ANAEROBIC DIGESTION OF MARKET AGRO-WASTES

Cropgen Project – Renewable energy from crops and agro-wastes

Franco Cecchi, David Bolzonella
University of Verona - Department of Science and Technology

Paolo Pavan
University of Venice - Department of Environmental Sciences

www.cropgen.soton.ac.uk

About Cropgen....

- It is a research project funded by the EU's 6th Framework Programme, involving 11 partners in 6 European countries.
- The overall objective of the research is to produce from biomass a sustainable fuel source that can be integrated into the existing energy infrastructure in the medium term, and in the longer term will also provide a safe and economical means of supplying the needs of a developing hydrogen fuel economy.
- The concept is based on the use of anaerobic digestion (AD) as a means of producing methane from biomass, including energy crops and agricultural residues.
- The research will determine how the technology can best be applied to provide a versatile, low-cost, carbon-neutral biofuel in an environmentally sound and sustainable agricultural framework

Partners….

- School of Civil Engineering and the Environment, University of Southampton, UK (Soton) *and* Centre for Under-utilised Crops, University of Southampton, UK, (Soton - CUC)
- Department of Environmental Science, University of Jyväskylä, Finland (JyU)
- Subdepartment of Environmental Technology, Department of Agrotechnology and Food Sciences, Wageningen University, Netherlands (WU)
- Department of Environmental Biotechnology, Institute for Agrobio-technology BOKU University of Natural Resources & Applied Life Sciences, Austria.
- Institute of Applied Microbiology, BOKU University of Natural Resources & Applied Life Sciences, Austria (BOKU - IAM)
- Department of Environmental Sciences, University of Venice, Italy (UNIVE-DSA)
- Department of Science and Technology, Università degli Studi di Verona, Italy (UNIVR-DST)
- Industrial Process & Environment Department, Instituto de la Grasa, Spain (CSIC)
- Greenfinch Ltd, UK (Greenfinch)
- Organic Power Ltd, UK
- Metener Ltd, Finland (Metener)

7 Universities, 1 Research Centre, 3 Companies

Trials on single phase thermophilic anaerobic co-digestion of waste activated sludge and market agro-wastes

University of Venice - Department of Environmental Sciences

cropgen

The pilot plant

200 liters working volume

mechanically stirred,

electrically heated at 55°C +/- 1°C

fed once a day

cropgen

Feed characteristics

Run	I	II	III	IV
feed				
Sludge				
pH	7,04	7,27	7,00	7,06
Alkalinity (mgCaCO3/l)	416	315	361	350
NH3 (mgN/l)	26,7	11,3	33,5	15,8
TKN (mgN/l)	1335	865	1595	1873
Ptot (mgP/gTS)	20,4	17,5	17,3	8,4
COD (mgCOD/l)	21.942	21.734	20.178	20.742
TS (g/kg)	20,9	24,8	30,4	34,6
TVS (g/kg)	13,3	13,9	20,5	21,7
%TVS	62,0	60.0	67.0	60,8
VFA (mgCOD/l)	49,8	40,1	62,5	
Market wastes				
TKN (mgN/gTS)		27,3	28,5	32,3
Ptot (mgP/gTS)		5,1	7,3	3,9
COD(mgCOD/gTS)		912	920	841
TS (g/kg)		242,5	241,6	276,4
TVS (g/kg)		192,8	198,4	218,7
%TVS		79,9	83,3	32,3

cropgen

Mixture characteristics

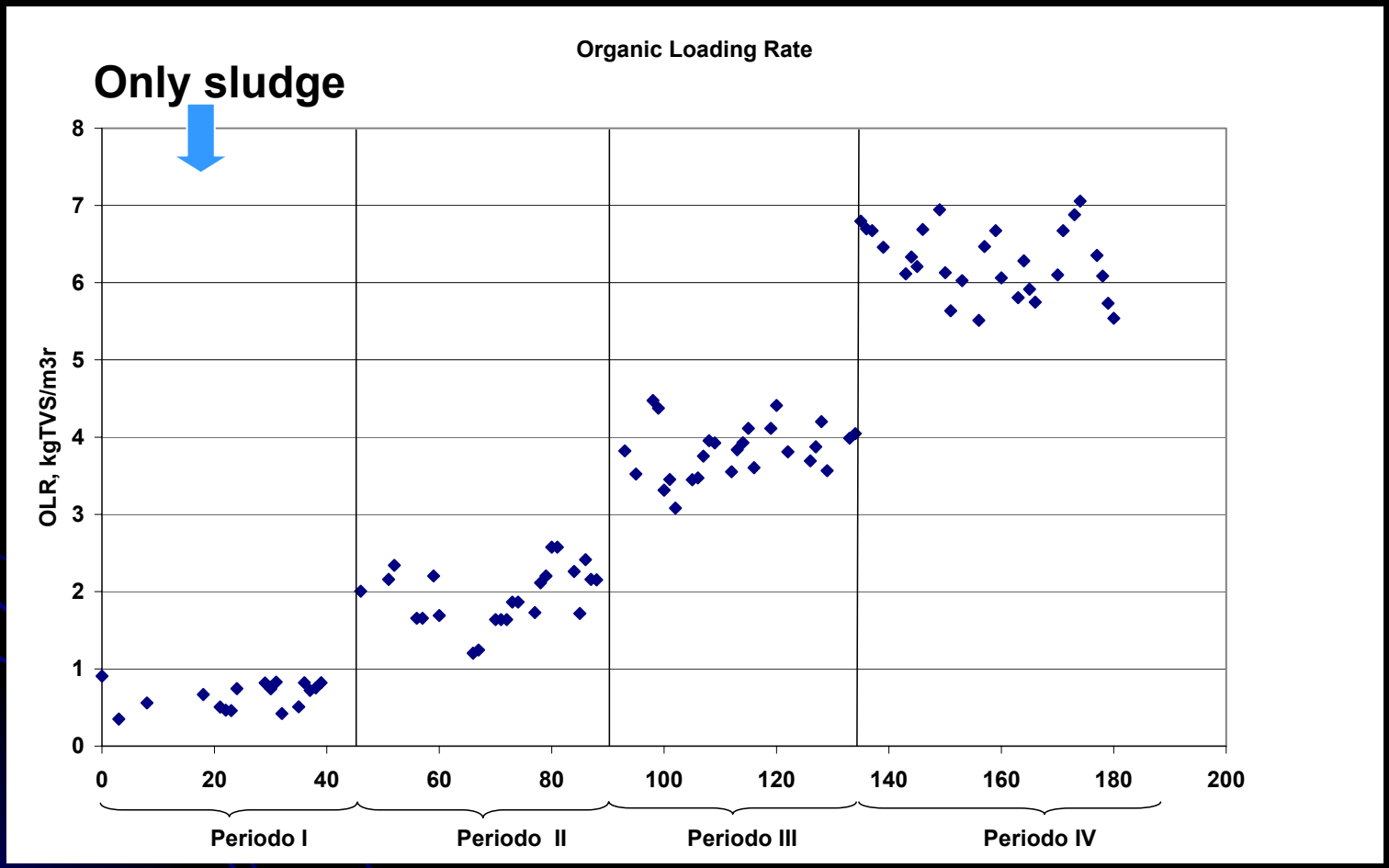
Run	I	II	III	IV
Mix				
pH	7,04	6,08	5,55	5,78
Alkalinity (mgCaCO3/l)	416	682	730	1019
NH3 (mgN/l)	26,7	40,1	95,6	131,2
TKN (mgN/l)	1335	1477	3282	3592
Ptot (mgP/gTS)	20,4	12,8	10,6	5,2
COD (mgCOD/l)	21.942	35.380	61.190	88.826
TS (g/kg)	20,9	45,2	75,7	106,2
TVS (g/kg)	13,3	33,9	60,2	82,9
%TVS	62,0	73,1	78,3	77,8
VFA (mgCOD/l)	49,8	192,8	522,4	

