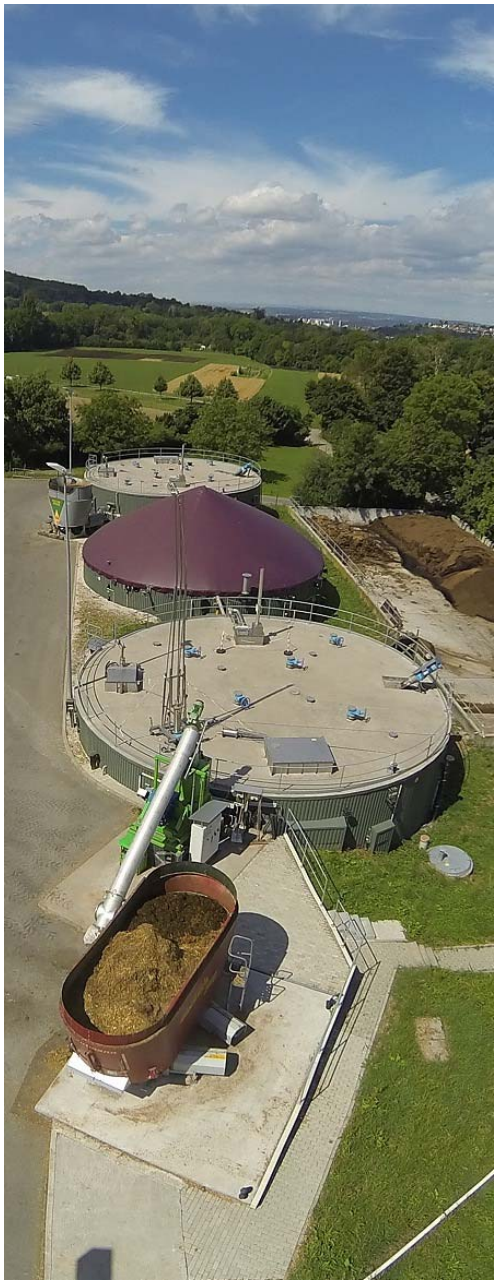
UNIVERSITY OF HOHENHEIM

LANDESANSTALT
für Agrartechnik
& Bioenergie

ANNUAL REPORT 2016



The state institute of agricultural engineering & bioenergy

The year 2016 is characterized by extensive activities by the State institute in the field of biogas and bioeconomic research. Thanks to the extensive experience gained over the past decades in the field of biogas and particularly the pronounced commitment of the employees, the technical equipment of the State institute has been further optimized and expanded. This was achieved both through the acquisition of third-party funds and through the support of the University of Hohenheim. One of the latest achievements is a completely new biogas laboratory. In this, BMP-tests are carried out in 774 small biogas digesters - also called the "Hohenheimer biogas yield test (HBT). The reliability of the results is regularly checked in ring trials with other well-known laboratories and research facilities. Larger digesters within this laboratory are also available for more specific topics.

Research projects in the field of bioeconomy have expanded the research potential of the State institute by setting up a container plant that is equipped with 8 continuously feed digesters for hydrogen methanation, which can be used as fully-mixed systems or as anaerobic filters. Significant improvements were also made in the area of high pressure anaerobic digestion. A system operates at a pressure of 100 bar resulting in combined biogas production and up-grading to bio methane in a single step. Hydrogen methanation under pressure was further developed and equipped with special trickle bed reactors as well.

At the "Lindenhöfe" test station, major developments were carried out or further planned:

- The increase in capacity of the CHP to an electrical output of 355 kW_{el} with the associated expansion of the periphery was implemented and put into operation. A share of the electricity produced in the future will be used at the test station.
- An important element for the full utilization of this new CHP output and for the flexible generation of biogas streams is the further development of the plans for the construction of a modern manure tank, which has a capacity of 4,800 m³ and has additional gas storage facilities. Construction is expected to be completed in 2017.
- The construction of three special sugar beet silos started and will be finished in spring 2017. This would extend the research possibilities for flexible biogas production as well as for the production of platform chemicals at a practical scale.

The planning in the vicinity of the research biogas plant at the "Unterer Lindenhof" is excellently conducted by Dr. Lemmer. Thanks to the temporary support of the rectorate Dr. Nägele and Dr. Zielonka are able to assist him. The outstanding and highly cooperative collaboration with the "Unterer Lindenhof" field station and their employees was continued.

The production of electricity from renewable sources in Germany has significantly increased in recent years. In the meantime, 33% of the electricity consumed comes from renewable sources. On the one hand, the fluctuating sources of wind and solar power in particular are experiencing a significant increase, meaning that their share of renewable energies is further increased. The share of biogas in power generation is stagnating, on the other hand, due to changes in legal requirements. However, the fluctuating energy sources cannot always satisfy the demand because they are not constantly available. Electricity out of Biogas could occupy an important key position, as it is the only renewable source of energy that can be stored in the form of the chemical energy carrier biomethane. Society and politics have so far ignored this important biogas property and slowed their further expansion. The research work of the State institute is focusing on this problem and will provide further solutions. The further development of technologies for the flexible generation of biogas or biomethane is a particular focus. These are carried out on a practical scale mainly at the research biogas plant. The two-phase anaerobic digestion systems, e.g. in anaerobic filters, investigated in the laboratories provide very promising solutions for demand depended biogas production and require a test on a practical scale. The biogas measurement program III was started in 2016 and the State institute is now

participating for the third time. Together with three partner institutes (DBFZ Leipzig, CAU Kiel, LFL Weihenstephan), a total of 60 practice biogas plants will be investigated for at least one year, where process and technical data will be collected and balances will be recorded. These data will show the state of the art in modern biogas plants and also contribute to policy advice.

Through the visit of scientists from different countries (Albania, China, Russia, Ukraine, USA), the scientific cooperation could be significantly improved. It is worth highlighting the detailed study on the biogas yield of energy crops in tropical regions, e.g. Hawaii. The use of by-products of food production such as of coffee production residues plays an important role in cooperation with Ethiopia. Through the participation in several workshops in Costa Rica, the state of German biogas technology and its aims were demonstrated and preparatory work for planned research projects was carried out.

The efficiency and the environmental impact of biogas plants have been the focus of the State institute for many years. In 2016, investigations were carried out on municipal waste biogas plants. With the help of investigations on the residual gas potential, weak points were determined in order to specifically recommend process optimization. Research in the area of platform chemicals has continued. The BMBF project: Comprehensive optimization of the biogas process chain to increase operational, material, energy and ecological efficiency has been completed. A new BMEL project on the "development of efficient two-phase biogas plants via a coupled energy and material utilization after separation of acidification products" was started.

The work of the State institute is sustainably supported by its advisory board, whose impulses are often addressed in research work. Traditionally, the State institute's tasks include providing expert advice to farmers, providing technical advisory services to companies, as well as the training of teaching and consulting of staff. Together with ALB Baden-Württemberg, the Biogas Association, Renergie Allgäu e.V., the biogas technical advisors and the IBBK, the State institute regularly organizes joint conferences, workshops and training events as well as trade fair participation for farmers and operators of biogas plants. The current research knowledge is conveyed directly to the practice and is thus applied quickly. Thus, the State institute fulfills an essential task of the research transfer. In the meantime, the support of teaching at the University of Hohenheim is taking up a considerable part of the activities of the State institute, predominantly in the bachelor's program "Renewable Resources and Bioenergy" and in the corresponding master's program as well as in the masters course "Agricultural Sciences". Above all, graduate work such as bachelor's, master's and project work are supervised professionally. An average of 20 students are involved as research assistants or by their thesis annually in the research tasks of the State institute, which is an excellent opportunity for the direct application of the subject learned in lectures and contributes to a close networking of research and teaching. The very close cooperation with the Institute of agricultural engineering, in particular with the Chair of the senior director, Prof. Dr. Thomas Jungbluth, is particularly effective and successful.

With a highly motivated and dedicated, very young team, the State institute faces new challenges. We welcome your suggestions and are very open to cooperation with research and industry partners in Germany and worldwide.

Dr. Hans Oechsner
Head of the state institute

Developing a procedure for the fermentative conversion of hydrogen by fluctuating sources of biomethane in biogas plants (H2-Transfer)

M. Sc. Bernhard Lecker

Dipl.-Ing. agr. Christoph Serve-Rieckmann

B. Sc. Daniel Riehle

Dr. sc. agr. Hans Oechsner

As a research area, “Power-to-Gas” (PtG) is gaining more and more relevance. In the future, PtG could also be a very important part for the “energy transition”. Excess electrical energy out of fluctuating sources is converted into hydrogen and subsequently, after its methanation, injected in the natural gas grid and therefore stored as chemical bound energy.

