



DEMETER



Demonstrating more efficient enzyme production to increase biogas yields
Grant Agreement n. 720714

Scientific approach for the demonstration of an enzyme effect during anaerobic digestion

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Rimini, 07.11.2018



EU funded Project





- Introduction
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- Selected results
- Conclusion

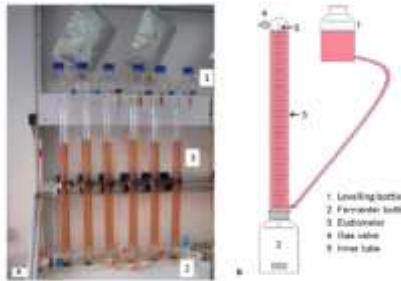


Disintegration

- a way to improve degradation by means of mechanical, chemical or biological measures
- treatment of substrates or digestate for biogas plants
- it aims to destruct the cell walls, to increase the particle surface area or to change the quality of the substrate for a faster and easier microbial use



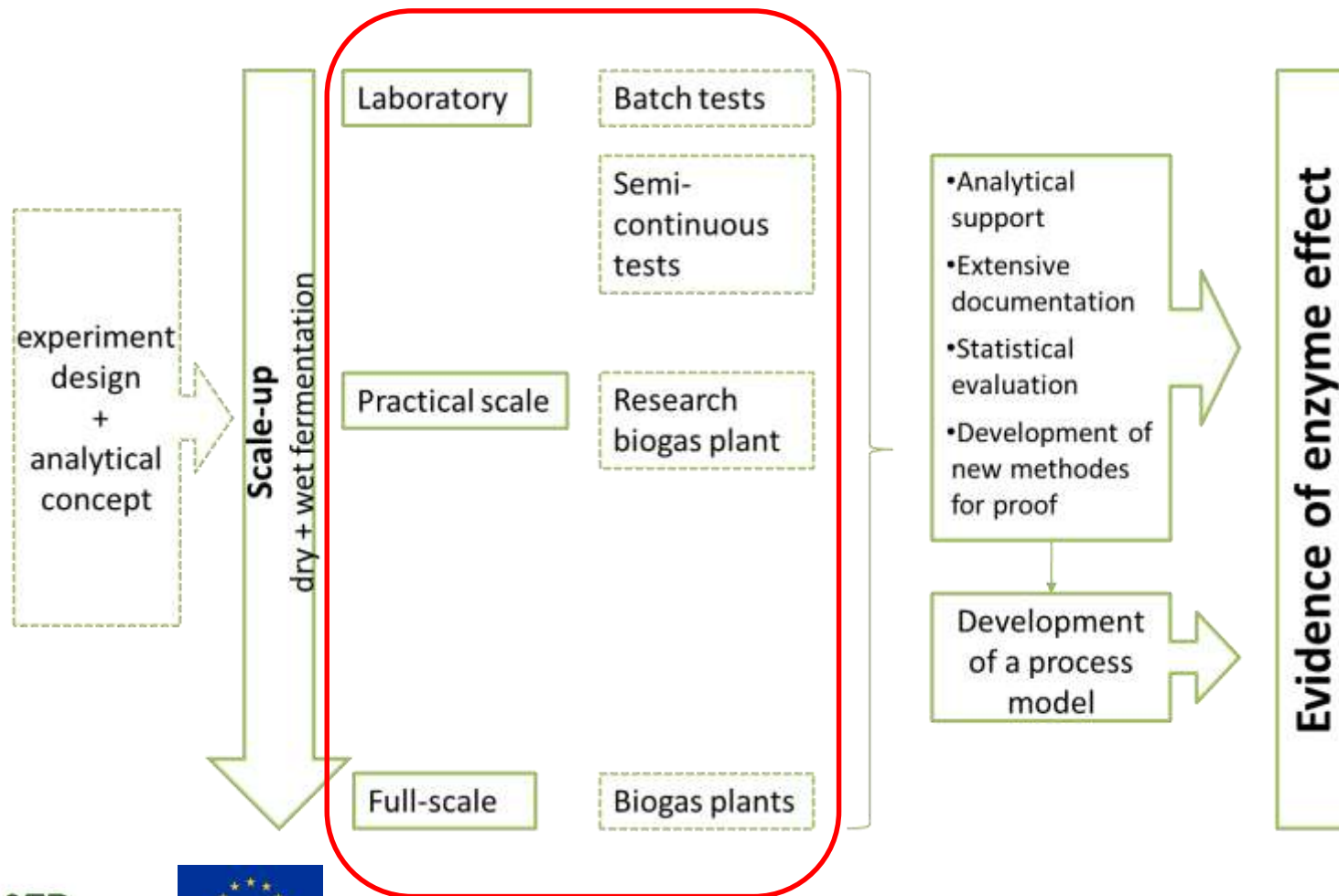
Introduction

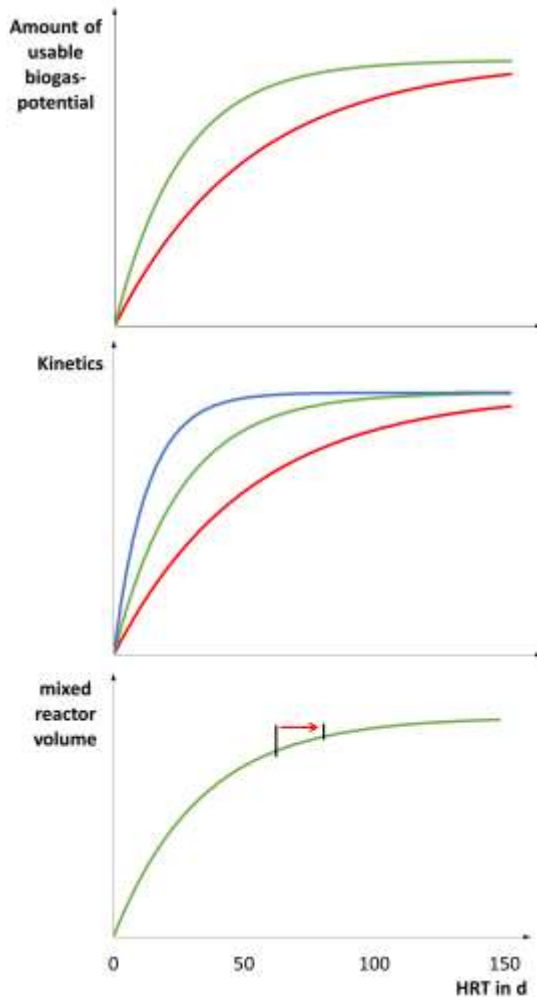


scale	Batch-Tests	Semi-continuouse rectors in lab	Full-scale
Reported effects	Increased CH ₄ -potential by AD of maize silage, rye silage, cow dung and feed residues (Quiñones et al. 2009)	Increased biogas production and higher CH ₄ -content by AD of maize silage, rye silage, cow dung and grass silage (Quiñones et al. 2011)	Raised biogas production in 30 biogas plants (Gerhardt) 30% performance increase (150 kW-biogas plant with cow manure, maize silage, grass (lawn cutting) and Reduction in viscosity (500 kW-biogas plant with cow dung) [Gerhardt und van den Heuvel 2009]
	Digestate of a full-scale plant + enzyme → no influence of CH ₄ -potential (Brulé et al. 2011)	No effect on biogas production or viscosity during AD of maize silage using 5 partly commercial enzyme products (Binner et al. 2011)	No clear effect in 10 full-scale biogas plants (FNR-Projekt BiogasEnzyme - Heiermann et al. 2014)



• Approach in DEMETER





- Increase of biogas potential
 - Batch and continuous tests
- Speed-up FOM-degradation → higher kinetic factors
 - Batch and continuous tests
- Improvement mixing in the fermenter, reduction of dead volume, increase of retention time
 - Difficult to measure, apparent only in full scale



