International Water Association

Specialized Conference – Sustainable Sludge Management: State of the Art, Challenges and Perspectives

Single and two-phase thermophilic co-digestion of waste activated sludge and solid agro-waste. Performance comparison on pilot scale.

Pavan P. [1], Fatone F. [2], Cavinato C. [2], Bolzonella D. [2], Cecchi F. [2]

1 Department of Environmental Sciences, University of Venice. Calle Larga S. Marta 2137, 30123 Venice, Italy.

2 Department of Science and Technology, University of Verona. Strada Le Grazie,15 - 37134 Verona, Italy.

cropgen

Moscow, 29-31 May 2006

CROPGEN PROJECT

VI framework program financially supported by the European Union, the "Cropgen" project (contract n. SES6-CT-2004-502824).

The main aim of the cropgen project

is to firmly establish biogas technology as an economically attractive energy production process for both on and off-site use.

Our role into the partnership
concerns the thermophilic anaerobic co-digestion of solid agro-waste (mainly rest of fruits and vegetables from markets) with waste activated sludge originated from the biological treatment of municipal wastewaters

the applicable side concerns the best exploitation of the already existing anaerobic digesters (more than 36000 in EU)

cropgen

This paper deals with:

the results of 2 years experimenting

- in single and two-phases plant confugurations
- on big size pilot plants
- always on substrates from full scale Treviso plant
- on growing OLRs (~ 2-4-6… $kgTVS_f\ m^{-3}\ d^{-1}$) so to reach the stress loading of the system *(this work is still in progress…)*

The pilot plant: single phase

- 200 lt working volume
- mechanically stirred,
- electrically heated at 55°C +/- 1°C
- fed once a day

cropgen

The pilot plant: two phases

- 800 lt working volume
- mechanically stirred
- electrically heated at 55°C +/- 1°C
- fed once a day

Digester

I° Phase

cropgen

Substrates characteristics

WAS from full scale BNR WWTP operating SRT of 14 ÷ 16 days

Organic Wastes from the Treviso full scale plant

Run	I	II	III	IV
Sludge				
pH	6,81	7,16	7,01	7,03
NH_3 (mg/l)	2,4	4,0	8,6	7,0
TKN (mgN/l)	1.341	778	2.127	1.520
Ptot (mgP/gTS)	15,5	15,6	13,7	13,8
COD (mgCOD/l)	13.079	8.391	26.651	20.933
TS (g/l)	22,9	16,4	47,9	25,8
TVS (g/l)	14,3	10,5	25,8	21,1
TVS (%TS)	62,7	64,2	53,0	59,0
VFA (mgCOD/l)	9,8	26,7	76,0	115,0
Market waste				
TKN (mgN/gTS)		31	33	30
Ptot (mgP/gTS)		3,4	3,6	4,4
COD (mgCOD/l)		200.000	210.790	194.150
TS (g/l)		250	283	213
TVS (g/l)		210,6	238,0	184,7
TVS (%TS)		82,4	83,7	86,7
VFA (mgCOD/l)			1.059	

cropgen

Conditions studied till now

- **Single phase:**

Start-up ~ 45 days
Period I ~ 42 days
Period II ~ 50 days
Period III ~ 45 days

Run	Start-up	I	II	III
Operating conditions				
T, °C	55,0	54,8	54,5	55,1
HRT (days)	20	18	16	14
OLR (kgTVSf/m3 d)	0,66	2,19	3,97	6,18