Production of biomethane can either be carried out chemical-catalytically or in biogas plants biologically. This is accomplished in the presented project. For this approach, the amount of carbon dioxide in the biogas is measured and the fourfold amount of hydrogen is injected in the reactor for the complete methanation of CO_2. Methanation itself is performed by hydrogenotrophic bacteria which are present in every biogas plant. As a result of the conversion of carbon dioxide, the proportion of methane in the biogas increases. If necessary for injection into the gas grid, this high calorific biogas can be subsequently upgraded to meet the requirements of the gas grid.

Four identical 100 liter reactors are fed with substrate to produce biogas. The amount of carbon dioxide is measured online with a micro gas chromatograph and the stoichiometric amount of hydrogen is calculated and injected directly afterwards. Hydrogen is injected as fine bubbles via a submerged pump intoto the liquid fraction. Around 80 % of the produced biogas is recirculated to ensure a higher retention time and a better conversion efficiency of H_2 and CO_2. The digesters are operated at a mesophilic temperature level of 37°C and with an organic loading rate of 2.6 kg oDM m^{-3} day^{-1}. The PH value is not adjusted and is in the range between 7.7 and 8.0.

Half-stoichiometric hydrogen injection was tested in a preliminary experiment and delivered good results of a methane increase of 36.6% methane and a decrease of 41.1% carbon dioxide. A residual concentration of 6.6% hydrogen was measured. Variations with full-stoichiometric hydrogen injection, thermophilic temperatures and higher volumetric loads arecurrenlty being tested.

In-situ - the hydrogen conversion directly in an existing anaerobic biogas reactor - is a possible and promising Power-to-Gas option. A great number of German biogas plants could be “repowered” in this way.

Laboratory container for hydrogen injection experiments (Lecker, 2016)

Funding:
Ministry for Science Research and Art Baden-Württemberg „Bioökonomie-Projekte“

Partners:
DVGW Research Unit at Engler-Bunte-Institut (DVGW-EBI), KIT

Project duration:
June 2014 – Sep 2017

Process development for the use of biological methanation in two-stage production of biogas; Subproject 1: Investigation of a fixed-bed fermenter and continuous stirred tank reactor (BioHydroMethan)

M. Sc. Lukas Illi

M. Sc. Bernhard Lecker

B. Sc. Daniel Riehle

Dr. sc. agr. Hans Oechsner

The planned expansion of renewable energies in Germany requires considerable storage capacity for electrical energy, which of this size, can only be provided by chemical energy carriers. The biological methanation of hydrogen in the biogas digester is a promising alternative to catalytic methanation.

Within this project, the two-stage digestion with separate acidification stage and the targeted introduction of hydrogen into the methane reactor will be investigated. A particular advantage of this approach is that the produced carbon dioxide during the anaerobic digestion process can be used by hydrogenotrophic methane bacteria, which almost completely convert it to methane. Subsequently, the biogas can be injected into the natural gas grid as biomethane with, compared to conventional biogas, significantly lower treatment costs or can be used as fuel.

As part of this joint project, which consists of three sub-projects, technological tests with different reactor designs, such as anaerobic filters, continuous stirred tank reactors and membrane reactors are carried out on a laboratory scale. The development of a technique for fine bubble hydrogen injection, entering the digester liquid, will be a fundamental task in order to achieve an optimum supply for the archea. Additionally, the influence of bubble size, injection technique as well as the design of the bubble ascension on the transfer efficiency to the digester liquid and the methane bacteria will be examined. A special emphasis will be on the change in the biological community by adding hydrogen to the methane reactors. By measuring the composition and concentration of volatile fatty acids, the buffering capacity, the pH-value, the concentration of dissolved gases in the fermentor substrate and the quality of the resulting product gases, the reactor types will be evaluated, optimized and refined.

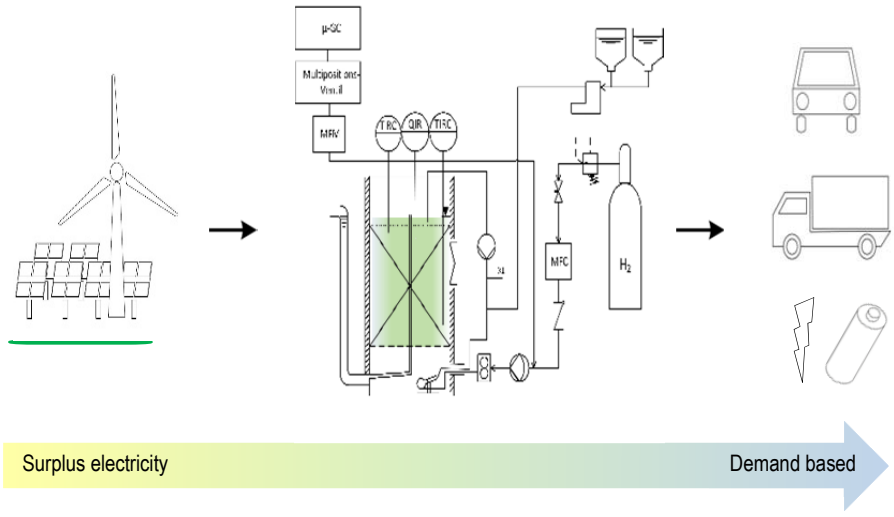
Funding:
Federal Ministry of Food and Agriculture

Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

Partners:
DVGW Research Unit at Engler-Bunte-Institut (DVGW-EBI) – Water-chemistry and water-technology

Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB)

Project duration:
May 2015 – May 2018



Concept: Bio hydro methane production

Use of biological methanation for Power-to-Gas Concepts: Fermentative high-pressure methanation of hydrogen

M. Sc. Timo Ullrich

Jochen Harder

Armin Kinigadner

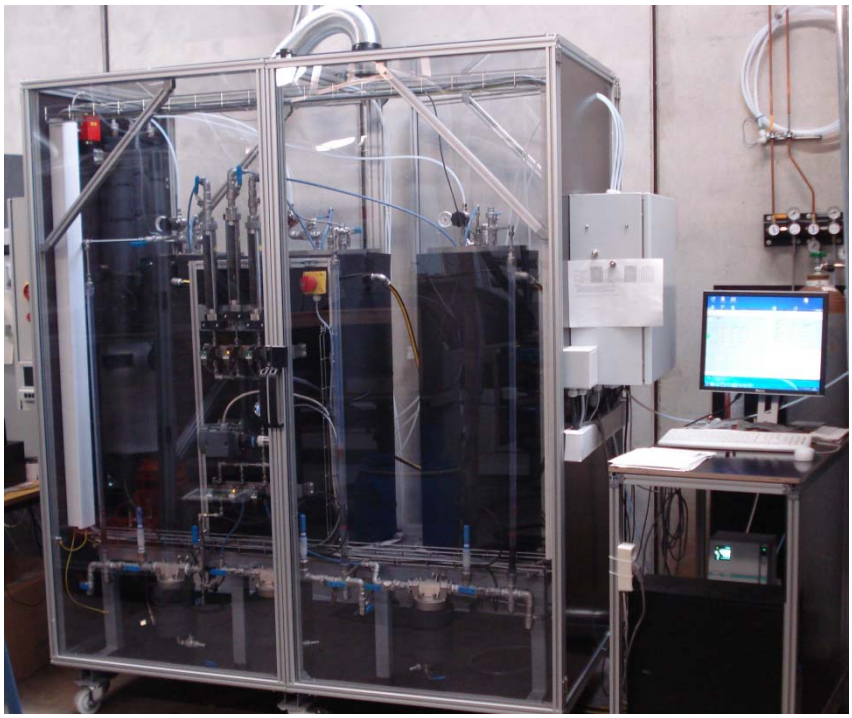
Dr. sc. agr. Andreas Lemmer

The biological high-pressure methanation of carbon dioxide and hydrogen to methane is an interesting vector technology for the storage of surplus flow in natural gas networks. Carbon dioxide is converted microbiologically to methane in a pressure reactor by hydrogen produced by electrolysis from wind and solar energy. This "bio-natural gas" can be used as fuel in the area of mobility or fed into natural gas networks. The biological high-pressure methanation of hydrogen to methane is thus a solution approach for a sustainable energy supply in rural areas.

Within the scope of the project, a novel concept of multi-phase high-pressure trickle bed reactors is investigated for methanation, which can be connected downstream of a conventional biogas plant. Compared to alternative methods, this new approach has significant advantages. For example, the fixed bed allows intensive contact between microorganisms and gases and the increased reaction pressure of up to 10 bar improves the previously problematic gas solubility. As a result, high gas and methane yields are expected with this concept.

To this end, a laboratory system for the conversion of hydrogen and carbon dioxide into methane was initially planned andconstructed, and equipped with a measuring, control and regulation technology. Experimental series on the influence of the operating parameters, such as loading rates, residence time, pressure and temperature, are currently being carried out with regard to an increase in the gas and methane yields.