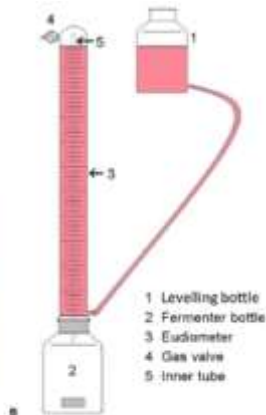
- Laboratory experiments at OWS and DBFZ
 - Biogas tests (DBFZ + OWS)
 - Recovery high-value products (OWS)
- 5 relevant substrates will be tested
 - straw, sorghum, manure, maize-, grass- and rye silage
- Different scales of experimental setup for biogas tests
 - Batch tests
 - Semi-continuous tests
- Test in different reactor systems
 - wet fermentation → CSTR (DBFZ)
 - dry fermentation → plug flow (OWS)



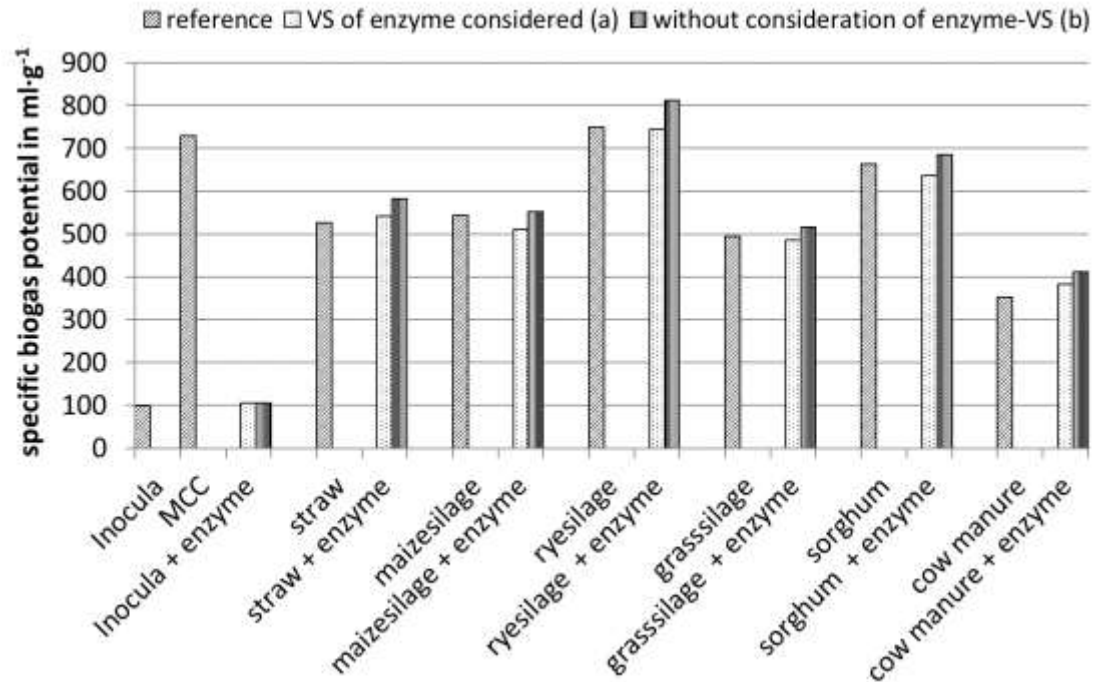


Batch tests

- identification and quantification of the effect of enzymes on the biogas process (biogas potential and kinetics)