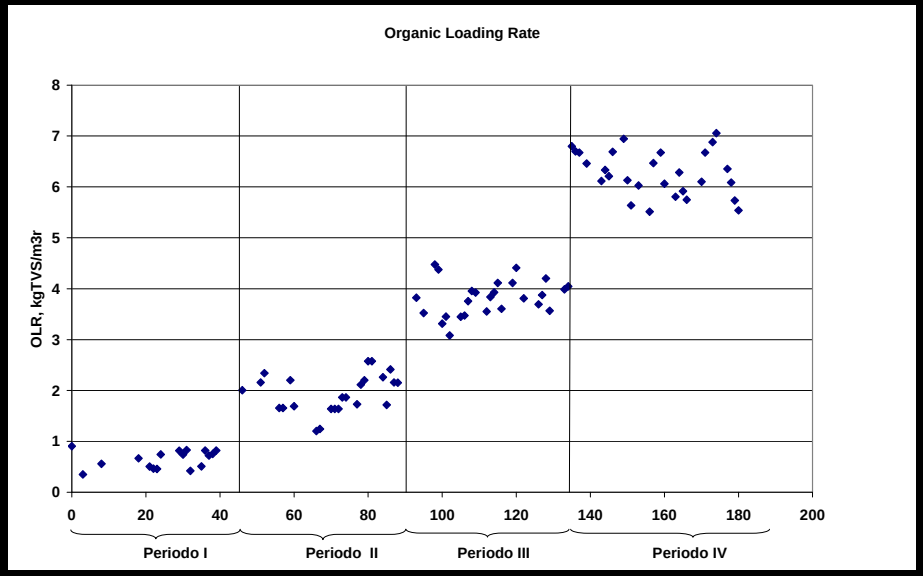
- **Two phases:**

Start-up ~ 35 days
Period I ~ 55 days
Period II ~ 140 days
Period III ~ *in progress*

Run	Start-up	I	II	*III+*
Operationg conditions				
T, °C (I phase)	55,1	55,3	54,7	*54,8*
T, °C (II phase)	55,0	55,1	54,9	*54,5*
HRT, days (I phase)	1	1	1	*1*
HRT, days (II phase)	16,0	14,1	13,6	*12,9*
OLR, kg TVSf/m^3d (I phase)	12,4	26,1	56,3	*74,4*
OLR, kg TVSf/m^3d (II phase)	0,84	1,82	4,15	*5,70*