In initial preliminary tests, the functionality of the concept was successfully demonstrated. Thus, methane contents >97% and methane formation rates of 2.5 l / (l d) were achieved in the three reactors realized.



Facility at laboratory scale for fermentative high-pressure methanation of hydrogen and carbon-dioxide

Funding:
Ministry of science, research and art Baden-Württemberg

Partners:
DVGW Research Unit at Engler-Bunte-Institut (DVGW-EBI)

Engler-Bunte-Institute of KIT (KIT-EBI)

Project duration:
June 2014 – Dec 2017

Bio-electrochemical production of high calorific biogas from waste materials (BioElektroGas)

M. Sc. Padma Priya Ravi

Jochen Harder

Armin Kinigadner

Dr. sc. agr. Andreas Lemmer

The aim of the research joint project is to convert biogenic waste to highly caloric biogas in compact and very efficient systems. The basis of the novel process is the combination of fermentative processes for the digestion of solid biomass with bioelectric systems for methane production, so-called microbial fuel cells. By means of this process combination, various substrates, such as market waste or feedstuffs, can be utilized flexibly. These organic residues are first fermentatively decomposed ("dark fermentation") at low pH values and converted into organic acids, which in turn are fed to the bioelectrochemical reactor.

The research group is to develop and test suitable anode and cathode materials for the microbial fuel cell. The electrode structure must also be adapted to the bio-chemical conversion processes. Further investigations are aimed at influencing the microorganisms at the electrodes. Finally, the overall fermentation-bioelectrochemical process has to be optimized at technical level in the laboratory scale at the state institute.

In the first test phase, hypermarket waste from “Bayha Gemüse”, Filderstadt, was used. This consisted of a mixture of carrots, carrot processing waste (puree), celery, cabbage and potatoes and thus showed typical components of hypermarket waste. The substrate mixture was fermented in a 2-stage system at various target pH values (5.5 and 6.0) in the acidification reactor. For both target pH values, the acid composition in the acidification reactor was examined. The gas quantities and gas compositions produced were measured for the acidification stage and the subsequent methane reactor.

Funding:
Projektträger Karlsruhe – Baden Württemberg Programme

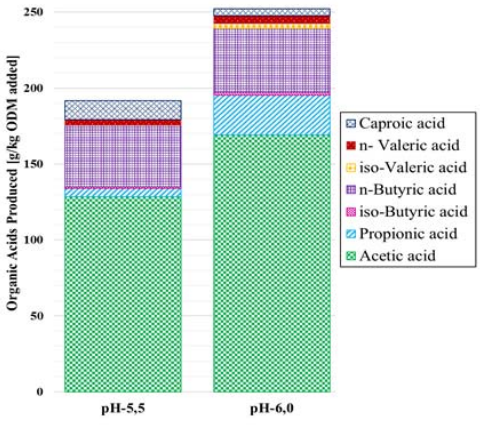
Partners:
Karlsruhe Institute of Technology (KIT)
Institute of Applied Biosciences (IAB)

University of Freiburg
Department of Microsystems Engineering (IMTEK)

University of Stuttgart
Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA)

Project duration:
Sep. 2015 – Aug. 2018

Vegetable waste



organic acids produced (g/kg)

Development of sensor technology and basics for a flexible load dependent intermediate production in two stage anaerobic digestion systems by a fully substrate utilization (Elast2P)

Dr. sc. agr. Jonas Lindner

Jochen Harder

Dr. sc. agr. Simon Zielonka

Dr. sc. agr. Andreas Lemmer

The expansion and use of weather dependent renewable energies like photovoltaic and wind power lead to fluctuations in the electricity grid. As a result, it is becoming ever more important to develop production processes for balancing renewable energy fluctuations. The answer may be in biogas, an easily storable and transportable energy source. Two-stage biogas plants are particularly suitable for flexible electricity generation. However at its current stage of development, the full potential of this technology has not yet been realized.

In the research association "ELAST2P", two objectives will be investigated at the University of Hohenheim:

- Sensor-guided, load-dependent methane production in a two-stage system.
- Increasing of the overall efficiency by a mechanical-biological treatment of the non-degradable fibres and a subsequent return to the process.

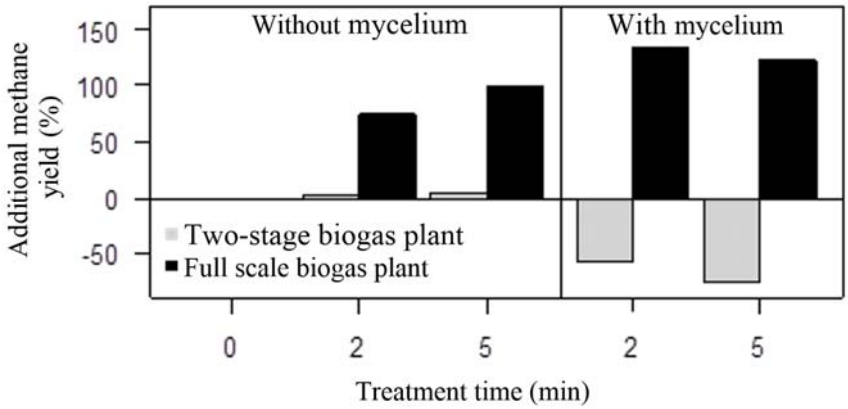
We will perform the experiments at two-stage biogas plants consisting of a continuous stirred tank reactor as the acidification reactor and an anaerobic filter as the methanogenesis phase. The project is subdivided into four working packages:

WP1: During the primary formation, the organic acids, alcohols and sugars that are formed must be separated from the undigested fibres. At this part of the project, we will investigate how different filter sizes and substrates affect the intermediate separation in the acidification reactor.

WP2: To improve the overall substrate degradation rate, we will determine how the methane yield will be affected by a combined mechanical treatment with a ball mill, together with an additional biological treatment by aerobic fungi of only the non degraded fibres, and a subsequent refeeding to the process.

WP3: An online measurement of the intermediate concentration and composition is necessary for a load dependent operation of the anaerobic filter. Therefore an acoustic waveguide sensor for an online measurement of the intermediate concentrations and compositions must be calibrated.

WP4: For a load dependent methane production, the feeding of the system needs to be coupled with mathematical models. The aim of this WP is to test such a model in a two-stage system developed by the Goethe University Frankfurt (G-CSC).



Influence of a combined mechanical / enzymatic treatment (mechanical: treatment time 0, 2, 5 min; enzymatic treatment: with aerobe Shiitake mycelium, incubation period 29 days) on the digestates (substrate hay/straw, maize silage) of a two-stage system and of a full scale biogas plant on the additional methane yield.

Funding:
Federal Ministry of Education and Research (BMBF)

Partners:
The Institute of Agricultural and Urban Ecological Project at Humboldt-University in Berlin (IASP)

Johann Wolfgang Goethe-University Frankfurt am Main: The Goethe Center for Scientific Computing (G-CSC)

Bavarian State Institute of Agriculture, Freising (LfL)

Project duration:
Dec. 2012 - March 2016

MethanoQuant - Quantifying ways of methane generation in two-phased anaerobic digestion

M.Sc. Johannes Krümpel

Jochen Harder

Armin Kinigadner

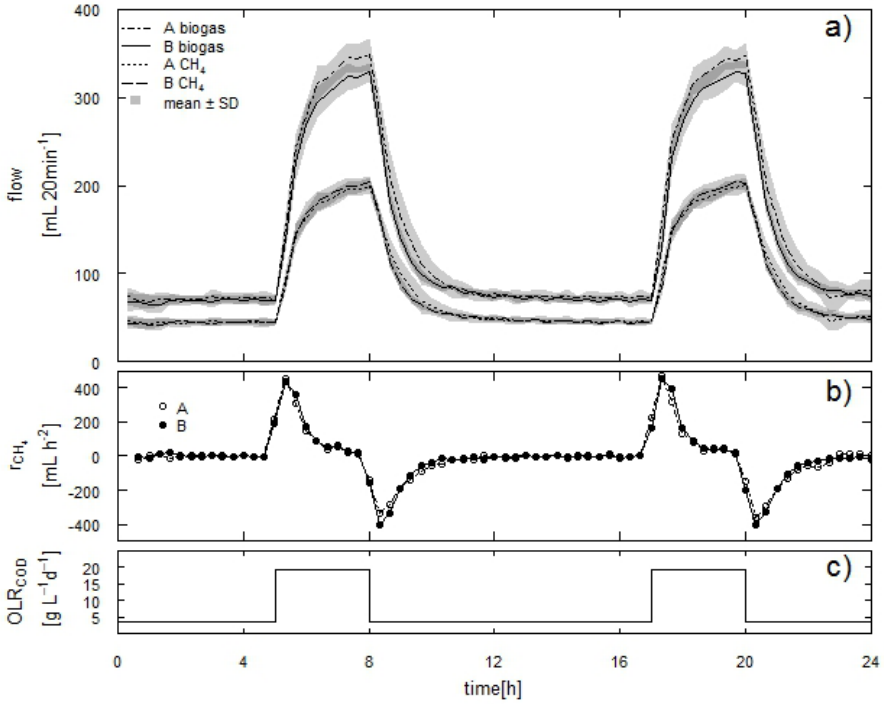
Dr. sc. agr. Andreas Lemmer

Dr. sc. agr. Simon Zielonka

The Two -phased process for biogas production is gaining more and more attention in science due to the high process stability, substrate flexibility and high methane contents of the produced biogas. The goal of the project is to describe the process of two-phased biogas production through mathematical computing to lay the foundation for a rapid and purposeful development of the process. Therefore, fundamental research is conducted at the state institute of agricultural engineering and bioenergy. In this respect, the individual components of process liquids of anaerobic filters that are responsible for the methane generation shall be identified. Furthermore, the individual gas production kinetics of these components shall be described. From the data, the mathematical models are adjusted and verified to lay the foundation for further optimization of the process.