cropgen

Operational conditions studied

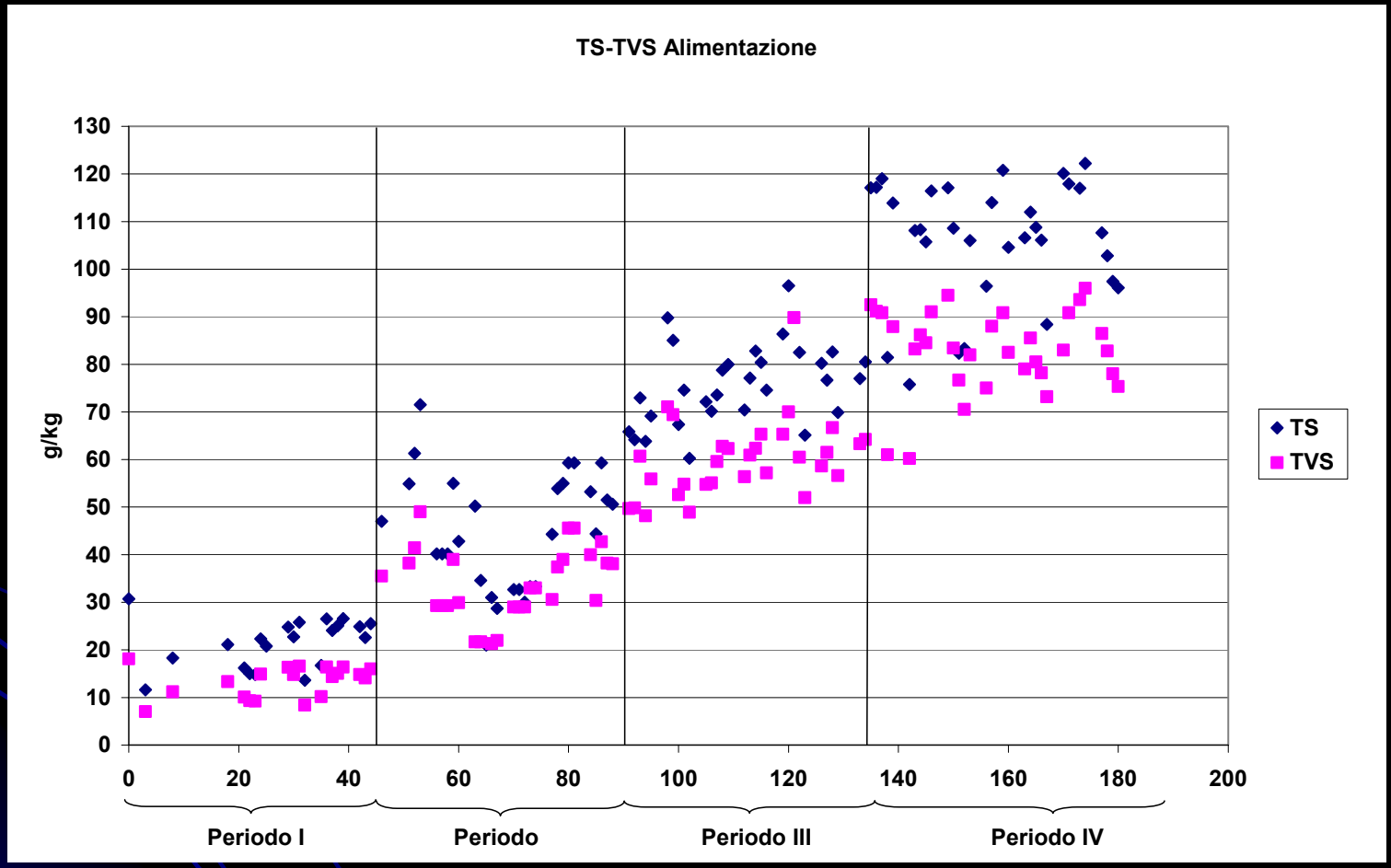
Run	I	II	III	IV
Operational conditions				
T, °C	55.0	54.8	54.5	55.1
HRT (day)	20	18	16	14
OLR (kgTVSa/m3r)	0,66	2,19	3,97	6,18

Applied Organic Loading Rate, (kgVS per m^3 per day)