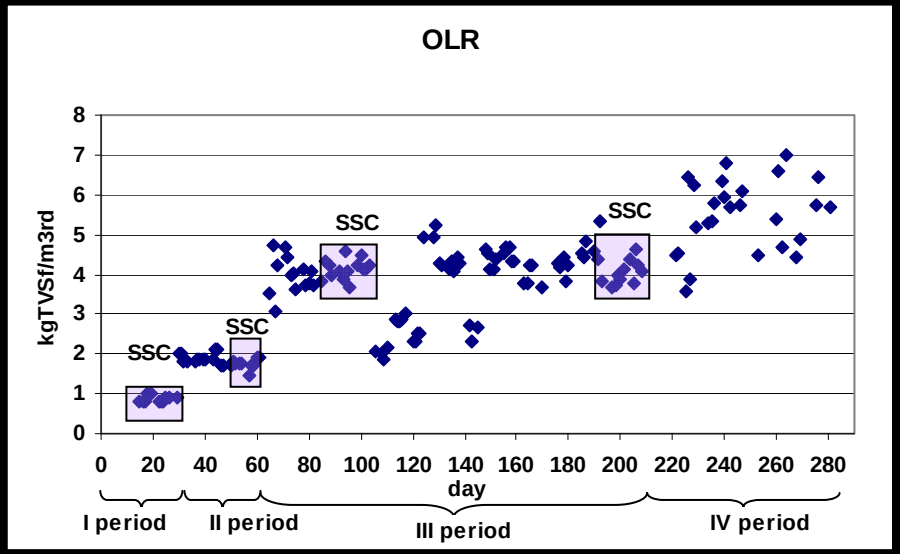
cropgen

OLRs operated



Single phase

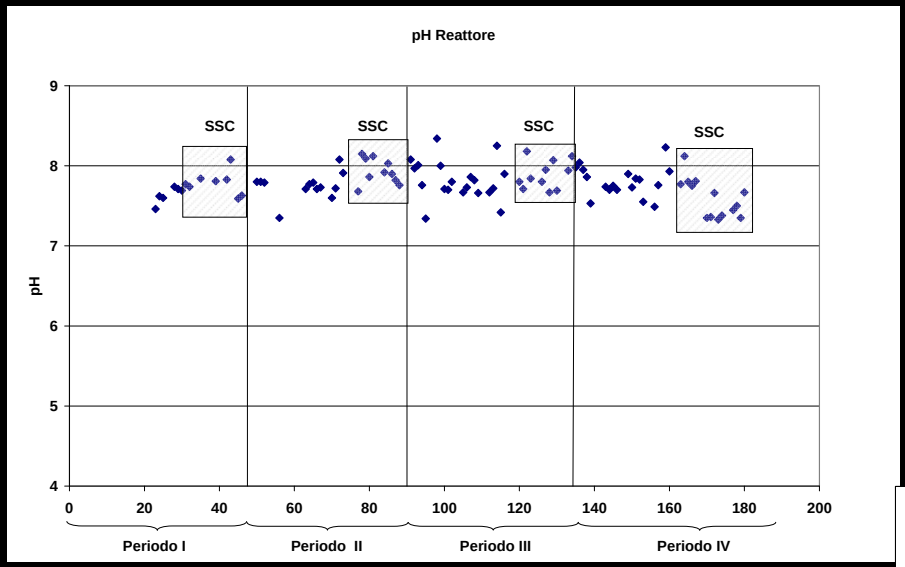
Two phases



cropgen

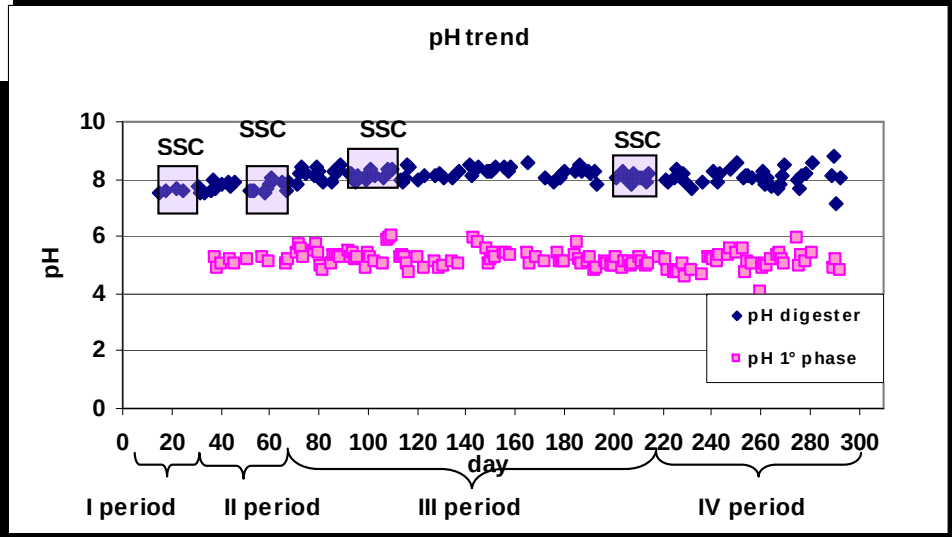
Moscow, 29-31 May 2006

Process Stability, pH



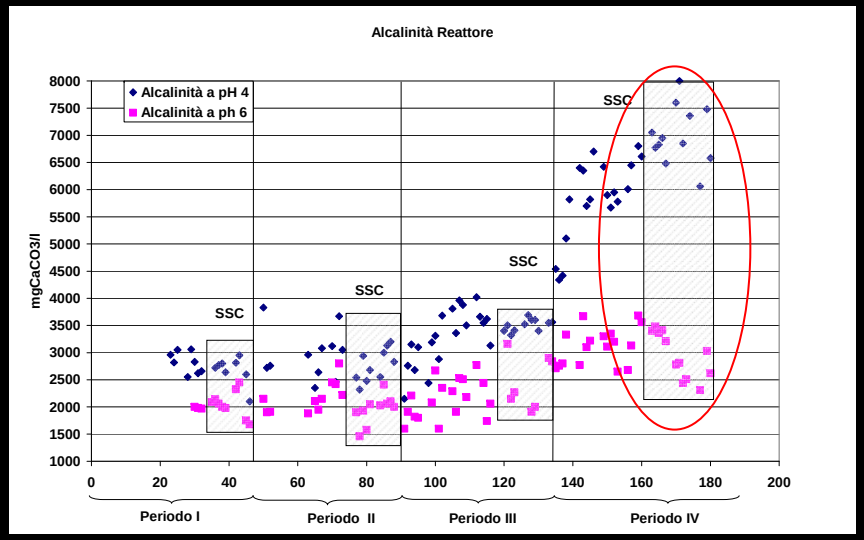
Single phase

Two phase



cropgen

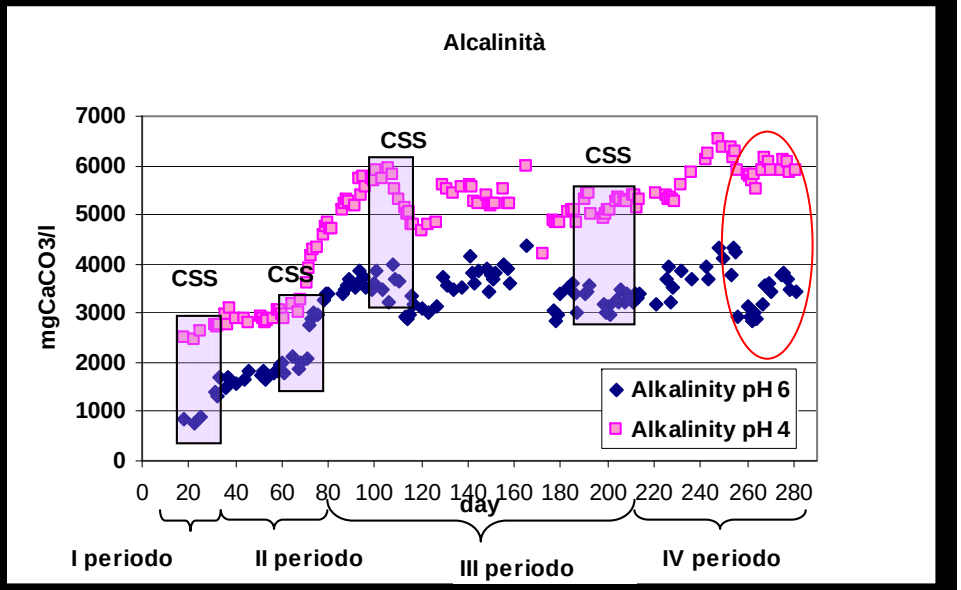
Process Stability, Alkalinity



Single phase:

Buffer capacity from ~2700 to ~7000 mgCaCO3/l

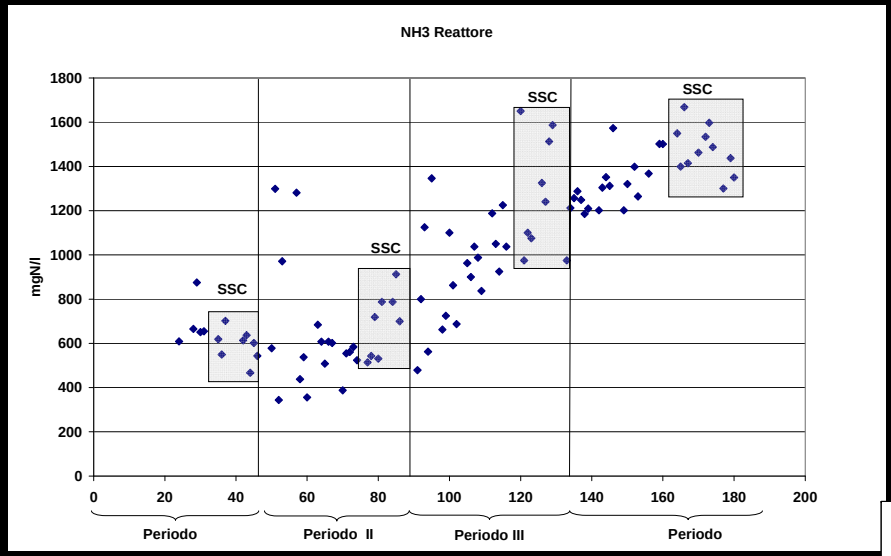
Two phase



cropgen

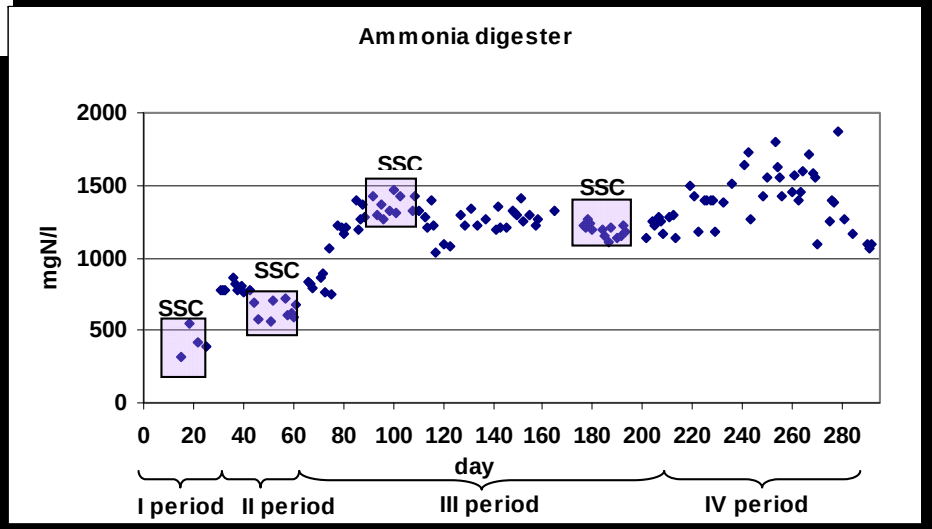
Moscow, 29-31 May 2006

Process Stability, Ammonia



Single phase:
from ~ 600 to ~ 1500 mg/l

Two phase



cropgen

Moscow, 29-31 May 2006

SSC: Single phase characteristics

Run	Start-up	I	II	III
Reactor				
pH	7,83	7,90	7,89	7,59
TA(6), $mgCaCO_3/l$	2.029	1.952	2.345	2.947
TA(4), $mgCaCO_3/l$	2.678	2.767	3.505	7.000
VFA, mgCOD/l	50	70	200	321
NH_3/, mgN/l	598	687	1.265	1.473
TS, g/kg	21.3	27.0	42.0	62.1
TVS, g/kg	12.4	17.0	28.9	41.3
TVS reduction, %	20	50	48	57
COD, mg O2/l	14.600	17.110	30.930	40.980
TKN, mgN/l	643	839	1.910	2.580
Ptot, mgP/gTS	23,0	16,5	12,8	6,0

