Biogas digestate: a hotbed of pathogens and microorganism - relevance of plant pathogens surviving anaerobic digestion to agro-ecosystems

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a joint research project,
granted by BMEL (formerly BMELV)

Bundesministerium für Ernährung und Landwirtschaft

ATB

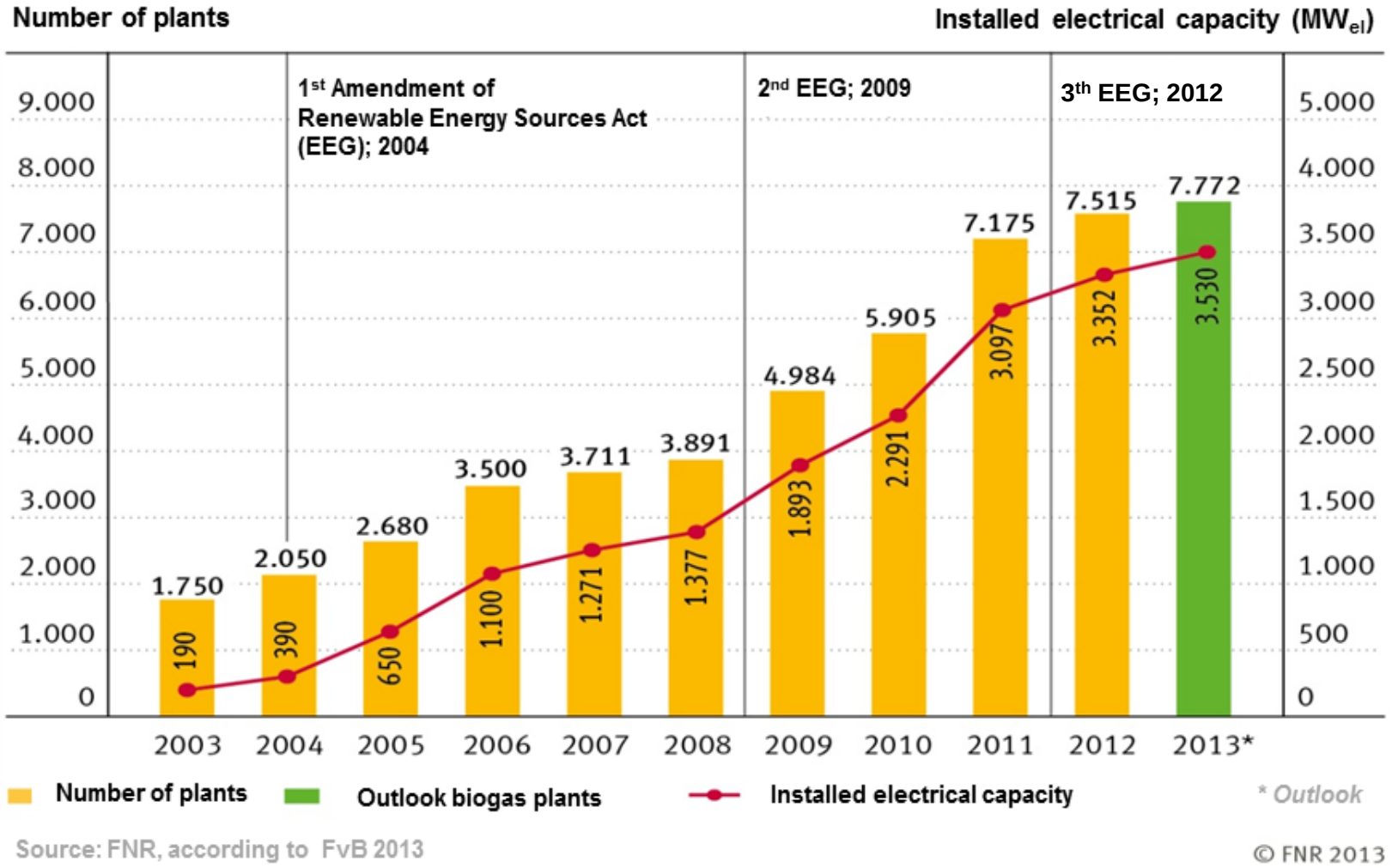
JKI Julius Kühn-Institut

Humboldt-Universität zu Berlin

Universität Rostock Traditio et Innovatio

KTBL Kuratorium für Technik und Bauwesen in der Landwirtschaft

Introduction
- Development of biogas plants in Germany -



http://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biogas.html; 8.5.2014