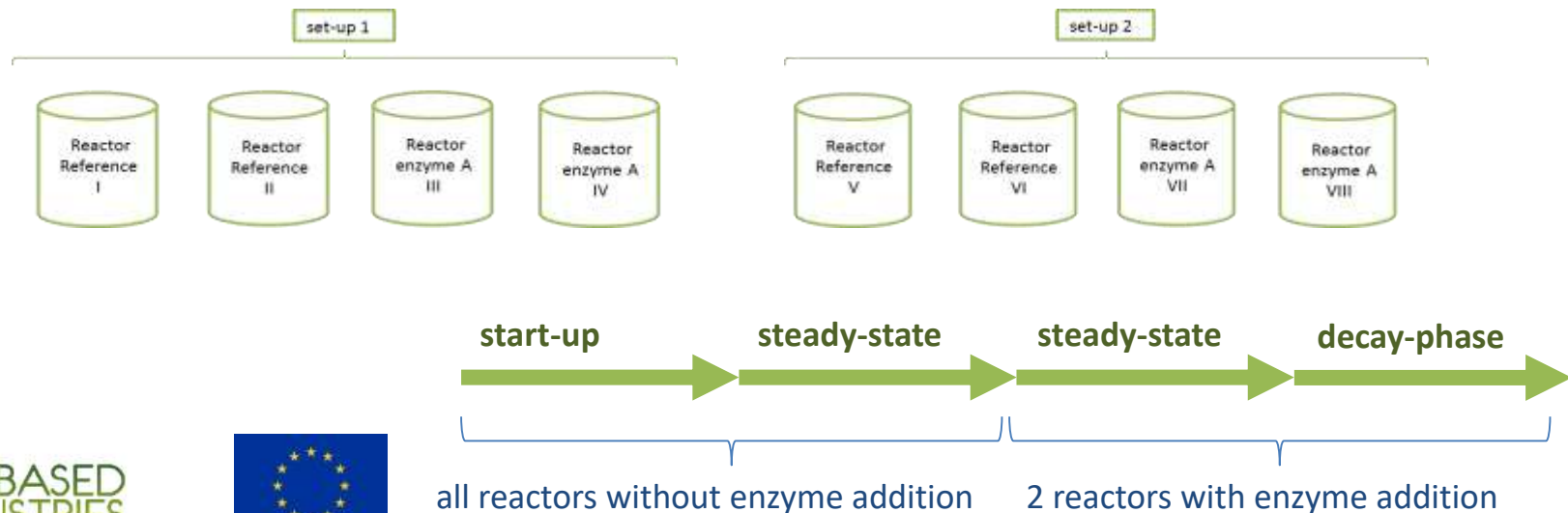
- 2 g VS sample per bottle
- 500 g FM inoculum
- T = 39 °C
- t = 37 d