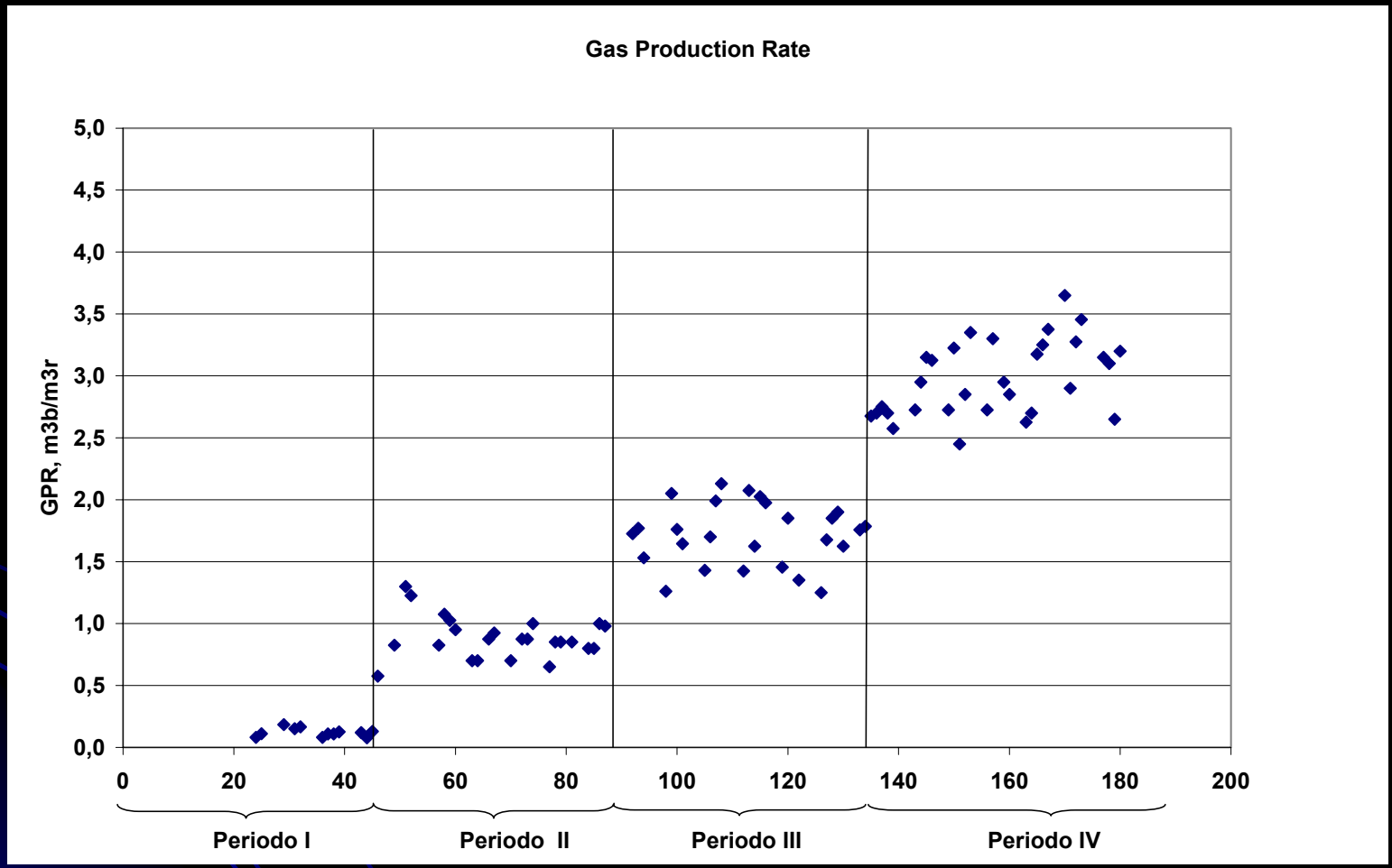


cropgen

Total and Volatile Solids in the feed

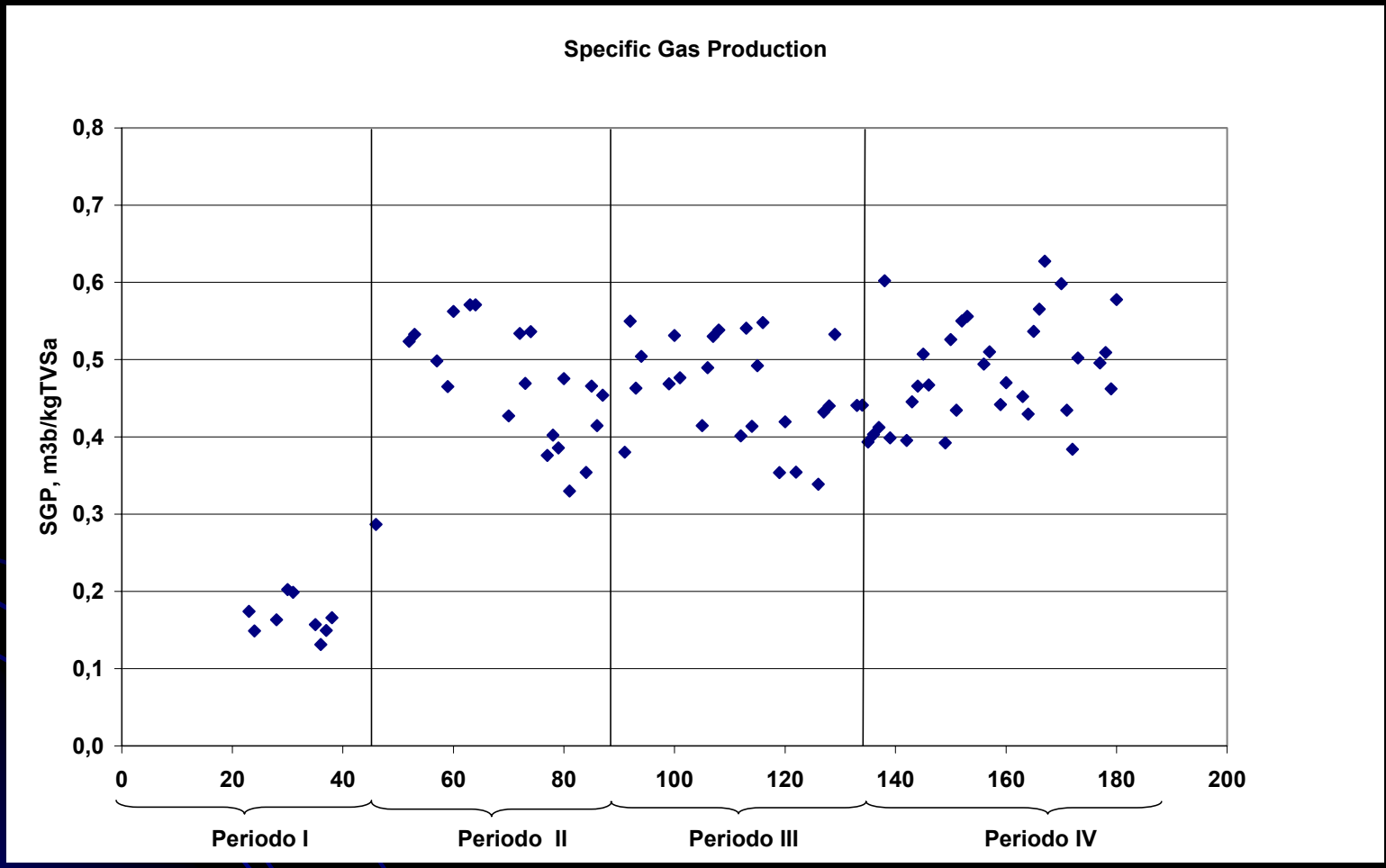


Yields, Biogas Production Rate (m^3 per m^3 reactor per day)