Introduction
- Fast facts, medium-sized biogas plant -

Installed electrical capacity:

- 250 kW_{el} per annum

Daily feedstock:

- 10 t Maize-silage,
  1 t grist
  10 m^3 pig manure

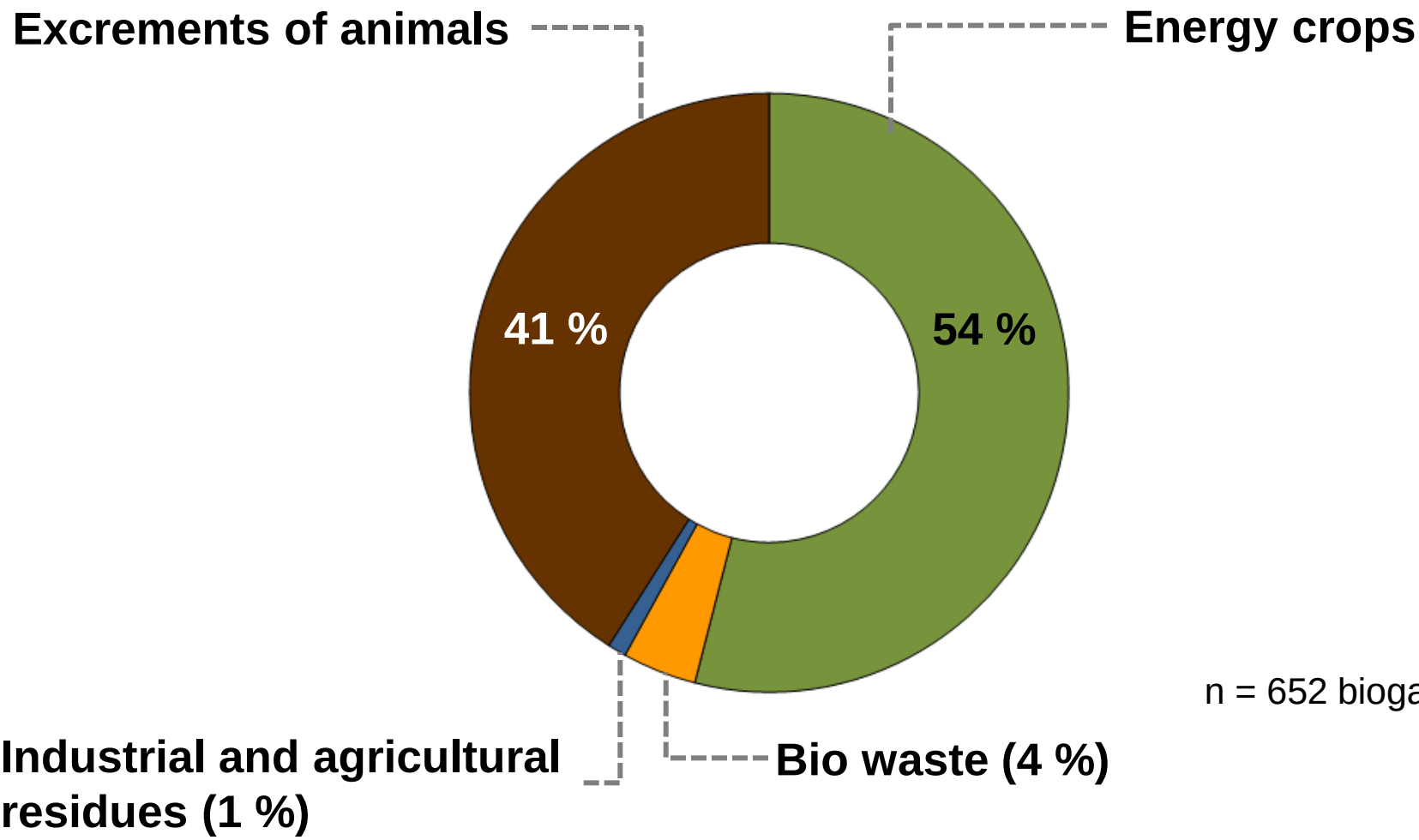
Degradation-rate of ODM:

- 30 to 80 % of the ODM

Digestates accruing each day:

- 8 t liquid digestates respectively 6,4 t after separation
  (calculated using the “Fugatfaktor” provided by the Saxon State office of Agriculture)

Introduction
- Feedstock for biogas poduction reffered to mass -



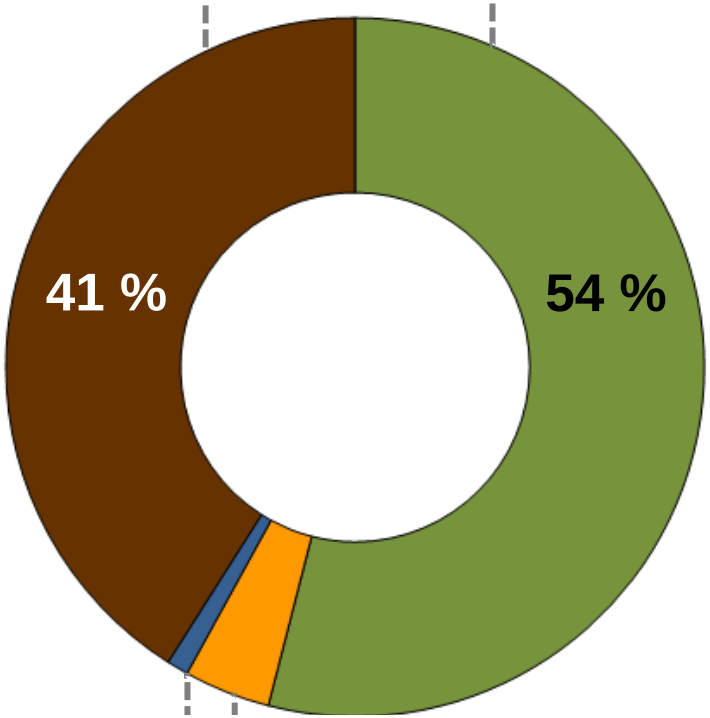
n = 652 biogas plants

Source: DBFZ survey (2013) – Feedstock fielding in biogas plants in 2012; http://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biogas.html; 08.05.2014

Introduction
- Agricultural biogas plant, contaminated feedstock -

Excrements of animals

- human and animal pathogens
- heavy metals
- antibiotic agents



Energy crops

- plant pathogens
- mycotoxins
- weed seeds

It has to be avoided to raise the extent of pathogens naturally occurring in soil and to counteract an accumulation of pathogens

Introduction
- hygienization -

- **anaerobic digestion is described as a suitable process for inactivation of weeds, fungi, bacteria, and viruses in literature**

But:

- **Most studies are focused on inactivation of human and animal pathogens such as *Escherichia coli*, *Salmonella* spp. *Clostridium* sp., *Listeria monocytogenes* and *Mycobacterium avium*** (e.g. Iwasaki et al. 2011; Bonetta et al. 2011; Cunault et al. 2011; Goberna et al. 2011; Ottoson et al. 2008, Sahlström 2003)

- **Only few studies are reporting on inactivation of plant pathogens or weed seeds during mesophilic anaerobic digestion** (Seigner et al. 2010; Weinhappel et al. 2010)

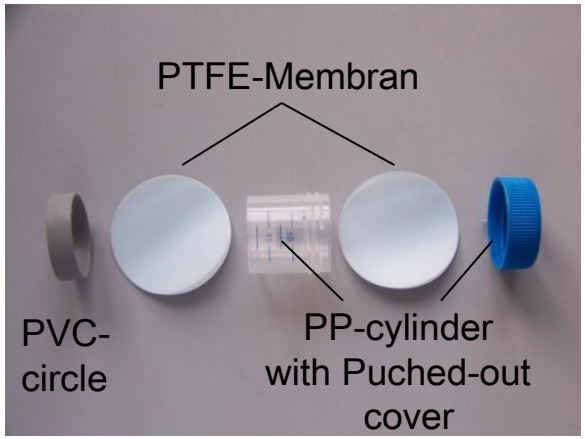
Introduction
- Inititiation of a joint research project -

Studies on the phytosanitary risk associated with the anaerobic digestion of plant material in biogas plants

- Which plant pathogens are relevant for specific feedstock?
- Will plant pathogens inactivated during anaerobic digestion?
- Which influence have:
  - ensiling of plant material
  - exposure time
  - storage of digestates?