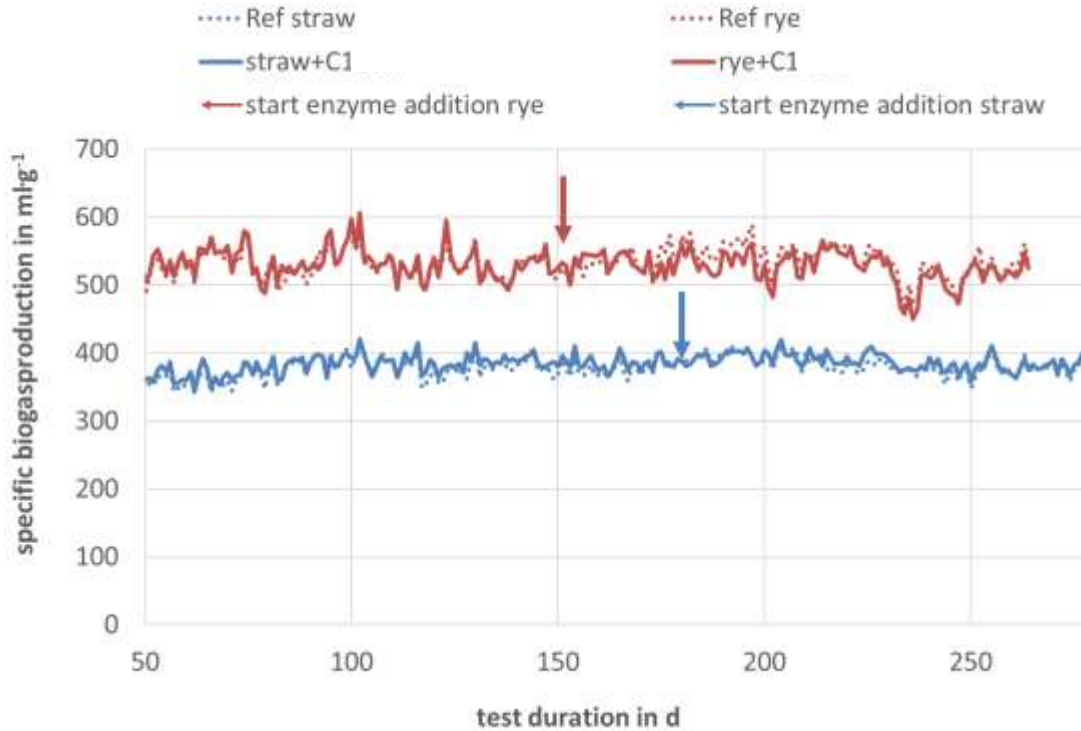
- Semi-continuous tests

HRT	40 d
OLR	$3.5 \text{ g} \cdot (\text{l} \cdot \text{d})^{-1}$
substrate 1	straw (set-up 1) rye-silage (set-up 2)
substrate 2	cow manure with defined DM 8% (± 0.3)
trace elements	weekly addition