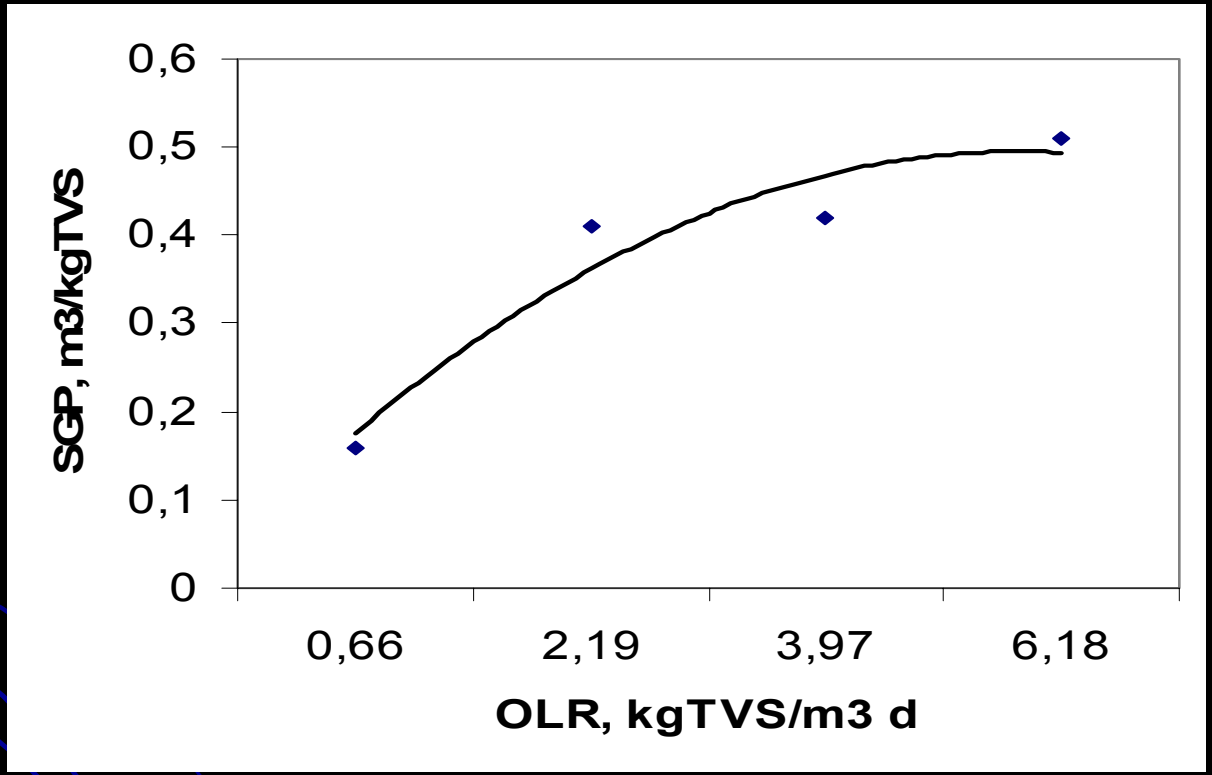


cropgen

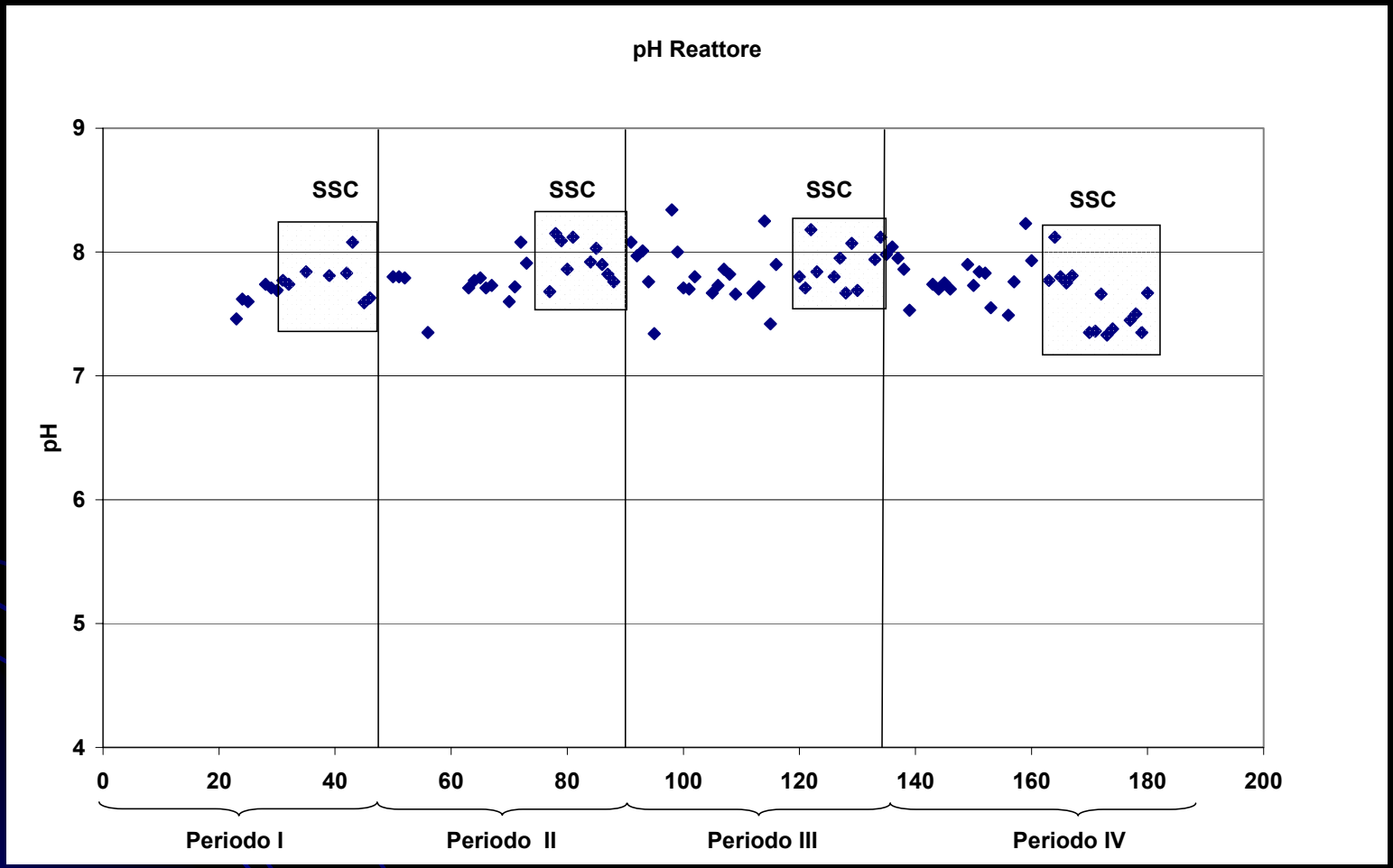
Yields, Specific Biogas Production (m^3 per kg VS fed)