For the experimental part, three anaerobic filters of identical construction are operated continuously. The data is acquired online in high resolution to construct an exact picture of the process. The process liquids are analyzed by GC and HPLC. The total organic carbon (TOC) is determined by the differential method from total carbon (TC) and inorganic carbon (IC) analysis. The experimental reactors are designed to be exchanged easily to enable research on different reactor types.

In the year 2016, the focus of the project was the flexible, demand-orientated biogas production with the help of anaerobic filters. It is found that these reactor systems are especially well suited for demand-oriented biogas production due to the very high re-producibility and predictability of the methane yield.



Biogas production of anaerobic filters during shock loads

Funding:
Federal Ministry of Education and Research (BMBF)

Partners:
Brandenburg University of Technology Cottbus – Senftenberg (BTU)

Goethe Center for Scientific Computing (G-CSC), Goethe University Frankfurt

Steinbeis Research Center Technical Simulation

Project duration:
Nov. 2012 – Aug. 2016

Autogenerative two-phase high pressure fermentation - AG-HiPreFer

M. Sc. Wolfgang Merkle

Jochen Harder

Armin Kinigadner

Dr. sc. agr. Simon Zielonka

Dr. sc. agr. Andreas Lemmer

Objectives:

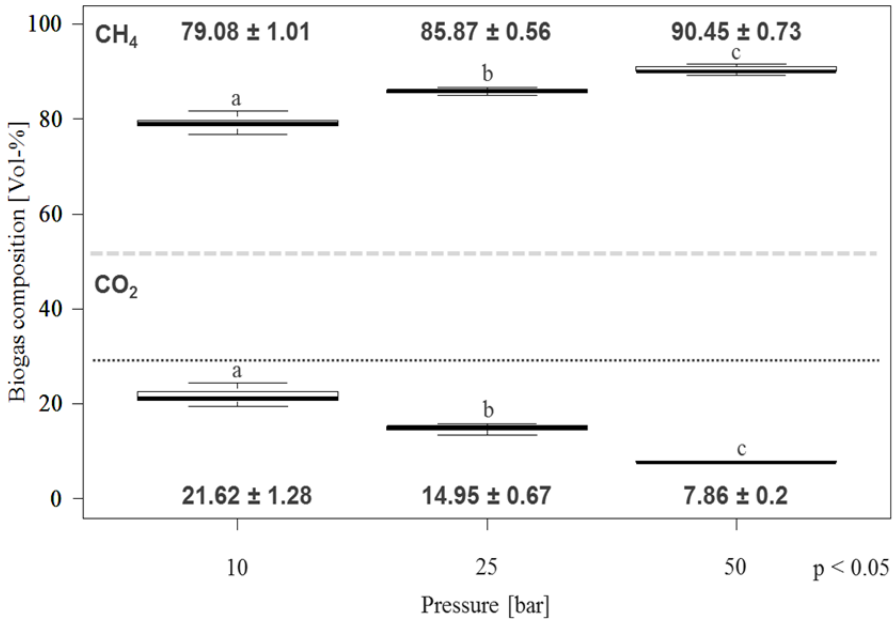
The aim of this project is to integrate biogas production, purification and pressure boosting into one process, saving up to 30% of energy consumption for the gas conditioning by avoiding the compression.

Therefore, a new, two-phase pressurized anaerobic digestion process, with an autogenerative increase of the pressure in the digester up to 100 bar, will be developed (AG-HiPreFer), producing biomethane of natural gas quality inside the methane reactor, which can then be fed directly into the grid. In contrast to the technologies commonly used, additional chemicals or compression are not required. Moreover, this biophysical process makes use of the fact that CO2 is more soluble than methane, resulting in a higher CO2 content in the liquid phase at increased pressures. Methane contents over 92% can be reached in the gas phase.

Additionally, studies involving an anaerobic Microbial Fuel Cell (AMFC) being integrated into the process will be conducted in order to increase the overall efficiency of the process.

Methods:

In the project, appropriate measurements and control concepts for process monitoring at operating pressures up to 100 bar have to be established. A new membrane concept for separating acids formed during the fermentation process will be developed. Experiments on the solubility of gases in the methane reactor will be conducted as well as studies to clarify the influence of pressure on microbiological process in the methane reactor. Moreover, basic research on the aMFC will be done, which uses the difference of the redox potential and hydrogen ions between the acidification reactor and the pressure methane reactor for a direct generation of electricity via carbon, stainless steel or iron cyanide electrodes. Finally, a system-analytical consideration and an economic evaluation of the process will conclude the project.



Influence of different operation pressures (10, 25, 50 bar) on gas quality in a continuous process

Funding:
Federal Ministry of Education and Research (BMBF)

Partners:
DVGW-Research Centre at the Engler-Bunte-Institute of Karlsruhe Institute of Technology (KIT)

Johannes Gutenberg University Mainz, Institute of Microbiology and Wine Research (IMW)

Associated partner:
Centre de Recherche Public Gabriel Lippmann, Département Environnement et Agro-biotechnologies (CRP), Luxemburg

Project duration:
July 2013 – April 2017

Two-phase anaerobic digestion of sugar beet for biomethane production – Process optimization of preservation and conversion for the improvement of energy yield (ZRCH4)

M. Sc. Elzbieta Kumanowska

Jochen Harder

Armin Kinigadner

Dr. sc. agr. Simon Zielonka

Dr. sc. agr. Andreas Lemmer

Dr. sc. agr. Hans Oechsner

The aim of this project is to offer the biogas plant operators an ecologically, energy-oriented and economically superior method. Our focus is to produce a high caloric biogas for the use as fuel or as SNG, which in turn provides an alternative to previous applications of electricity production.

To achieve this objective, we pursue a bilateral approach. We use the rarely-applied substrate sugar beet, which improves the ecology of the process and furthermore allows us to optimally use new process technology.

The first step is to develop a novel, optimal method to preserve the sugar beet. Accordingly, the results of storage tests and laboratory experiments are compared with those of conventional storage processes. As such, we are able to duly evaluate how preservation methods influence the energy yield.

The next step is to determine how suitable the ensiled sugar beets are for digestion within two-phase anaerobic digestion laboratory systems and to optimize crucial parameters. The new biological conversion processes are already able to fractionate the biogas during the production. This in turn significantly increases the methane content of the biogas. We are able to therefore reduce the cost of preparing biogas to a natural gas quality, and furthermore utilize the gas as a fuel. Producing biomethane could be an alternative for generating electricity using a CHP unit. The problem of using heat when converting biogas in a CHP unit is furthermore eliminated.

Although problematic in conventional biogas plants, sugar beet is an almost ideal substrate for the two-phase anaerobic digestion. With high sugar content and a low level of indigestible materials, such as lignin, sugar beet is very suitable for acidification.

