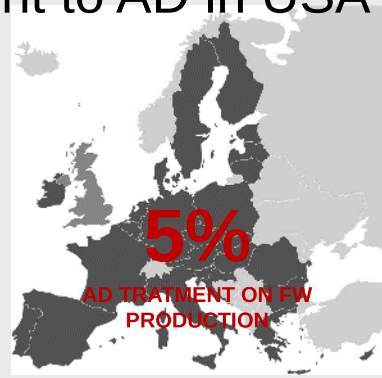
Aim of the Project Research

Introduction

To support an increasing of OFMSW Anaerobic Digestion treatment capacity along EU

- **244 AD** plants for almost **8 million ton** of OFMSW treated in 17 EU countries (2012, De Baere and Mattheeuws) [1]
- **688 AD** installations fed with generic bio-waste residuals (2016, EBA) [2]
- Percentage of Food Waste sent to AD in USA (2%) [3] and EU (5%) [4]





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Limits for AD plants widespread diffusion

Introduction

Factors that often limit the spread of AD digesters related to the most typical conditions applied at the full scale:

1 WET/DRY

- WET: the **elevate dilution** needed to reach a low TS content means building big digesters, usually centralized plants, and with an output digestate very liquid and not really vocated to composting [5] [6]
- DRY: dry digesters require elevate surface and soil consumption and often are associated with low biogas

2 CODIGESTION

- With codigestion the limit is usually that the cosubstrate is not available at the same site of Food Waste[12]
- Wastewater enriches the food waste of heavy metals adding troubles to the composting process
- The lignocellulosic addition usually makes the plant design and operation more

3 MULTI PHASE

- Reacrtors must usually be larger
- The plant design is moe complex
- Very good approach for centralized plants but not for promoting decentralized installations [14] [15]

Objective of the Study

Introduction

Stimulate the capillar diffusion of AD plants

↓

DECENTRALIZED, SMALL SIZE, EASY TO OPERATE AD PLANTS

↓

New plant Lay-Out

TEST IF PROCESS STABILITY IS POSSIBLE UNDER A MIX OF CONDITIONS USUALLY NOT APPLIED TOGETHER

- **PFR reactor**
- **Single Phase**
- **Monodigestion of OFMSW**
- **High OLR**
- **Hight stability**
- **Mesophillic**

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Pilot System, Fed Substrate, Tested Conditions

Materials and Methods

PILOT SYSTEM

- PFR, paralellepiped, stainless-steel
- Automatic, 24/24h and 7/7d feeding
- Completely automated system (feeding/discharge) by PLC
- Automatic data recording

	TS (g/kg)	VS (%TS)	pH	Total COD (gO_2/kg)	NH_4^+ (g/l)	TKN (g/kgTS)
Mean	**214.5**	**80.1%**	**5.3**	**203.5**	**0.63**	**4.7**
SD	±11.0	±3.8	±0.3	±24.9	±0.10	±0.9
n	23	23	10	10	10	10

FED SUBSTRATE

- Pure Food Waste (no garden wastes)
- From Separate collection
- Pretreated at an industrial plant with Screw Press
- Fed as collected, no dilution

TESTED CONDITIONS:

- Monodigestion of OFMSW with 21,5% TS
- Mesophillic 38.5°C
- Single phase without recirculation
- High OLR of 6.2 kgVS/m^{3}d [16] [13]
- HRT of 26 days