Material & Methods
- introduction of infected feedstock -

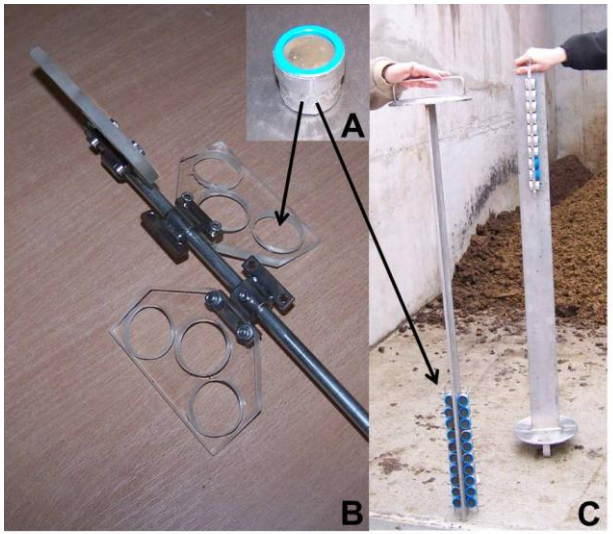
Germ carrier



Stirred tank reaktors lab-scale

Biogas plant full-scale

Holder for germ carries



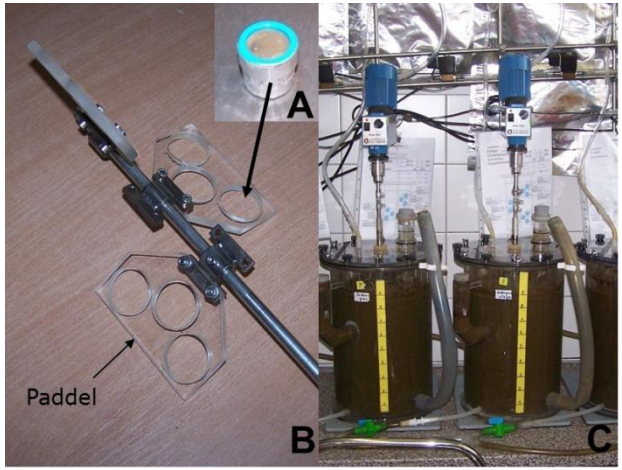
A = germ carrier
B = holder, lab-scale reactor
C = holder, full-scale digester

Material & Methods
- experimental design -

lab-scale

stirred tank reaktor

- mesophilic conditions (37°C ± 1°C)
- continuos feeding
- 10 L reactor
- organic loading rate level **3 kg ODM/m³**

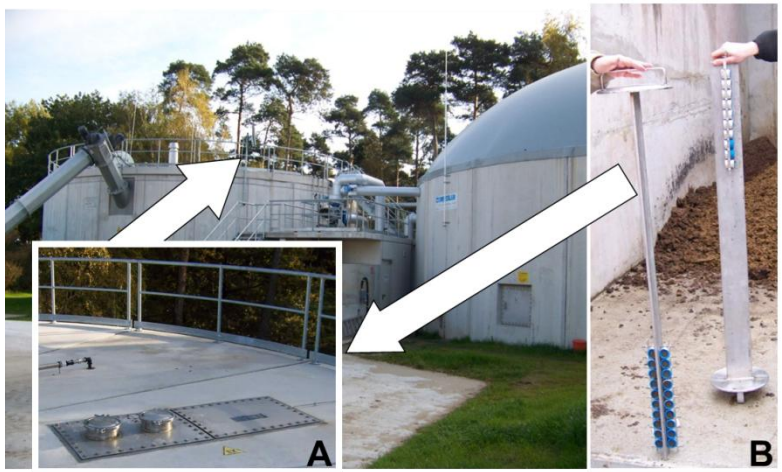


(A) germ carrier (B) stirrer
(C) stirred tank reactors

full-scale

digester

- mesophilic conditions (40°C - 42°C)
- continuos feeding (1 t/h)
- 800 L reactor
- organic loading rate level **5 kg ODM/m³**