Results of continuous tests



Reaching steady state
(88-110 d)
without enzyme addition

Reaching steady state
(58-107 d)
with enzyme addition



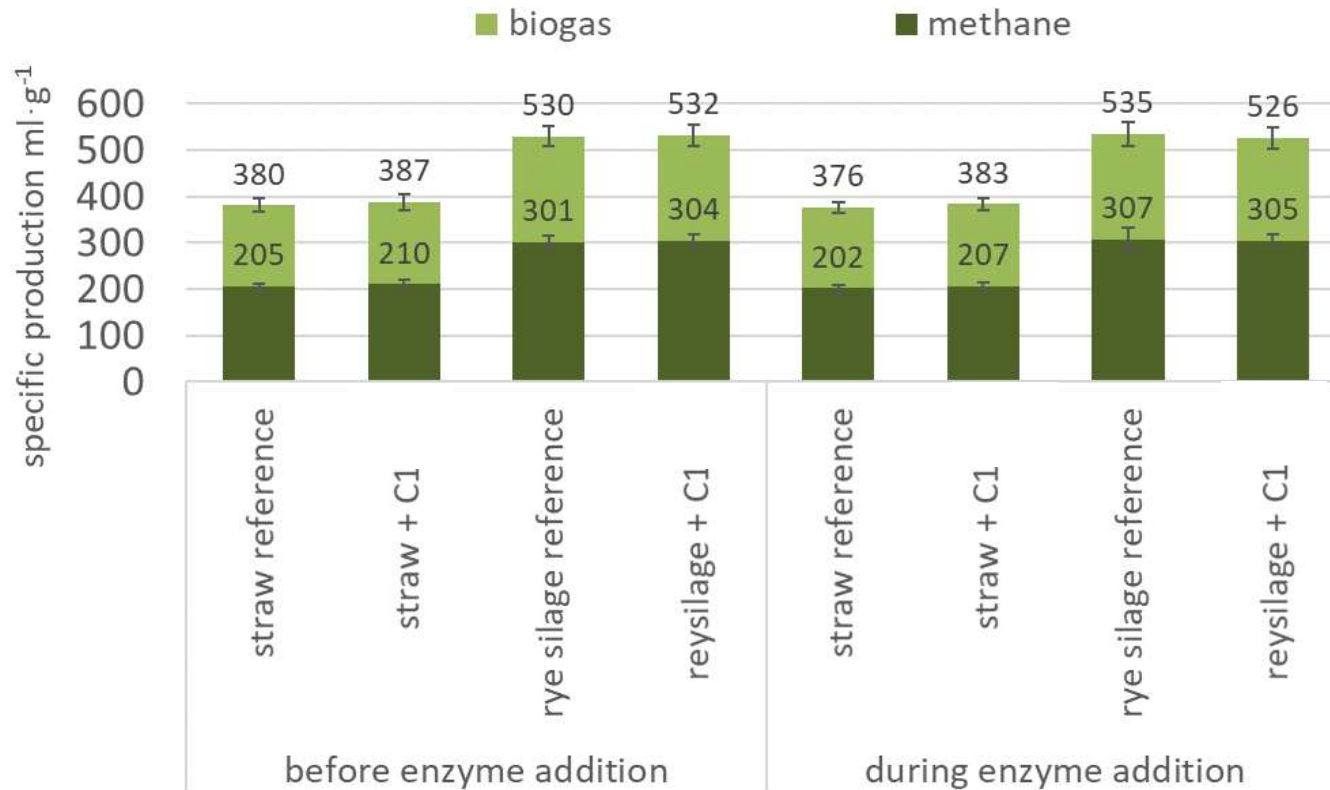
Results of continuous tests



- coefficient of variation in 4 reactors in steady state before enzyme addition
 - Straw = 1.8%
 - Rye silage = 1.6%
- Calculation how large enzyme effect has to be for a statistical proof of the enzyme impact on the biogas process (>4% of difference to the mean of the reference [based on duplicates])
- coefficient of variation in 4 reactors in steady state during enzyme addition
 - Straw = 1.4% (1.8% before enzyme addition)
 - Rye silage = 1.7% (1.6% before enzyme addition)



Results of continuous tests



→ Good reproducible process conditions necessary for statistical evaluation



Approach



- Scale-up from laboratory to practice



№	Bezeichnung	Angaben
1	2,7 Heizkessel	2,7 steam digester
2	2,2 Hochdruckmischer	2,2 high digester
3	2,4 Hochdruckmischer	2,4 plug flow reactor
4	2,4 Hochdruckmischer	2,4 secondary digester
5	2,8 Fermenter / Substratlager	2,8 digester / substrate storage
6	3,4 Dünslager	3,4 manure storage
7	0,7 Dünslager	0,7 digestate storage
8	2,8 Heißhaus	2,8 heating house
9	2,9 Pumpenhaus	2,9 pump house
10	Slurrytank	slurry tank
11	Reaktor	reactor
12	Feststoffwäscher	solid feeder
13	Dampfer	heat exchanger
14	Reaktor	bioreactor
15	Reaktor	bioreactor
16	Reaktor	bioreactor
17	Blockheizkessel - BHKW	combined heat & power unit - CHP
18	Abwassertank	wastewater tank
19	Slurrytank	slurry tank

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Forschungsbiogasanlage
 research biogas plant



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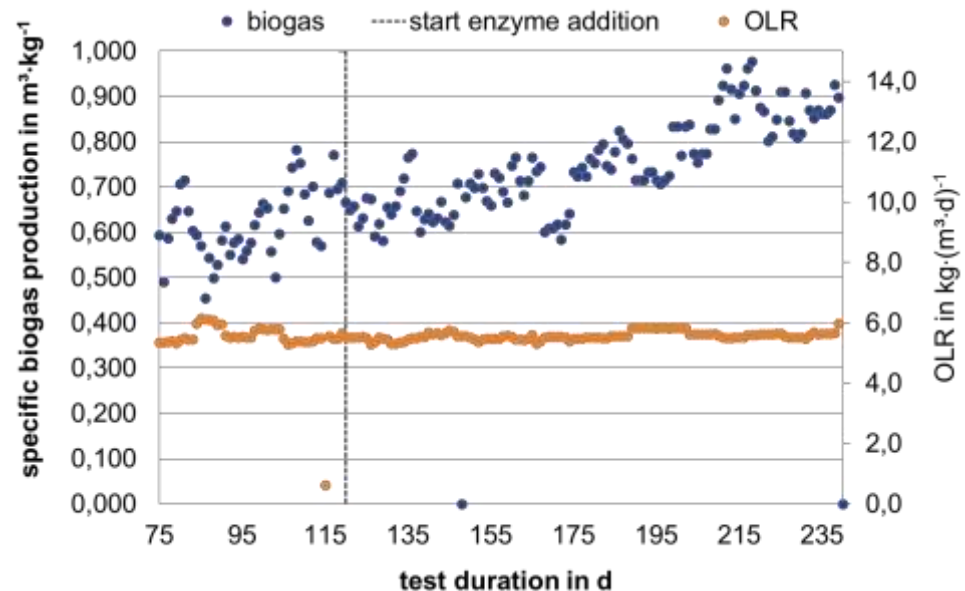


- Experimental set-up

	3.1.0 (+C1-enzyme)	3.2.0 (reference)	3.3.0
Type of reactor	CSTR		Plug-flow
Mixing system	central stirrer		Horizontal blade (paddle) agitator
Substrate	Sorghum silage + cow manure		Maize silage + cow manure
OLR in $\text{kg} \cdot (\text{m}^3 \cdot \text{d})^{-1}$	5,0		5,5
HRT in d	~25		~40
Enzyme addition	26.06.2018 – 01.10.2018 (97 days)		26.06.2018 – 24.10.2018 (120 days)