Funding:
Federal Ministry of Food and Agriculture (BMEL)

Fachagentur nachwachsende Rohstoffe (FNR)

Partners:
Novatech Corporation

Research Stations:
“Unterer Lindenhof“ and “Ihinger Hof”

Project duration:
Sept. 2014 – Aug. 2017

Experimantal silos for sugar beet storage under construction at research station “Unterer Lindenhof”

Flexible feeding in biogas processes with model-based process detection in full-scale - FlexFeed

M. Sc. Philipp Kress

Dr. sc. agr. Hans-Joachim Nägele

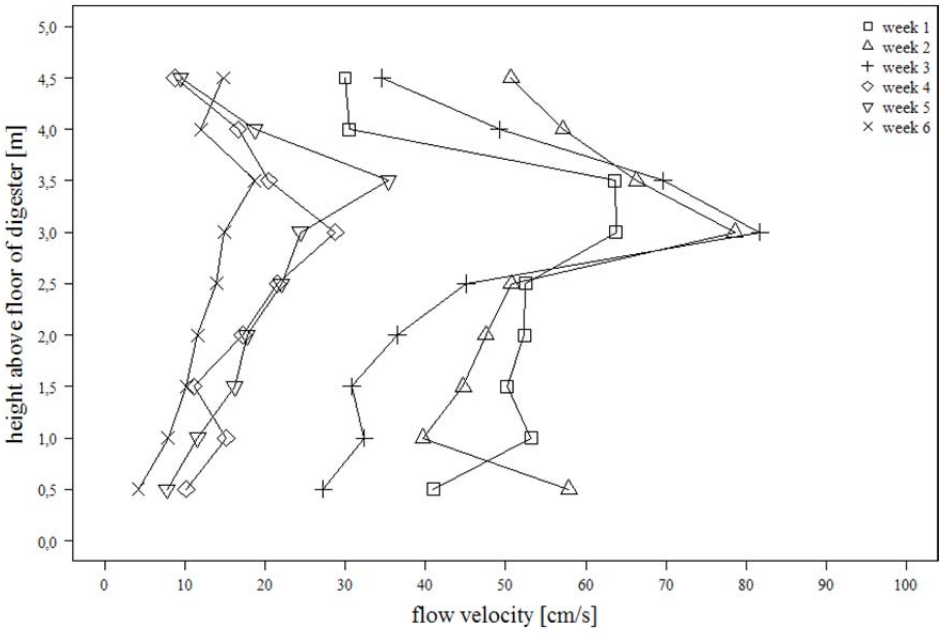
Dr. sc. agr. Hans Oechsner

Due to a decrease in farming area, the availability of raw materials as well as the current political conditions, biogas producers are using measuring techniques to either increase process efficiency or provide an alternative income. Biogas plants have the potential to secure the supply and stability by increasing dynamics in the power grid. As the gas upgrading processes are not profitable for many existing biogas plants, current attemps try to increase the flexibility of power production chiefly expanding gas storage and the co-generation unit.

With the help of storable biomass, it is possible to operate the digester in a controllable and flexible manner through optimized feeding management techniques. The impacts of the widely varying feeding management techniques on the biological, rheological process engineering parameters are not well understood. It is expected that through flexible process management, unknown conditions occur in the digester. They can endanger the undisturbed plant operation. It is therefor necessary to develop a strategy for innovative process monitoring and sample collection.

The aim of the investigtion is to evaluate and optimize the feeding management strategy in biogas plants. This strategy includes the combination of an innovative sensor in the liquid phase, model based monitoring and neural work as methodological approaches. This project is further divided into 3 different work packages:

- Package 1: Identification of crucial zones in the biogas digester
- Package 2: Installation and validation of the acoustic waveguide and near-infrared spectroscopy
- Package 3: Verification of developed models for a full scale biogas plant



Flow velocities at the lock 1.1 over the experimental period (Kolb 2016)

Funding:
Federal Ministry of Economic Affairs and Energy

Fachagentur nachwachsende Rohstoffe (FNR)

Partners:
Technical University - Berlin

SOTA Solutions (Berlin)

Project duration:
Aug. 2014 – March 2018

A study on measuring the efficiency of a new and innovative biogas-substrate stirrer and its flow behaviour

Dr. sc. agr. Hans-Joachim Nägele

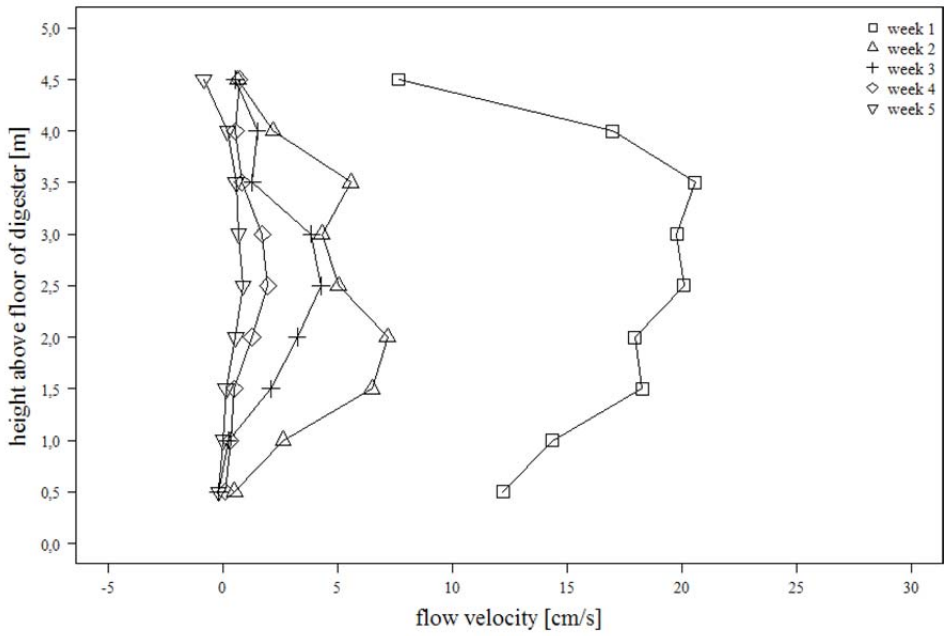
M. Sc. Philipp Kress

Dr. sc. agr. Hans Oechsner

For this research project, an exceptionally innovative bionic stirrer from the specialist WUSOA with two residence times (about 180 days) will be installed in one of the two biogas digesters at the research biogas plant „Unterer Lindenhof“ of the Lindenhof agricultural research stations at the University of Hohenheim. In particular, the following factors will be tested:

- Primary energy consumption (ongoing)
- Quantity and quality of biogas produced (ongoing)
- Nutrient distribution in the digesters (12 measuring points, 3 heights - every 2 months)
- Biological process activity of the digestate in the digester (fornightly)
- Viscosity of digester contents using a pipe viscosimeter (every two months)
- Flow pattern (together with Fraunhofer IKTS in Dresden)
- Comparison of the new measurement data to existing facility stirrers

The results show that with increasing viscosity in digester 2 and with a dry substance content of 9% in the fermentation substrate, flow velocities cannot easily be measured with the magneto-inductive flow sensor. The flow velocities at all positions and heights tend to be 0 cm / s. The nutrient distribution showed no measurable differences in comparison between conventional and bionic agitator feed. The dry substance and the ferric acids were uniformly distributed over all positions and heights. It was noticeable that during the transition phase from low to high TS contents in the fermentation substrate, massive float layers were formed on the surface which could not be introduced by the bionic agitator alone. The submersible mixer had to be used very frequently. The investigation also showed that the very short observation periods are not sufficient enough to determine the mixing quality. Long-term tests are necessary.



Flow rate at digester position 1.3 over all experimental weeks

Funding:
The state of Baden Baden-Württemberg as part of the Baden-Württemberg program

Project duration:
Realization in 2015 – Extended until Dez. 2016

Research into the use of N-rich and lignocellulosic biomass for biogas production: methane yield potentials, process stability and nutrient management

In Ukraine, the potential of bioenergy crops, which amounts to 3.8 thousand hectares, can substitute 21 million m^3 of natural gas. The current amount of cattle in Ukraine is significantly low (2,120 livestock units). For this reason, the organic fertilizers are applied only to 2.5% of cultivated areas. Bioenergy crops converting within the biogas production process can fill up this deficiency in fertilizers. Separation treatment can improve digestate characteristics for its application in organic precision farming.

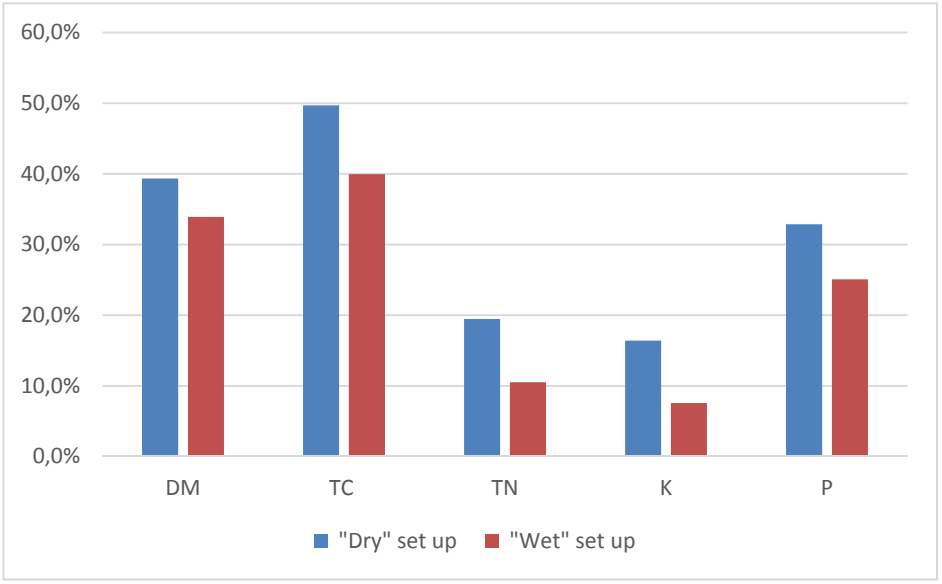
The project aims to fulfil three main objectives:

- Experimental investigation on the influence of plant-varieties, harvest times and biological pre-treatment on the methane yield potentials of miscanthus and other lignocellulosic bioenergy crops grown in Ukraine (HBT).
- Experimental investigation on the process stability during anaerobic digestion of N-rich and lignocellulosic biomass (CSTR-lab scale system).
- Separation of digestate: study on nutrient management technologies by testing different set-ups of screw-presses (Full scale application).

