

Aus der Professur für Abfall- und Stoffstromwirtschaft  
der Agrar- und Umweltwissenschaftlichen Fakultät

Thesen der kumulativen Dissertation

## **Optimization of anaerobic digestion of sugarcane waste for biogas production in Brazil**

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Doktor der Ingenieurwissenschaften (Dr.-Ing.)  
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vorgelegt von  
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## Background and aims of the research

- During the production of sugar and bioethanol based on sugarcane as feedstock large amounts of organic waste are generated. The AD of the organic waste for biogas production is a promising strategy to improve the energy balance and diversify the product portfolio of the sugarcane plants in a biorefinery concept. However, several aspects must be considered for an efficient AD process, such as crop seasonality, substrate availability and composition, degradation kinetics, methane yields and proper reactor configuration.
- The AD of vinasse is considered challenging by different reasons:
  - i.* The AD of sulfur-rich substrates can lead to various undesirable effects: (a) sulfate reducing bacteria (SRB) outcompete methanogens for hydrogen and acetate due to thermodynamic advantages, resulting in sulfides and less methane production; (b) high sulfide concentrations has a direct toxic effect on certain anaerobic microorganisms; and (c) sulfide production and metal-sulfide precipitation is known as one of the most important processes limiting the availability of trace metals for microbial uptake, thus negatively affecting the efficiency and stability of the AD process;
  - ii.* The low alkalinity and unfavorable pH of vinasse (between 3-5) for methanogenesis, requires the addition of alkaline compounds to counteract such acidity by buffering the pH to an optimum value for AD. As a result, the costs for alkalinity supplementation can be a major expense for anaerobic treatment of some industrial wastewaters, possibly exceeding the value of the methane produced.
- For large-scale applications, it is well known that using digestate taken from a stable working digester could be a good strategy to overcome the start-up challenges. However, in countries where biogas technology is not established in the market yet, plant operators must find alternative sources of inoculum suitable for the start-up of an anaerobic reactor. In this case, the utilization of animal waste, such as cattle manure, could be a useful strategy, since such material is rich in microorganisms from animal digesting system, as well important macronutrients and trace elements.
- Although bagasse is an organic waste already being used in cogeneration plants, often a share of it is not used as fuel due to specific thermal balance of some sugarcane plants. The AD of filter cake co-digested with a minor share of bagasse could be an interesting option to increase the energy production from a biogas plant based on sugarcane waste as substrate.

- Filter cake can play an important role on a year-round biogas production if stored to be used as substrate during the sugarcane offseason. However, if intended to be used in the same reactor of vinasse (e.g. UASB), a two-stage system (CSTR followed by separation of non-hydrolysed solids + UASB for biogas production from separated liquid) should be performed. However, it is well known that hydrolysis is often the rate-limiting step during AD when fibrous material, such as filter cake is used as feedstock due to the recalcitrant presence of lignin. In this case, substrate pretreatment could be an alternative to improve the AD process by increasing the accessible surface area, modifying the crystalline structure or partially depolymerize cellulose, solubilizing hemicellulose and lignin or to modify lignin structure.

### **Main research results**

- The understanding of the different waste types derived from the sugar and bioethanol production process is mandatory, since each waste has its own characteristics which directly influence the degradation kinetics, methane potential and reactor configuration for a proper substrate utilization.
- For a year-round biogas production filter cake should be stored/conserved by ensiling to be used as substrate during the offseason period, since a similar energy equivalence to vinasse was found, especially for annexed sugarcane plants.
- The addition of urea to the AD of sugarcane vinasse is an interesting strategy to improve the quality of the digestate and increase the alkalinity in the reactor, since by urea degradation  $\text{OH}^-$  and  $\text{NH}_4^+$  are provided. Besides that, such additional source of alkalinity was a key factor to reach higher OLR and lower HRT when trace elements were also supplemented in the reactor setup adopted in our experiment.
- Cattle manure demonstrated to be a suitable alternative inoculum for remote rural areas without access to digestate from stable anaerobic reactors, but due to the high initial organic acids concentration a proper acclimation period of around 20 days is required to avoid the risk of process failure during the reactor start-up.
- The mono-digestion of filter cake presents a higher substrate conversion than co-digestion with bagasse due to the lignin recalcitrance and unfavorable balance of nutrients found in bagasse. On the other hand, the co-digestion could produce more biogas in large-scale applications due to the higher amount of substrate being used.
- Sodium hydroxide is an effective pretreatment method to optimize the hydrolysis and acidification of filter cake, since this pretreatment method was able to improve the VFA production by 37% in an acidogenic reactor. Such approach could increase the final energy of an eventual two-stage reactor system (CSTR + UASB). However, it is still unclear whether this approach could fit to an economically efficient year-round biogas production system.