- Plug-flow reactor
 - Stable process before enzym addition
 - Specific biogas production $617 \pm 79 \text{ m}^3 \cdot \text{kg}^{-1}$ (n=77)
 - Since day 175 increase in specific biogas production
→ no hypothesis yet





Pipe viscosimeter

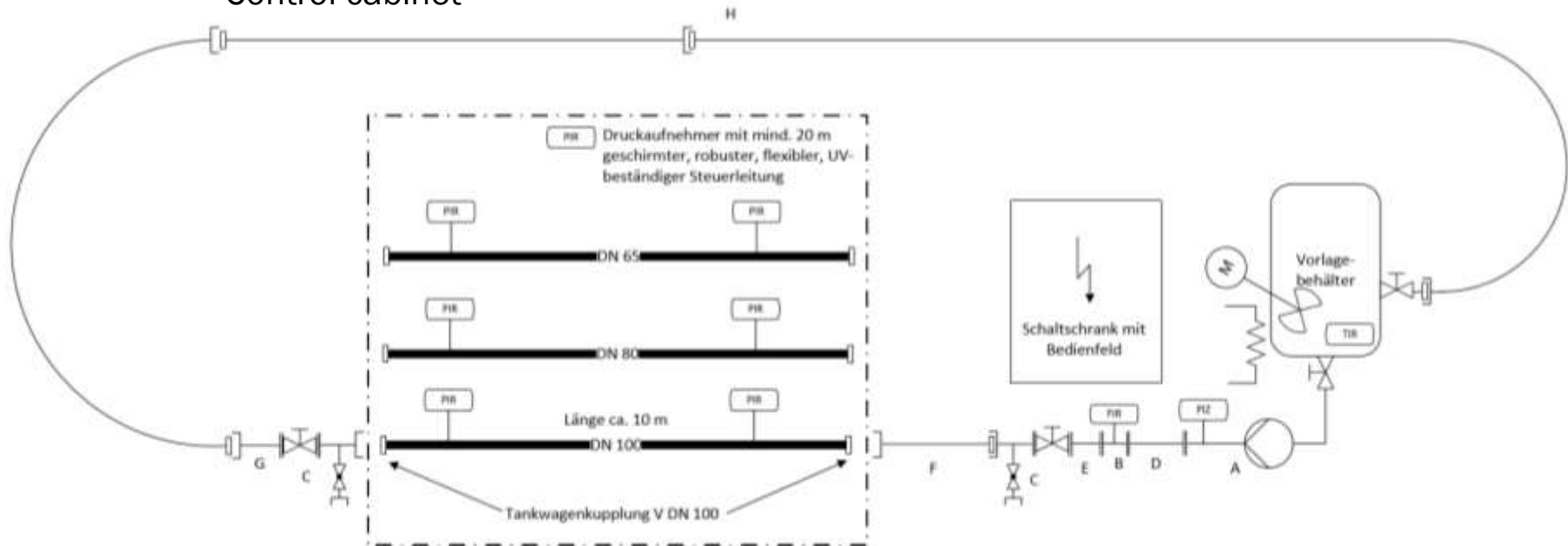




Pipe viscosimeter



- Development in cooperation with RTO
- Mobile system; consisting of:
 - tank → 1 m³, heated, mixed, covered (not gas tight)
 - 3 pipes with different pipe diameter; length 10 m
 - pump
 - 2 differential pressure manometer
 - Control cabinet





