Survivability of plant pathogens during anaerobic digestion of agricultural crops in biogas plants

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In Germany biogas is primarily extracted by the co-fermentation of energy crops and manure/slurry. The energy production via biogas contributes to the reduction of greenhouse gas emissions. In addition, digestates can be used as an organic fertilizer. However, these digestates have to be free of plant pathogens to prevent the spreading to farmland and the accumulation the respective soils. Thus, the survivability of selected plant pathogens during anaerobic digestion of diverse substrates in biogas plants has been studied. The investigation focused on biogas plants with mesophilic operating temperatures and continuous feeding. Exclusively infected plant material of maize, sorghum, rye, wheat, sugar beet and potato was used. The investigations included fungal, bacterial and viral pathogens as well as weed seeds. Initially a screening of the inactivation of selected pathogens during anaerobic digestion of infected feed-stock was carried out in lab-scale reactors. The results were validated in full-scale biogas plants.

Below the effect of different feedstocks, exposure times and the duration of storage of digestates on the inactivation of the plant pathogens is shown.

Preparation of infected plant material

Host	Pathogen	Inoculation method
Sorghum	*Fusarium proliferatum* *Fusarium verticillioides*	Injection of spores suspension
Sugar beet	*Sclerotinia sclerotiorum*	Application of contaminated agar pieces to beets
Rye	*Alternaria alternata*	Spraying of spores suspension
Wheat grain	*Alternaria alternata*	Application of contaminated cultural medium to grains
Potato	*Rhizoctonia solani*	Application of contaminated agar pieces to grains
	Potato virus Y	mechanical inoculation
	Synchytrium endobioticum	contaminated glass sand

Plant material

- Sorghum and rye were cultivated in greenhouses (lab-scale tests) respectively in the field (full-scale biogas plants)
- Sugar beets and wheat grains originate from last year´s harvest

Germ carrier

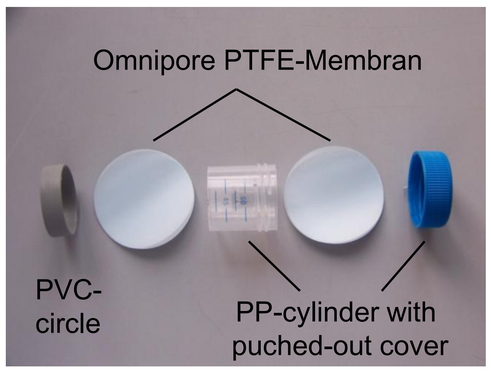

Fig. 1: Assembly of the germ carrier

Prior application the germ carriers were tested in regard to:

- physical and chemical stability
- permeability of membran

Lab-scale biogas plants

Fig. 2: Stirred tank reactors of the lab-scale biogas plant

- organic loading rate level: 3 kg ODM/m³
- operating temperature: 37°C (±1°C)
- fermentation volume: 10 L

Full-scale biogas plants

Fig. 3: Full-scale biogas plant

- organic loading rate level: 5 kg ODM/m³
- operating temperature: 40°C - 42°C
- fermentation volume: 800 m³

Results

In lab-scale reactors the majority of pathogens could be inactivated during the first 6 h within the process of anaerobic digestion. However sorghum infected with *Fusarium proliferatum* or *Fusarium verticillioides* was completely sanitized after an exposure time of 138 h. Ensiling of substrate and storage of the digestates reduced the time required for an inactivation of the contaminating pathogens (Tab. 1). The quarantine pathogen *S. endobioticum* could not be inactivated during anaerobic digestion; not even applying a dwell time of 14 days.

Tab. 1: Inactivation of plant pathogens during anaerobic digestion in lab-scale biogas plants with optimal process management (mesophil, 37°C, 3 kg ODM/m³)

\+ no inactivation +/- partial inactivation - complete inactivation

Storage of digestates		none			4 weeks			6 months		
Exposure time (dwell time)		**6 h**	**24 h**	**138 h**	**6 h**	**24 h**	**138 h**	**6 h**	**24 h**	**138 h**
Sorghum (fresh)	*Fusarium proliferatum*	+	+	-	+/-	-	-	-	-	-
	Fusarium verticillioides	+	+/-	-	+/-	-	-	-	-	-
Sorghum (ensiled)	*Fusarium proliferatum*	+/-	-	-	-	+/-	-	-	-	-
	Fusarium verticillioides	-	-	-	-	-	-	-	-	-
Sugar beet	*Sclerotinia sclerotiorum*	-	-	-	-	-	-	not done		
Rye (fresh)	*Alternaria alternata*	-	-	-	-	-	-	not done		
Rye (ensiled)	*Alternaria alternata*	Inactivation by ensiling								
Wheat grain	*Alternaria alternata*	-	-	-	-	-	-	not done		
Potato	*Rhizoctonia solani*	-	-	-	-	-	-	-	-	-
	Potato virus Y	-	-	-	-	-	-	-	-	-
	Synchytrium endobioticum	+	+	+	+	+	+	+	+	+

In full-scale biogas plants the dwell time required for a complete inactivation of plant pathogens tend to be significantly longer (Tab. 2). For example a dwell time of 138 h was required to inactivate *F. proliferatum* whereas 72 h were sufficient to inactivate *F. verticillioides.*

Tab. 2: Comparative list on the inactivation of plant pathogens during anaerobic digestion in lab-scale and full-scale biogas plants

\+ no inactivation +/- partial inactivation - complete inactivation nd = not done

		Lab-scale			Full-scale					
Exposure time (dwell time)		**6 h**	**24 h**	**138 h**	**6 h**	**24 h**	**48 h**	**72 h**	**96 h**	**138 h**
Sorghum (fresh)	*Fusarium proliferatum*	+	+	-	ne	+/-	-	+/-	+/-	-
	Fusarium verticillioides	+	+/-	-	+	+/-	+/-	-	-	-
Sorghum (ensiled)	*Fusarium proliferatum*	+/-	-	-	nd	+/-	+/-	nd	nd	nd
	Fusarium verticillioides	-	-	-	+/-	nd	-	-	-	nd
Sugar beet	*Sclerotinia sclerotiorum*	-	-	-	-	not done				

Conclusions

Inactivation of plant pathogens during anaerobic digestion in biogas plants depends on several factors. A key role comes up to the composition of the plant material and the strategy of the plant pathogen to colonize the host. A pretreatment of the plant material (milling and ensiling) and the storage of digestates reduced the time required for a complete inactivation of the tested plant pathogens.

Cultivation of energy crops considering good technical and scientific practice does not exclude the introduction of feedstock infected with plant pathogens into biogas plants. Consequently, it has to be ensured that digestates from biogas plants are sufficiently sanitized prior application as organic fertilizer on farmland. This can be achieved by ensuring dwell times required for complete inactivation of the particular pathogens.

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