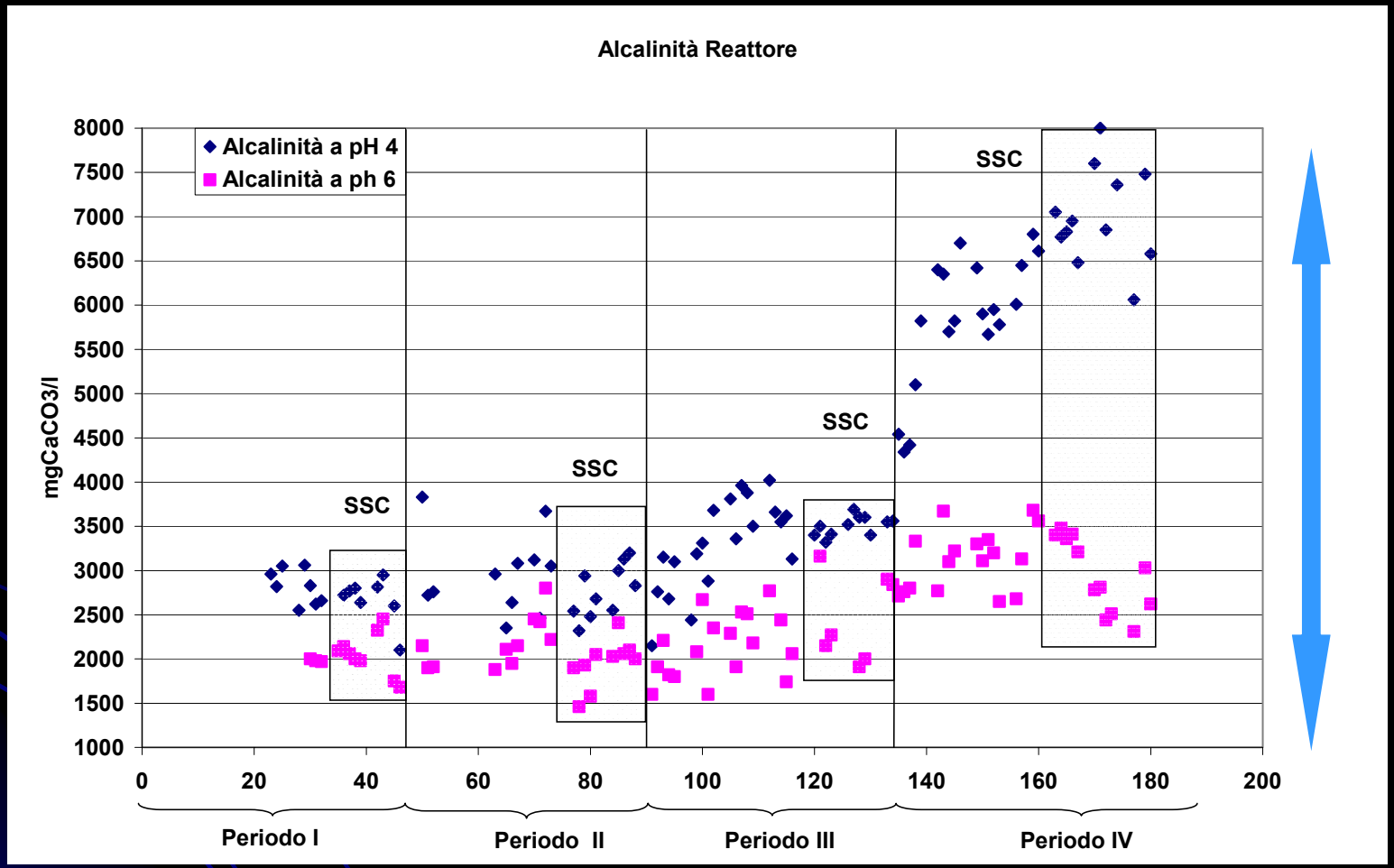
Biogas yields vs OLR



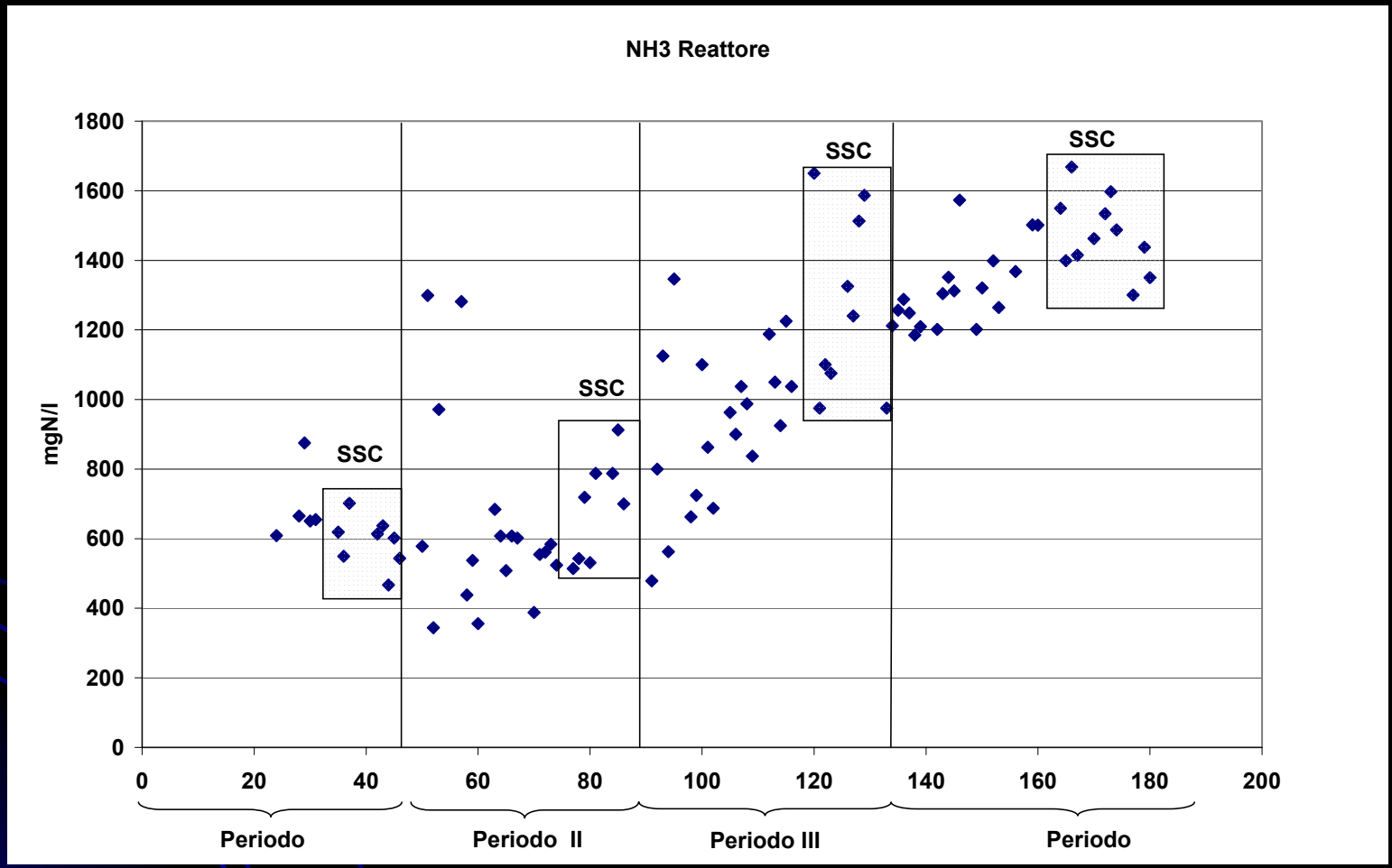
Process stability, pH



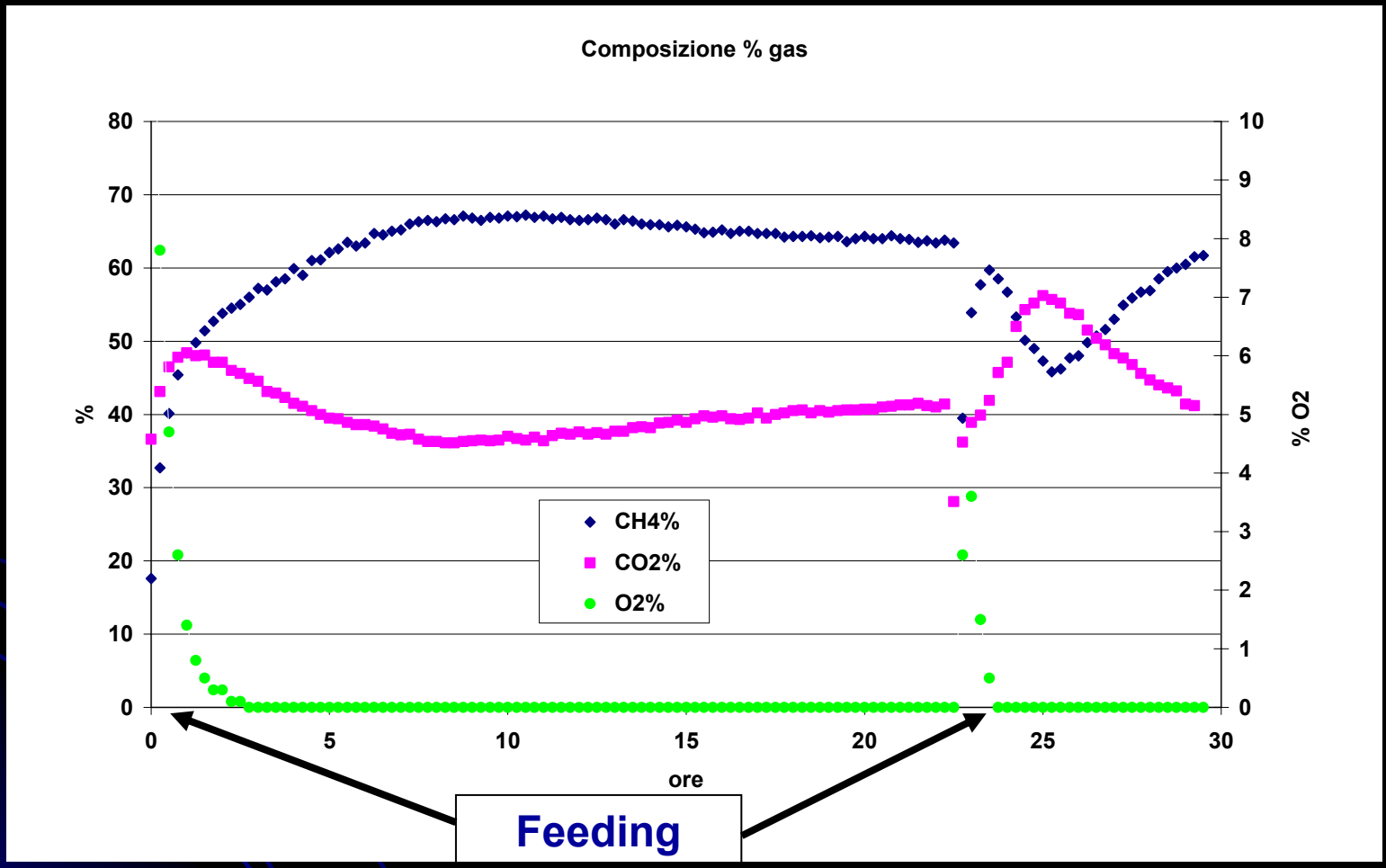
Process stability, Alkalinity



Reactor NH_3-N



CH_4-CO_2 trends



SSC reactor characteristics

RUN	I	II	III	IV
Reactor				
pH	7,83	7,90	7,89	7,59
TA (4), (mgCaCO3/l)	2678	2767	3505	7000
TA (6), (mgCaCO3/l)	2029	1952	2345	2.947
NH3 (mgN/l)	598	687	1.265	1.473
TKN (mgN/l)	643	839	1.909	2.583
Ptot (mgP/gTS)	23,0	16,5	12,8	6,0
COD (mgCOD/l)	14.600	17.109	30.932	40.983
TS (g/kg)	21,3	27,0	42,0	62,1