→ Process is feasible

→ fits existing digesters

cropgen

SSC: Two phases characteristics-I

Run	Start-up	I	II	*III**
I phase				
pH		5,17	5,38	*5,12*
NH3 (mg/l)		222	450	*531*
TKN (mgN/l)		1.162	2.405	*2.262*
Ptot (mgP/gTS)		10,7	8,8	*10,68*
COD (mgCOD/l)		16.354	39.120	*47.531*
TS (g/l)		24,7	58,8	*60,0*
TVS (g/l)		17,7	39,9	*44,1*
TVS (%TS)		71,6	65,5	*73*
VFA (mgCOD/l)		2.816	6.764	*7.701*

→ Seem too high…

** Period still in progress*

SSC: Two phase characteristics-II

Run	Start-up	I	II	*III**
	II reactor			
pH	7,59	7,67	8,19	*8,02*
NH3 (mg/l)	416	622	1.317	*1.512*
TA(6), $mgCaCO_3/l$	833	1.808	3.658	*3.449*
TA(4), $mgCaCO_3/l$	2.503	2.921	5.509	*5.955*
TKN (mgN/l)	921	732	1.491	*1.274*
Ptot (mgP/gTS)		16,0	12,1	*18,4*
COD (mgCOD/l)	11.438	12.018	23.526	*23.038*
TS (g/l)	21,3	21,5	45,5	*38,63*
TVS (g/l)	12,5	12,8	24,5	*22,10*
TVS (%TS)	58,8	60,5	54,2	*57,2*
VFA (mgCOD/l)	124	87	126	*411*

→ but process is feasible

** Period still in progress*

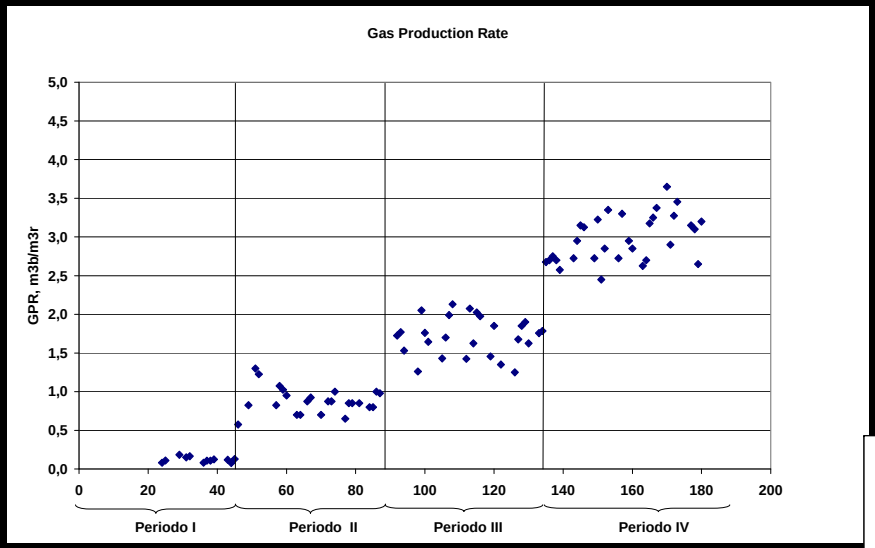
cropgen

SSC yields – final comparison

Run	Start-up		I		II		III	
	S.P.	T.P.	S.P.	T.P.	S.P.	T.P.	S.P.	*T.P.**
GPR (m^3/m^3r d)	0,12	0,10	0,85	0,71	1,65	1,62	3,12	*2,68*
SGP (m^3/kgTVSf)	0,16	0,12	0,41	0,41	0,42	0,39	0,51	*0,38*
SGP_{sludge} (m^3/kgTVSf)	0,16	0,12	0,16	0,12	0,16	0,12	0,16	*0,12*
SGP_{OFMSW} (m^3/kgTVSf)	-	-	0,55	0,58	0,52	0,54	0,59	*0,60*
CH4, %	-	-	-	73	-	72	67	*70*
TVS Reduction, %	20	18	50	51	48	58	57	*58*
HRT (d)	20	-	18	-	16	-	14	-
HRT, I° phase (d)	-	1	-	1	-	1	-	*1*
HRT, II° phase (d)	-	16,0	-	14,1	-	13,6	-	*12,9*