(A) openings in roof of main reactor
(B) holders for germ carriers

Material & Methods
- experimental design, tested parameters -

- **Exposure time**
  - lab-scale: 6 h, 24 h,138 h
  - full-scale: 24 h, 48 h, 72 h, 96 h, 138 h
- **Pretreatment**
  - lab-scale: ensilage (28 d)
  - full-scale: ensilage (35d – 70d)
- **Digestate storage**
  - lab-scale: 4 weeks, 6 months
  - full-scale: not tested

Results
- biogas plant, full-scale -

Exposure time necessary for complete inactivation of pathogen

feedstock	pathogen	format	exposure time					
			6 h	24 h	48 h	72 h	96 h	138 h
fresh sorghum	*Fusarium proliferatum*	lab-scale	●	●	○	○	○	●
		biogas plant	○	●	●	●	●	●
	Fusarium verticillioides	lab-scale						
		biogas plant						
ensiled sorghum	*Fusarium proliferatum*	lab-scale						
		biogas plant						
	Fusarium verticillioides	lab-scale						
		biogas plant						
sugar beet	*Sclerotinia sclerotiorum*	lab-scale						
		biogas plant						

● pathogen viable ● pathogen not viable ○ not evaluated

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- biogas plant, full-scale -

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		biogas plant						
ensiled sorghum	*Fusarium proliferatum*	lab-scale	●	●	○	○	○	●
		biogas plant	○	●	●	○	○	○
	Fusarium verticillioides	lab-scale						
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		biogas plant	●	○	●	●	●	○
sugar beet	*Sclerotinia sclerotiorum*	lab-scale						
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sugar beet	*Sclerotinia sclerotiorum*	lab-scale	●	○	○	○	○	○
		biogas plant	●	○	○	○	○	○

○ pathogen viable ● pathogen not viable ○ not evaluated

Results
- lab-scale reactors, effect of digestage storage -

Pathogen	Storage time		
	no storage	4 weeks	6 month
F. proliferatum ***(fresh sorghum)***	24 – 138 h	6 – 24 h	< 6 h
F. verticillioides ***(fresh sorghum)***	24 – 138 h	6 – 24 h	< 6 h
F. proliferatum ***(ensiled sorghum)***	6 – 24 h	6 – 24 h	< 6 h
F. verticillioides ***(ensiled sorghum)***	< 6 h	< 6 h	< 6 h
Sclerotinia sclerotiorum	< 6 h	< 6 h	not tested
Alternaria alternata	< 6 h	< 6 h	not tested
Rhizoctonia solani	< 6 h	< 6 h	not tested
PVY	< 6 h	< 6 h	not tested

Results
- pathogens surviving anaerobic digestion -

Quarantine pathogens:

- ***Clavibacter michiganensis* ssp. *sepedonicus***
- ***Synchytrium endobioticum***

Thermo-resistant viruses:

- ***Tobacco mosaic virus* (TMV)**, Seigner et al. (2010)

Conclusions

- **A generally sanitation of plant pathogens** during mesophilic anaerobic digestion **is not given**
- **Required incubation time for inactivation depends on**:
  - the substrate (plant species, texture)
  - the pathogen (← strategies of colonisation)
- **Inactivation-time can be reduced by applying:**
  - pretreatment (ensiling)
  - storage of the digestate (> 4 weeks)

Outlook

- **Effect of digestates on soil-born pathogens**
  soil microbial communities
  bacterial and fugal population and their diversity
  level of suppressiveness of plant diseases

- **Determination of soil suppressiveness**
  plant-soil-pathogen-system

- **Identification of microbial characteristics which correlate with suppressiveness**

…thank´s for your attention

Pathogens

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