Separation of digestate: The aim of this research is to analyze the distribution of nutrients in solid and liquid fractions by testing different working modes of the separators. The first experimental research trials were performed at the “Unterer Lindenhof” biogas plant. The digestate was separated by using the UTS screw press. The working mode of the screw press was regulated by changing the operating pressure. Research experiments were conducted under dry and wet working modes of the screw press with high and low dry matter content respectively.

M. Sc. Ievgeniia Morozova

Dr. sc. agr. Andreas Lemmer



Nutrients content of the solid fraction for “dry” and “wet” set ups

Funding:
German Academic Exchange Service (DAAD)

Partner:
Institute of Bioenergy Crops and Sugar Beet of the National Academy of Agrarian Sciences of Ukraine

Project Duration:
Oct. 2016 – Nov. 2019

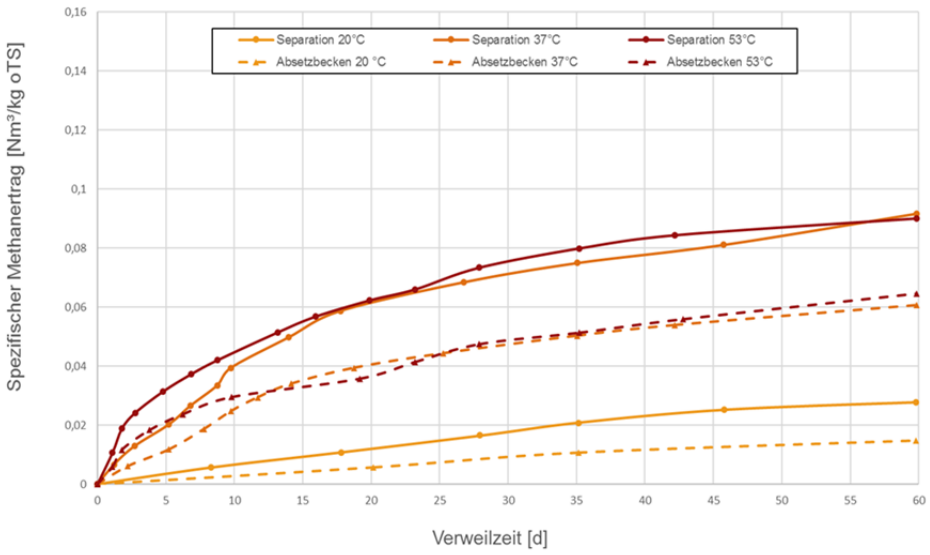
Detection of the methane emission potential of biowaste treatment plants by determining the residual methane potential

B. Sc. Tobias Bauer

Dr. sc. agr. Hans Oechsner

Approximately 5% of the biogas stream is currently produced in Germany from biowaste fermentation plants. Their production could be significantly increased if a larger proportion of the collected biowaste would not be recycled via composting plants but consistently via anaerobic systems. In the case of existing biowaste fermentation plants, it is not the generation of energy but the stabilization of the organic waste that is the main focus. As a result, the plants are usually not designed for full utilization of the energy potential. Thereby valuable energy quantities remain unused.

On behalf of the LUBW, fermentation residues from five waste water treatment plants were tested for their residual gas potential. In plants with a different construction principle, which are operated in the thermophilic temperature range at approx. 55°C, only very short hydraulic residence times of less than 20 days are available compared to agricultural NaWaRo systems. The fermentation residue is then separated into a liquid fraction and a solid fraction in separating plants. While the solids fraction is fed to an aftertaste, the liquid fraction is first temporarily stored in settling tanks for several days in order to free them from sediments. They then enter storage containers. It has been shown that the settling basins and also the storage containers are not covered with gas in many systems. Since a high temperature prevails in the sedimentation basin and storage takes place for up to 13 days, the separated fertilizer substrates were sampled prior to the inlet and while leaving the basins and the residual gas potential was investigated. In this method, according to VDI guideline 4630, the substrate was fermented for a period of 60 days at fermentation temperatures of 20°C., 37°C. and 55°C. in the laboratory. In addition, data on the anaerobic plants were recorded. It was found that only up to 10% residual methane potential is present in the liquid fraction after separation. Part of this potential is lost and has a nagative environmental impact. The project will provide guidance on the optimization of the procedures.



Exemplary result of the residual methane potential of a waste fermentation plant - consideration of separated fermentation residue and substrate after leaving a sedimentation basin, fermentation at different temperatures

Funding:
Ministry of the Environment,Climate Protection and the Energy Sector Baden-Württemberg, LUBW

Project duration:
June 2016 – March 2017

Development of efficient two-phase anaerobic digestion plants via coupled energetic and material utilisation (Optigär)

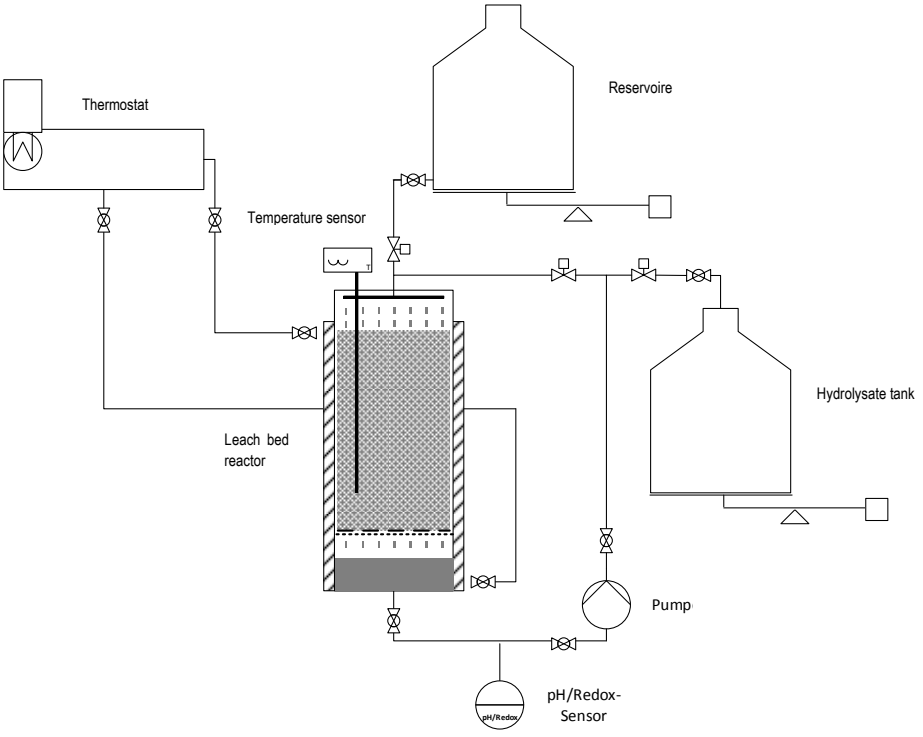
The overall objective of this project is to develop a procedure for a cascade use and thereby a sustainable and integral utilisation of agricultural raw materials. In this procedure, the main focus is on organic acids with a high economic value.

In this project, a new concept will be developed for the integrated material use of two-phase biogas plants. This approach will enable a coupled material and energetic use of agricultural raw materials. Different process parameters such as temperature, organic loading rate, pH-value and buffering capacity, the addition of various additives (enzymes, microorganism cultures, buffer substances) and a specific feed material selection, will be tested to increase the concentration of usable platform chemicals in the acidification process. The produced hydrolysate will then be treated with selective membranes to separate valuable products. Process residues will be recycled in anaerobic digestion.

To optimize the yields of valuable substances, there will be both a screening of a variety of agricultural raw materials and of the different reaction conditions. The aim is to select suitable substrates and appropriate acidification reaction conditions. For process control, the acidifcation products are regularly analysed by wet chemistry analysis.