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2 Materials and Methods

3 **Results Discussion**

4 Conclusion

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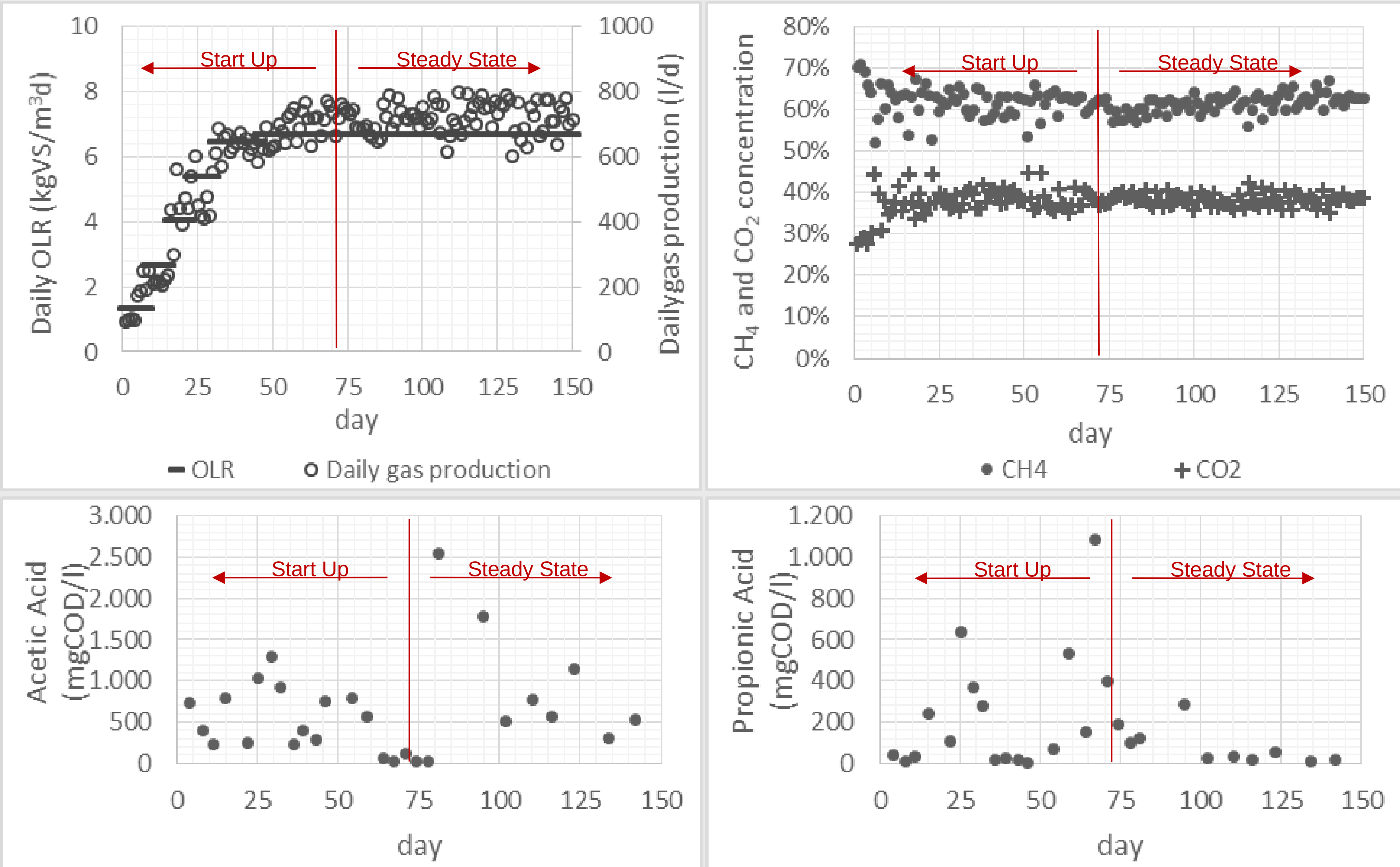
Start Up and Steady State

Result Discussion



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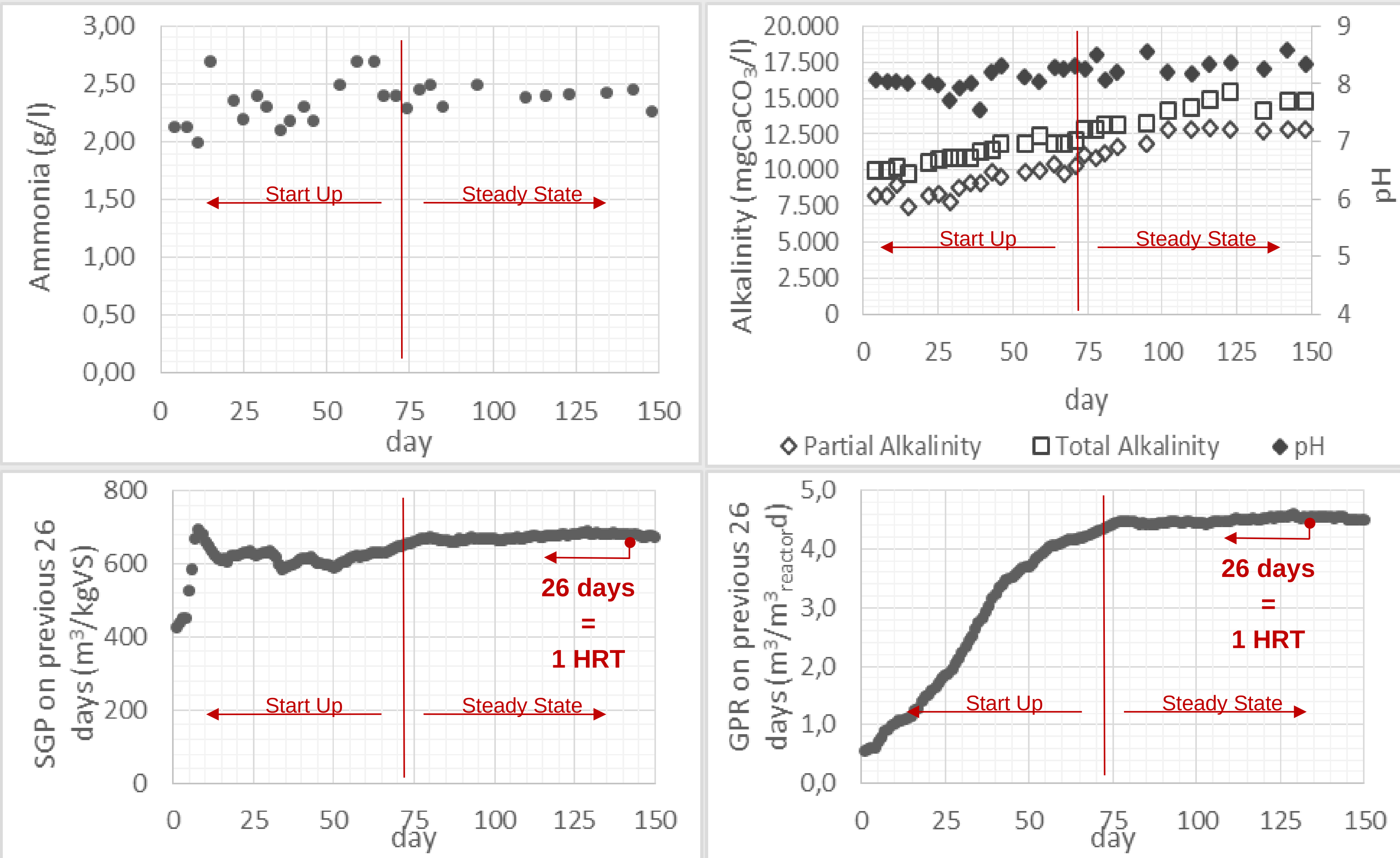
Start Up and Steady State