TVS (g/kg)	12,4	17,0	28,9	41,3
%TVS	56,2	65,0	69,1	66,0
VFA (mgCOD/l)	156,2	69,9	199,8	

cropgen

SSC yields

Run	I	II	III	IV
GPR (m3/ m3r)	0,12	0,85	1,65	3,12
SGP (m3/ kgTVSf)	0,16	0,41	0,42	0,51
SGP_{sludge}(m3/kgTVSf)	0,16	0,16	0,16	0,16
SGP_{waste}(m3/kgTVSf)	-	0,55	0,52	0,59
CH_4,%	-	-	-	67
HRT (d)	20	18	16	14
TVS reduction, %	20	50	48	57

SGP for waste = ~ 0.55 m^3/kgTVS

cropgen

PARTIAL CONCLUSIONS

- Thermophilic start up is possible using waste activated sludge as inoculum at an OLR=0.6-0.7 kgTVS/m^3d, HRT= 20 days;
- The process is very stable in the OLR range of 2-6 kgTVS/m^3d. VFAs concentration was < 300 mg/l;
- Average SGP of 0.55 m^3/kgTVS;

Next steps

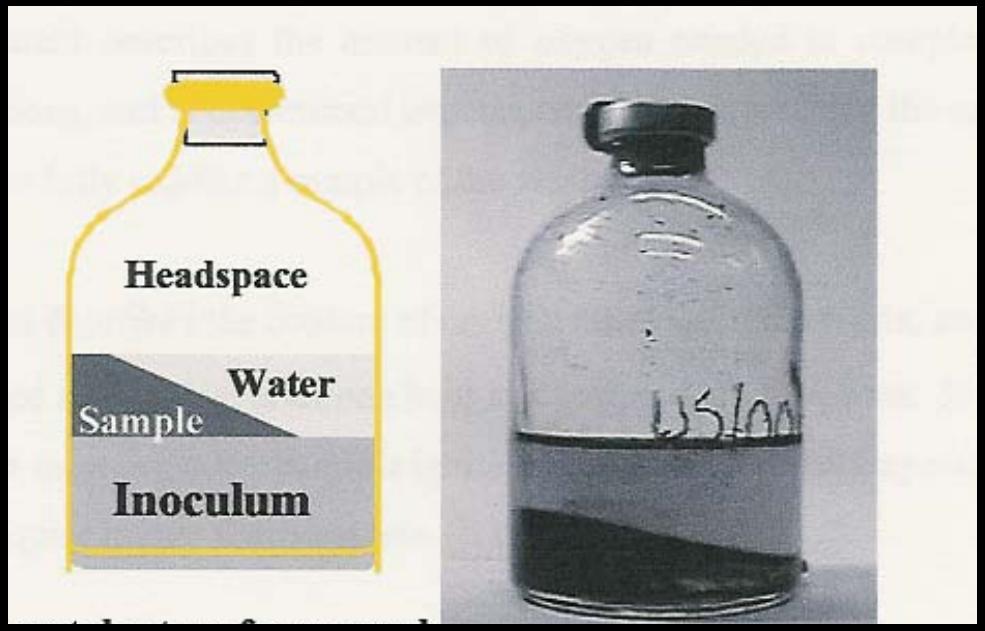
- Two phase experiments: thermo-thermo
- Solid recycling to uncouple SRT and HRT

BMP and kinetic modelling for design purposes

University of Verona
Department of Science and Technology

cropgen

BMP determination



- Owen – like (1979): > 30 days batch digestion of inoculum + substrate
- triplicate
- measurement of produced biogas (methane)
- specific methane yield (liter (STP)/g VS added)

Substrate size:

~ 10 mm

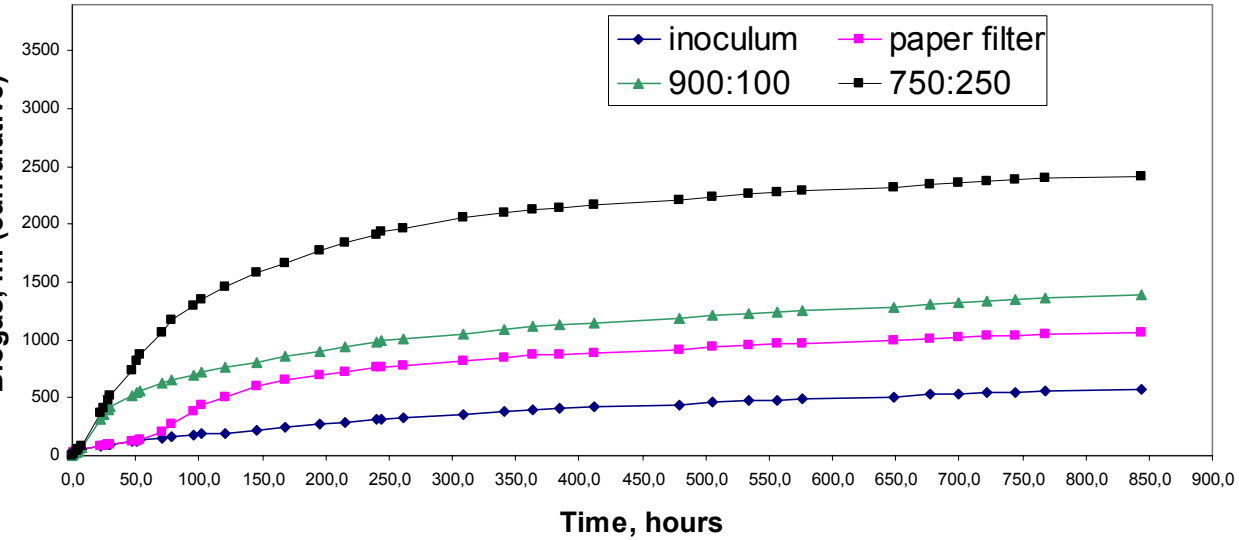
cropgen

An adapted inoculum, if you can…

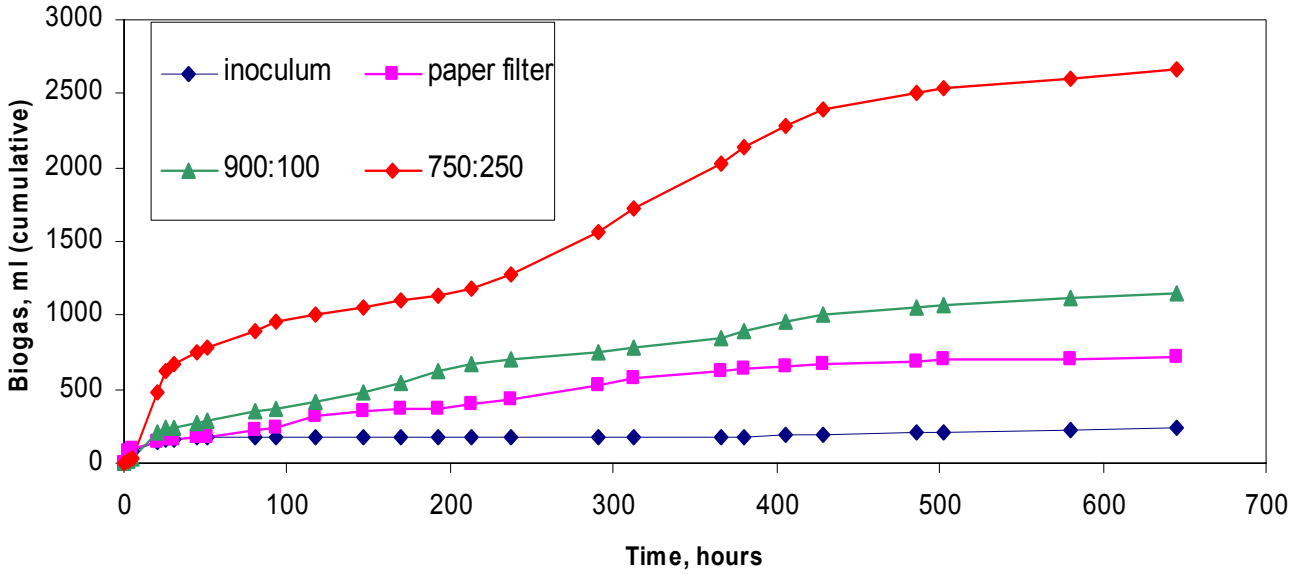
$$V_{inoculum} = \frac{V_{sub} \cdot VS_{sub} \cdot K_h}{VS_{inoc} \cdot A_{inoc}}$$

$V_{inoculum}$	= volume of the inoculum (sludge), litre
V_{sub}	= volume of the substrate, litre
VS_{sub}	= volatile matter in the substrate, gCOD/l
K_h	= first order hydrolysis constant, d^{-1}
VS_{inoc}	= volatile matter in the inoculum, gVS/l
A_{inoc}	= activity of the inoculum, $gCODgVS^{-1}d^{-1}$

Mesophilic trials



Thermophilic trials



BMP values determined

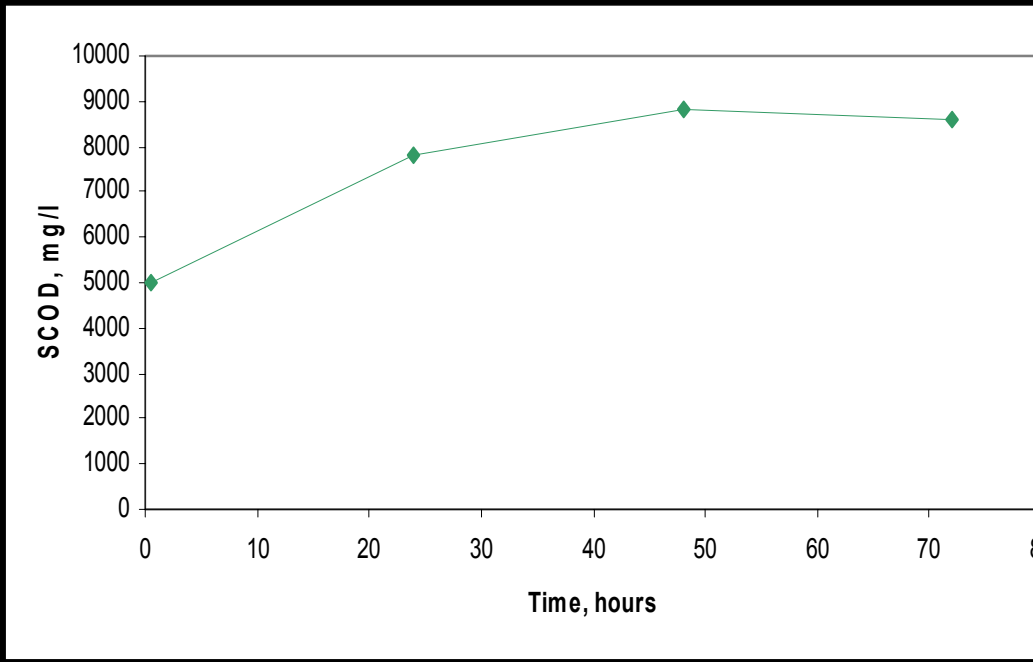
Mesophilic conditions (37 °C) =

0.730 +/- 0.137 litre/gVS (@ STP)

Thermophilic conditions (55 °C) =

0.850 +/- 0.222 litre/gVS (@ STP)

Trials for the determination of the hydrolyisis constat



Applying a model for a first order kinetic

$$\frac{dS}{dt} = -k \cdot S$$

cropgen

Determination of the hydrolysis constants (very preliminary results)

Value of the hydrolysis constant, k (1/day)

Mesophilic conditions : 0,17 1/d

Thermophilic conditions : 0,28 1/d

Partial conclusions

- Results indicate a good biodegradability with high BMP and values of the first order kinetic constant in both mesophilic and thermophilic conditions.

Future steps…

- New tests for the determination of the BMP and the value of the first order kinetic constant changing the size of the feeding (yogurt-like substrate)