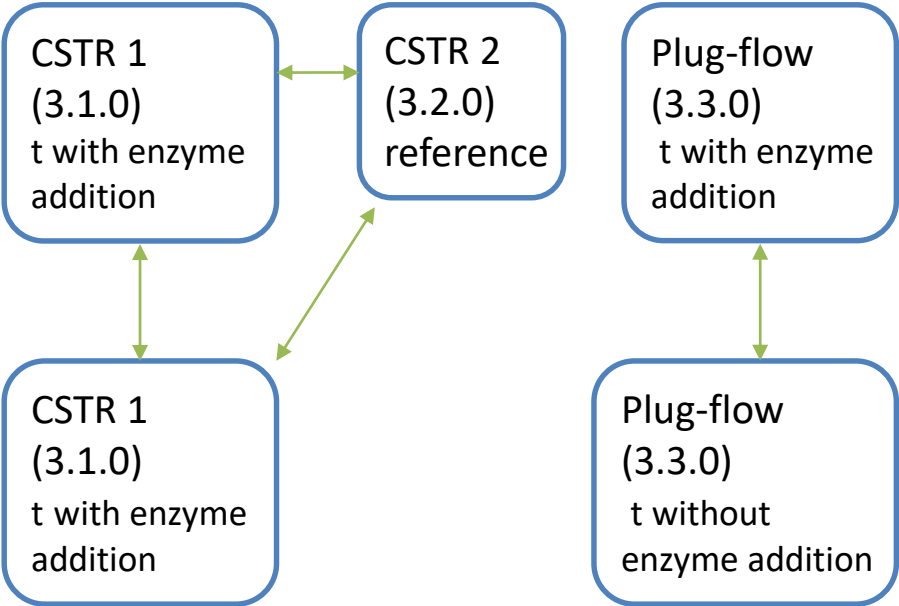
Pipe viscosimeter



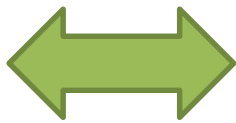
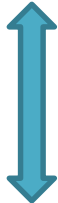
Start-up + validation of method

- definition of procedure
- measuring interval
- repeatability
- precision
- calibration

Comparable measurements for DEMETER

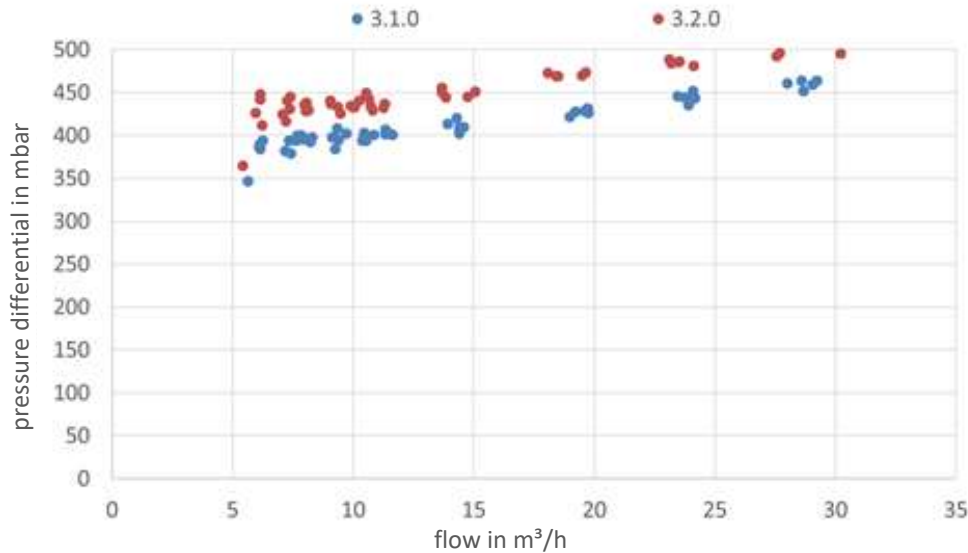


Tests with rotational viscometer





Viscosity test



3.1.0 with enzyme

3 times done, effect was always there, could be positive impact
Quantification, statistical and method validation follows



Conclusion



- DEMETER analysis the proof of enzymatic disintegration in the whole process chain → scale-up
- Hypothesis is that disintegration will likely have an impact on yield through potential, kinetic or rheological change
- Lab experiments did not show significant impact on potential or kinetics yet, rheology to be investigated
- Results and expert system will give guidance to the parameters of a plant if addition of enzymes will have a positive effect



Thank you for your attention!

Are there any questions?

Demonstrating more efficient enzyme production to increase biogas yields

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