The Fraunhofer Institute for Chemical Technology (ICT) will separate valuable organic acids via special membranes. To achieve a fully integrated process flow, the separation unit will be integrated into the digester chain.

In addition, the European Institute for Energy Research and Lipp GmbH will perform a profitability assessment, a life cycle assessment and develop a concept for industrial scale production.



Acidification in a leach bed reactor system

M. Sc. Jörg Steinbrenner

Dr. Hans-Joachim Nägele

Dr. sc. agr. Hans Oechsner

Funding:
Fachagentur Nachwachsende Rohstoffe (FNR)

Partners:
Frauenhofer Institute for Chemical Technology (ICT)

EiFER European Institute for Energy Research

Lipp GmbH

Project duration:
Sep. 2015 – Aug. 2018

Optimized substrate management and how the composition of biogas digestate influences soil-nitrogen and soil-humus balance

B. Sc. Florian Siemeister

M. Sc. Natali Böttcher

Dr. sc. agr. Hans Oechsner

The nutrient composition in fermentation residues and thus also the later humus efficiency is very different, depending on the fermentation substrates. The influence of the fermentation residue treatment on the composition of fermentation residues and their fertilizing effect has so far not been adequately investigated. Furthermore, storage capacity problems result from the observance of blocking periods to a seasonal shift in nutrient supply. The storage capacity in the farms is often already exhausted in the autumn, while the nitrogen requirement is highest in the spring.

The aim of the overall project is to characterize various specific substrates with the help of a stable isotactic 15N tracer in order to evaluate their fertilization.

For this purpose, different investigations were carried out at the Landesanstalt for the isotopic nitrogen labeling of fermentation residues, the investigation of influences on the fermentation residue composition and the analysis of the nitrogen conversion during the process. In order to be able to carry out the chemical characterization of the fermentation residues, maize, ryegrass and sugar beet were first labeled with 15N in the greenhouse and then fermented in a 2L Fed batch system.

For the better usability of the nutrients and the improvement of the transportability, there are technical procedures for the processing of fermentation residues. These methods (dryers, vacuum evaporators) are now to be recorded using a mass balance and checked for their efficiency. The aim is to develop an optimized process that allows nitrogen to be separated from the circuit and to provide manure that can be stored .

By providing a planning tool to optimize the estimation of the fertilizer's own fermentation residue by the plant operator, production recommendations can be given for ecologically and economically sustainable biomass production systems.

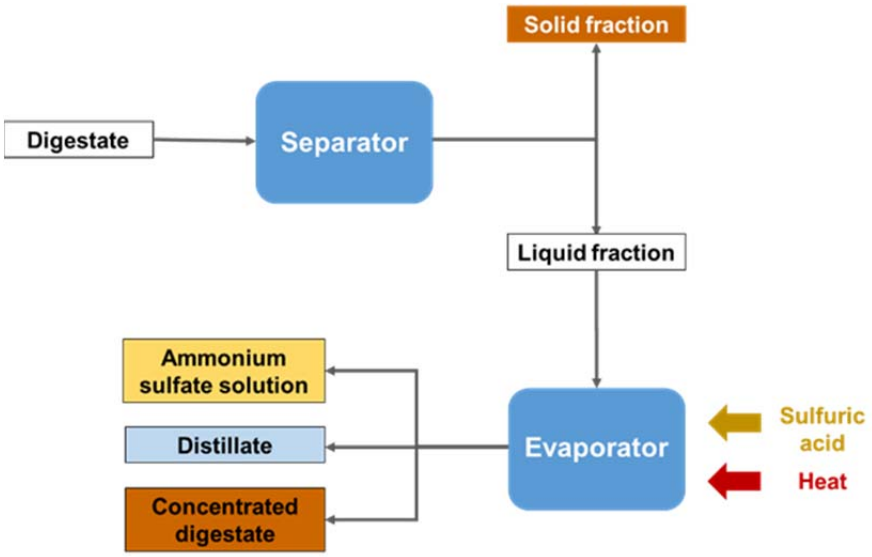
Funding:
Fachagentur für Nachwachsende Rohstoffe (FNR)

Partners:
University of Hohenheim
Institute of Crop Science, Fertilization and Soil Matter Dynamics (340i)

University of Rostock
Professorship of soil science

Steinbeis Research Center (SFZ)

Project duration:
Nov. 2014 – Oct. 2017



Concept of vacuum evaporation

Effect of TE application on bio-methane yield and process stability of digestion of coffee pulp and husk

M. Sc. Bilhate L. Chala

Dr. sc. agr. Hans Oechsner

Prof. Joachim Müller

Ethiopia is the birth place for Coffea Arabica. Coffee production has vital economic and cultural implications and nearly a fifth of the population are dependent on producing coffee for their livelihood in Ethiopia.

Primary coffee processing happens mostly in developing countries and produces green coffee bean both for domestic and export purposes. However, the process produces a large amount of biomass as a by-product (pulp, husk, mucilage and parchment) which is subsequently dumped without any use. This creates significant environmental and social problems.

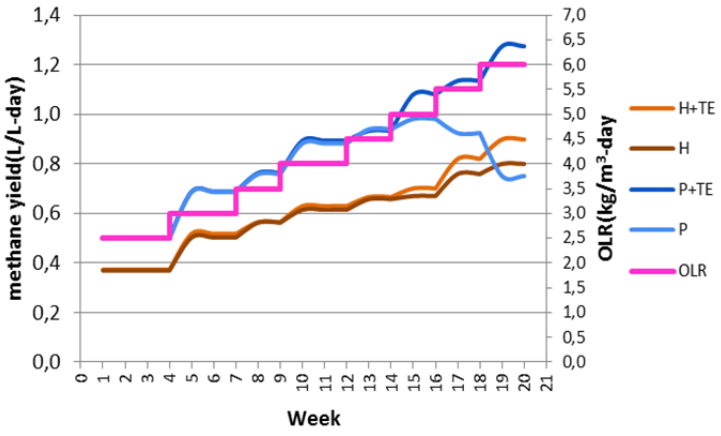
The biomethaneyield potential was examined with HBT and was found to be promising for all by-products except parchment. The methane yield during digestion at 37°C of pulp, husk and mucilage was 0.245, 0.159 and 0.294 m_N^3/kg_{oDM} respectively.

The elemental analysis of coffee pulp and husk indicated that both substrates lack important trace elements (TE) like manganese, zinc, cobalt, molybdenum, iron, nickel, selenium, and tungsten; which are critical for stable anaerobic fermentation in continuous mono-digestion systems.

The bio-methane production performance for digesters fed with pulp and husk, with and without the application of trace elements, was evaluated in duplicate 20L volume CSTR reactors for 20 weeks. The organic loading rate started at 2.5 kg_{oDM}/m^3 d and gradually increased up to 6 kg_{oDM}/m^3 d.

The average stable methane productivity from-fed pulp containing digesters with and without TE was 1.3 m^3/m^3 d and 1 m^3/m^3 d for OLR of 6 kg_{oDM}/m^3 d and 5 kg_{oDM}/m^3 d, respectively. Similarily, the productivity of the husk with and without TE was 0.9 m^3/m^3 d and 0.8 m^3/m^3 d, respectively, with an OLR of 6 kg_{oDM}/m^3 d.

In comparison to their counterparts without TE, digesters with TE were found to be more stable with consideration to VFA and FOS/TAC values as well as pulp and husk substrates. In addition, the bio-methane yield was also superior for digesters containing TE. Moreover, TE application favours a higher organic loading rate for digesters containing pulp.



Methane productivity of pulp and husk with and without application of trace elements (TE), with different OLR

Funding:
GlobE BiomassWeb project

Partners:
University of Hohenheim
Institute of Agricultural Engineering
Agricultural Engineering in the Tropics and Subtropics (440e)

Biogas Measurement Program III - Factors for the efficient operation of biogas plants

M. Sc. Benedikt Hülsemann

M. Sc. Lijun Zhou

Dr. sc. agr. Hans-Joachim Nägele

Dr. sc. agr. Hans Oechsner

The construction of new plants has been significantly reduced in recent years due to changes in the Renewable Energy Sources Act (EEG). At the same time, the end of the 20-year-long remuneration under the EEG 2004 and 2009 threatens to lead to a decommissioning of old plants. This situation has changed the biogas sector in Germany. An improvement in efficiency and thus profitability as well as a sensible re-design of bonuses in the EEG are urgently necessary to maintain the number of plants and the market leader in biogas in Germany.

In Biogas Measurement Program III, biogas plant operators and politicians are being developed with the help of a monitoring system for 60 biogas plants throughout Germany. A complete picture of the plant stock and current practice is presented as well as an evaluation of new measurement methods for the exact determination of the efficiency of biogas plants. This is intended to show both efficient plant concepts and difficulties in the operation of biogas plants.