Result Discussion



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Average Process and Stability Parameters at Steady State

Result Discussion

Parameter	Measure Unit	Average Value (along 3 HRT)	Standard Deviation
TS	(g/kg)	83.5	±1,8
VS	(g/kg)	41.0	±4.4
VS	(%TS)	49.1%	±4.9%
pH		7.85	±0.14
Partial Alkalinity	(mgCaCO3/l)	12,046	±949
Total Alkalinity	(mgCaCO3/l)	13,840	±1,000
Total VFA	(mgCOD/l)	1,956	±1,210
Acetic Acid	(mgCOD/l)	755	±787
PropioniC Acid	(mgCOD/l)	113	±129
Butirric Acid	(mgCOD/l)	81	±107
Pentanoic Acid	(mgCOD/l)	39	±52
Hexanoic Acid	(mgCOD/l)	834	±1,012
Eptanoic Acid	(mgCOD/l)	97	±96
NH_4^+	(g/l)	2.4	±0.1
CH_4	(%)	61.4%	±2.2%
CO_2	(%)	38.2%	±1.4%
H_2S	(ppm)	358	±136
SGP	(m^3/KgVS)	0.674	±0.043
GPR	($m^3/m^3_{REACTOR}d$)	4.5	±0.3

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Comparison with other Authors results

Result Discussion

Author	Ref.	SGP	GPR	OLR	TS in feed	HRT	Type of OFMSW
		(m^3/kgVSd)	(m^3/m^3)	(kgVS/m^3d)	(%)	(d)	
This study		**0.67**	**4.5**	**6.2**	**21.5**	**26**	**SS- + MS-**
Bolzonella et al. (2003)	[17]	0.23	2.1	9.2	20	13.5	MS-
Cecchi et al. (1991)	[18]	0.26-0.40	2.5-4.1	5.9-13.5	16-22	8-15	MS-
Mata-Alvarez et al. (1993)	[19]	0.32-0.37	3.1-6.1	9.7-17.8	18-25	8-12	MS-
Vallini et al. (1993)	[20]	0.30	4.1	13.5	22	7.8	MS-
Pavan et al. (2000)	[16]	0.32	3.1	9.7	25	11.7	MS-
Pavan et al. (2000)	[16]	0.78	4.9	6.0	10	11.8	SS-
Scherer et al. (2000)	[22]	0.22	5.7	7.6	16	18	MS-
Bolzonella et al. (2006)	[23]	0,71	3.2	4-6	33	40-60	SS-

SS- Source Selected; MS- Mechanically Selected

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Main Results

Conclusion

1. The research demonstrates that the OFMSW can be treated in a mesophilic PFR with an elevate **OLR of 6.2 kgVS/m^{3}d** and without any dilution or co-substrates addition; the **SGP is 0.67 m^3/kgVS** (biogas)**.** The low SGP respect to wet processes was justified by a **high GPR of 4.5 m^3/m^{3}d**
2. The reached **Total Solid concentration of 8.4%** doesn't permit to refer as a Semy-Dry process; the observed density of the digestate could potentially however cause troubles of mixing efficiency if a normal propelled agitation system is adopted
3. A real **homogeneus feeding** is essential to allow process stability. The **mixing system** is also a key factor for a successful process :
   - to avoid sedimentation and permit full exploitation of the entire reactor volume
   - to avoid formation of floating layers or crusts
   - to assure smooth spill and release of the methane in highly dense digestate

These results encourage the treatment of sole OFMSW and the diffusion of DECENTRALIZED, SMALL SIZE, and easy to operate PLANTS

30.000 inh/eq → 100 KWel with 290 m^3 reactor

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Authors
Conclusion

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