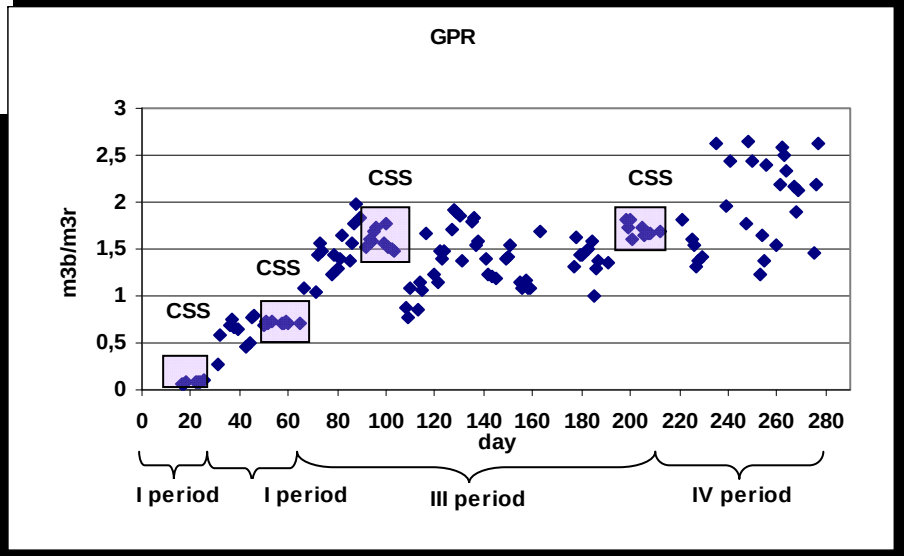
cropgen

Yields, GPR



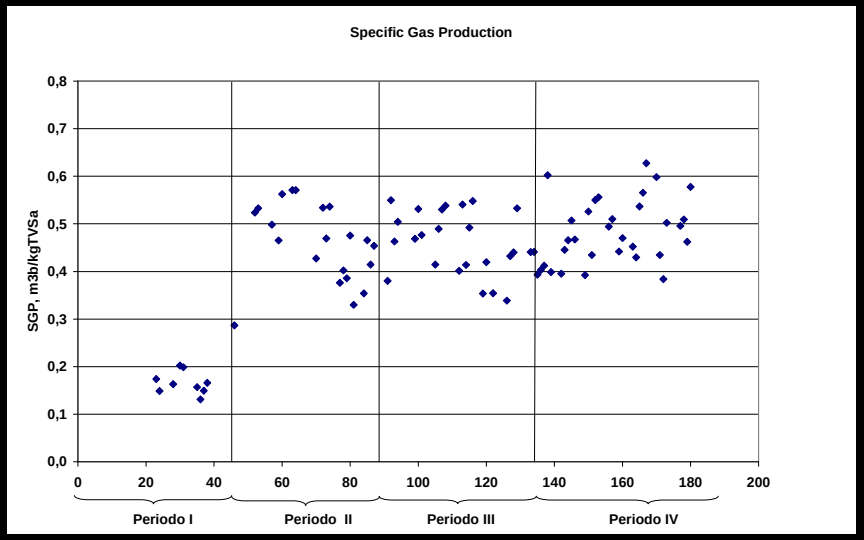
Single phase

Two phase



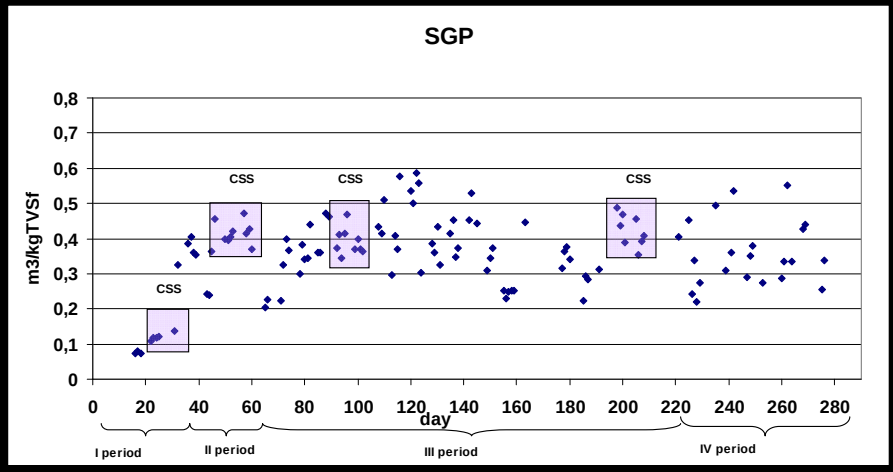
cropgen

Yields, SGP



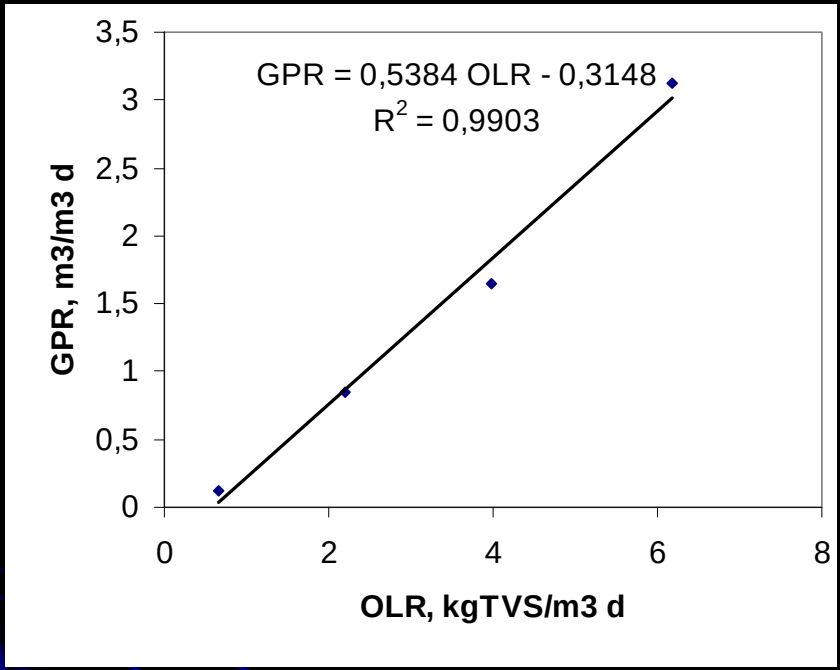
Single phase

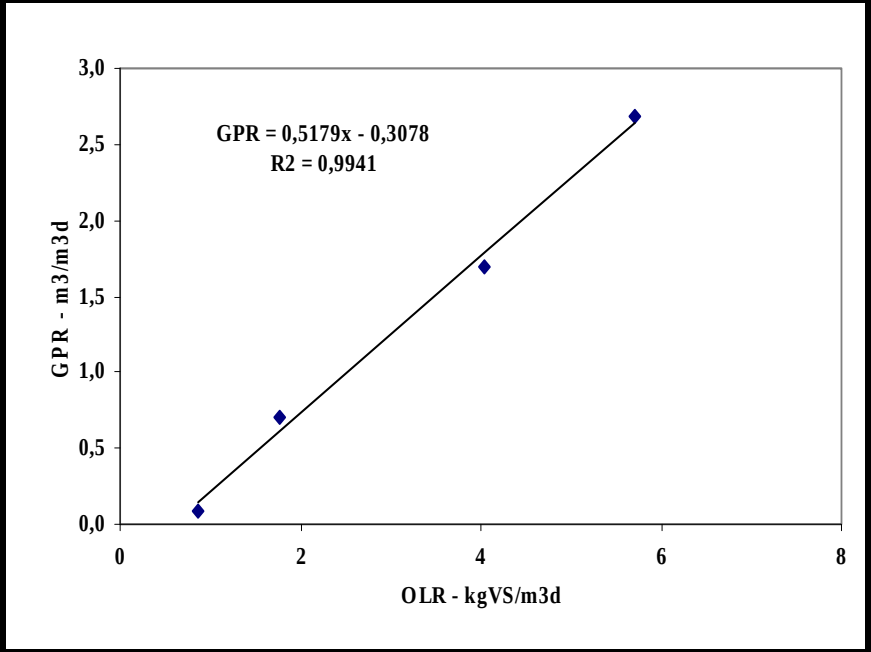
Two phase



cropgen

GPR-OLR

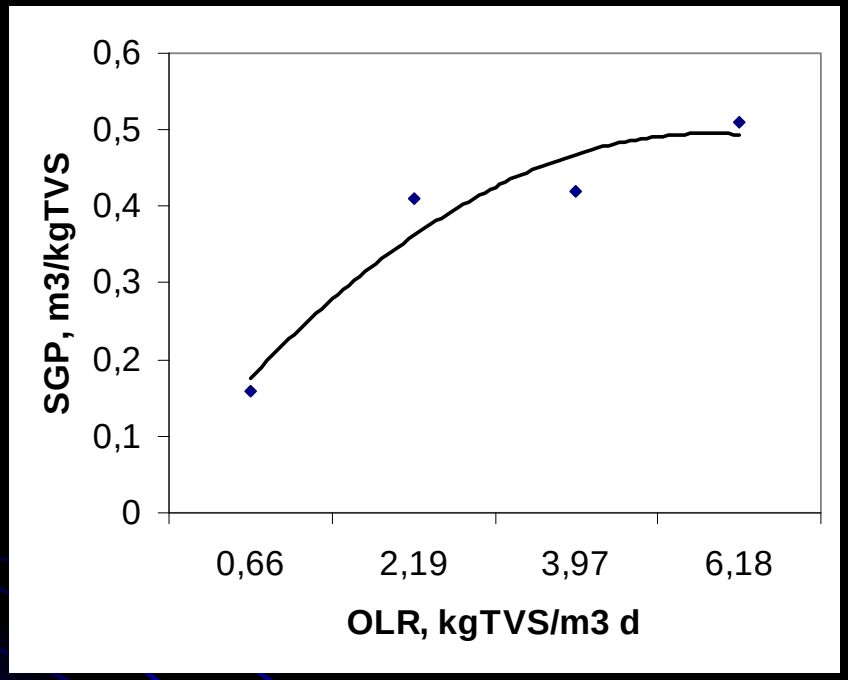


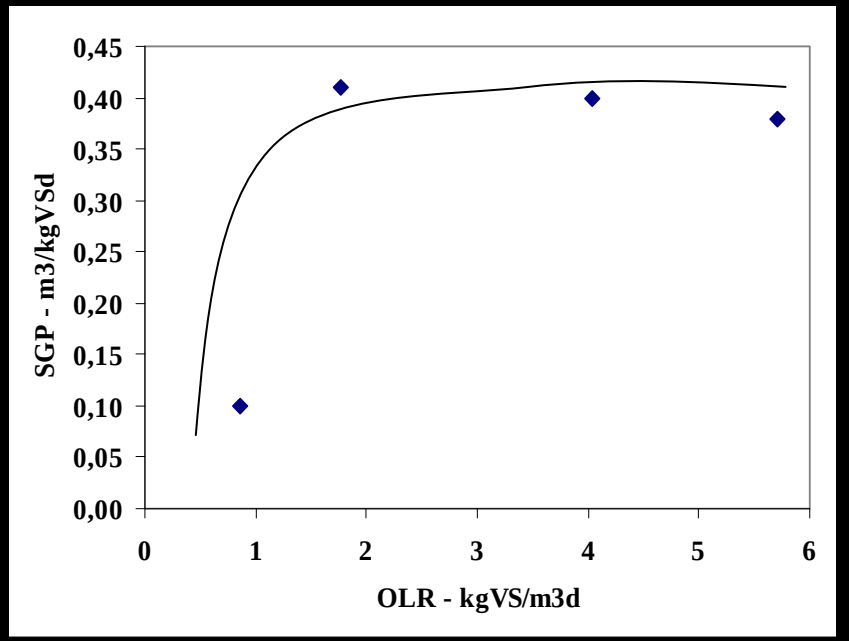


Single phase

Two phase

SGP-OLR





Single phase

Two phase

Conclusions I

The work shows how is possible to implement the thermophilic codigestion process to treat activated sludge and agro wastes coming from markets. In particular:

- **OLRs ranging from 2 to 6 kgTVS/m^{3}d showed a completely stable situation. pH and alkalinity values were always in typical ranges. The addition of increasing amount of waste in the feeding led to the improvement in buffer capacity of the digester (from 2700 to 7000 mg $CaCO_3$/l and from 2500 to 6000 mg $CaCO_3$/l);**

- Biogas production (GPR) in both cases increase linearly with OLR;

Conclusions II

- As for SGP vs OLR, the two phases allows to reach the max specific yield since the second period (2 **kgTVS/m^3** d), while in the single phase process this happens only at the highest load (6 **kgTVS/m^3** d).

- Single and two phases thermophilic co-digestion did not show relevant differences for OLRs up to 4 kgTVS $m^{-3}d^{-1}$

- In the last period (6 kgTVS/m^3 d), the alkalinity trend of two phases process shows the possibility to increase the amount of waste up to 8 kg TVS/m^3 d. This is the development of the research.

cropgen

Thank you
for your attention !