An economic, biological and technical analysis of the plants is prepared to determine the efficiency. For biological analysis, samples are taken from all containers and substrates on a monthly basis, and they are analyzed for a variety of parameters. All other analyses are based on operating data. In order to record these, operating daybooks as well as available meter readings are recorded and read.

A comparison of theoretical data calculated from the results of the biological analysis and the operating data is used to validate the measurement results. At the same time, the comparison is used as the basis for the doctorate awarded in BMP III. In the doctoral dissertation, the deviations of the data from one another are examined and the causes examined in more detail.

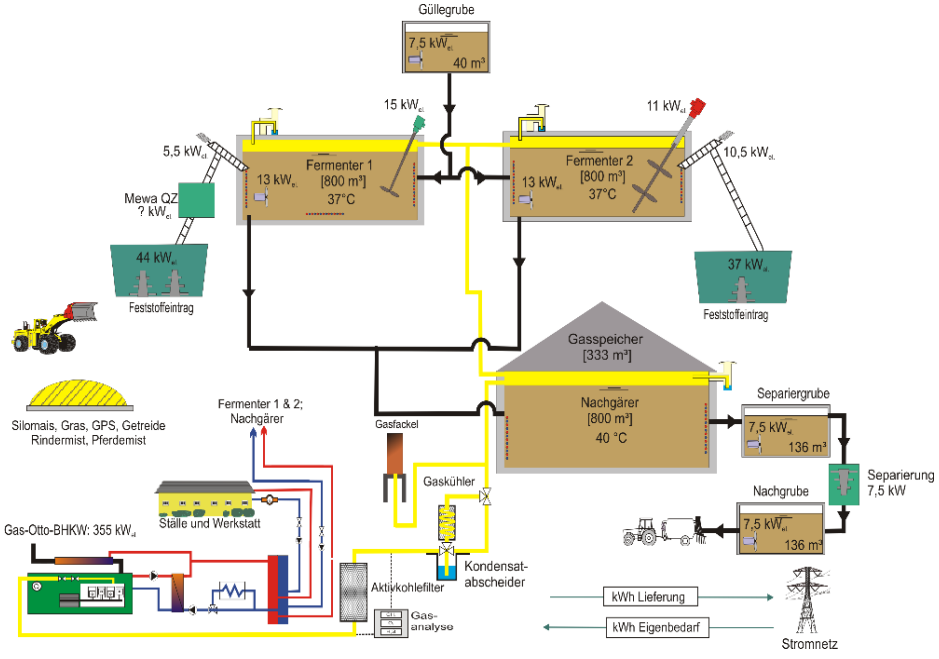
Funding:
Fachagentur für Nachwachsende Rohstoffe e.V.

Partners:
Bavarian State Research Center for Agriculture

DBFZ Deutsches Biomasse Forschungszentrum (Coordinator)

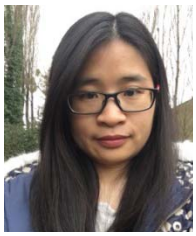
EEK.SH Competence Centre Renewable Energies and Climate Protection Schleswig-Holstein

Project duration:
Jan. 2016 – Dec. 2018



Scheme of the Unterer Lindenhof facility examined under the BMP III

German Biogas Measurement Program III – A Suitable Program for China? Biogas Plant Operation and Performance Assessment



M. Sc. Lijun Zhou

M. Sc. Benedikt Hülsemann

Dr. sc. agr. Hans-Joachim Nägele

Dr. sc. agr. Hans Oechsner

Prof. Dong Renjie (CAU, Peking)

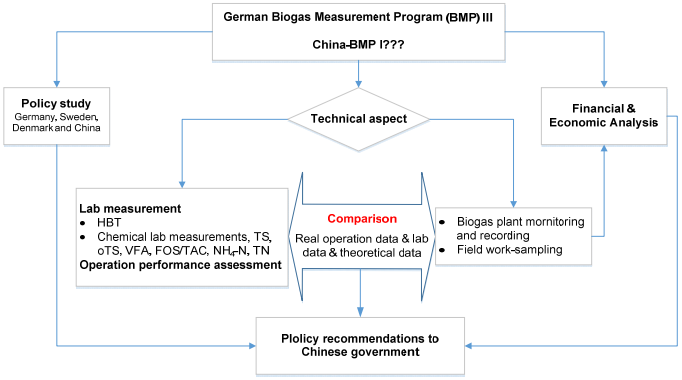
China's fast-growing economy has seen rural energy consumption surge and the rapid expansion of the livestock breeding and agro-industries. These rural businesses create billions of tons of biomass waste annually, which can potentially be used to produce energy. According to the country's 13th Five-Year Plan (2016-2020), China will allocate CNY 50 billion ($7.3 billion) to build biogas projects on rural areas to boost its clean energy use, which will include construction of 172 new biogas projects and 3,150 large-scale biomethane projects.

However, given the current development status quo and obstacles in the biogas sector, such as low plant operation efficiency and low biogas production efficiency, lack of standards and insufficient policies have emerged. The research will be drawn from lessons learnt from the previous two German Biogas Mesurement Programs (BMP) and carried out before the BMP III. Furthermore, BMP III methodology will be applied and adjusted in China, to establish the first Chinese BMP as appropriate.

Technically, based on German BMP III, the research will be carried out at 10+ biogas plants, through plant operation monitoring, substrate sample collection and lab mesurements of key indicators, i.e., biogas potential of different substrates through HBT, features of samples (TS, oTS, VFA, FOS/TAC, NH_4-N, etc.), to understand and familiar with the biogas plants operation in Germany, which might be used as a good reference to Chinese biogas plant operators. Building further on this foundation, sample biogas plants in China based on different scales (i.e., 500-10,000 m^3 reactor capacity), substrates (i.e., pig manure, cow manure, chicken manure, organic waste and crop straws), biogas utilization (i.e., household supply, power generation and biomethane) and locations will be selected to conduct the similar monitoring and measurements as German BMP III. Furthermore, the methodology will be adjusted to reflect the situation and establish the first Chinese BMP as proper.

In terms of policy, studies related to the government policy in countries with more advanced biogas technologies and market, for instance, Germany, Sweden and Denmark, will be carried out to present a complete and clear picture to the Chinese government about how other governments are developing and supporting the sector.

In addition, financial and economic analysis will be carried out to all studied biogas plants to assess the viability. This will draw a picture about how to make the biogas plant operation more profitable in the market, rather than only relying on government subsidies. The analysis results will also provide the government a picuture about how the policy shall be structured appropriately.



Research roadmap (March 2017)

Partner:
China Agriculture University, the People's Republic of China

Project duration:
Nov. 2016 – June 2019

Anaerobic digestion of high yielding tropical energy crops for biogas production: Effects of crop types, locations and plant parts

Surendra K C, ABD

Dr. Richard Ogoshi

Dr. sc. agr. Annett Reinhardt-Hanisch

Dr. sc. agr. Hans Oechsner

Dr. Andrew G. Hashimoto

Dr. Samir K. Khanal

Hawaii, one of the most isolated landmass inhabited by humans, is heavily dependent on the imported energy resources to meet its energy demand. Currently, about 90% of the energy consumed on the islands is met by the imported fuels. To address the energy security, environmental and economic issues associated with the heavy reliance on the imported fuels, Hawaii Clean Energy Initiatives targets to meet 100% of its energy demand by clean energy sources by 2045, which envision bioenergy as an important component of the clean renewable energy portfolio. To achieve an ambitious target of meeting 100% of the energy demand by clean sources, bioenergy generation via anaerobic digestion (AD) of C4 perennial energy crops have gained significant attention due to several environmental and ecological merits. Additionally, the subtropical to tropical climatic conditions of Hawaii provide a year round growing season for tropical perennial energy crops. However, not only the biomass yield, but also the composition of the lignocellulosic energy crops varies with crop type (i.e., genotype), crop management, crop maturity, location (i.e., environmental conditions), and plant part. Such variations significantly affect the anaerobic digestibility and subsequent biogas yield. Very limited information is available on the composition and anaerobic digestibility (for biogas production) of the different plant parts of tropical energy crops harvested across different years/seasons and locations. Detail characterization of the plant parts of energy crops grown across different locations will help with selecting an appropriate crop type (for a specific location) and plant parts for efficient AD.

This study examined the effects of locations, harvest years/seasons, and plant parts (i.e., leaves and stems) of different cultivars of two perennial C4 energy crops, namely Energycane (Saccharum spp.) and Napier grass (Pennisetum purpureum), on the composition and subsequent anaerobic digestibility for biogas production. Biomass samples were collected from three locations on the island of Maui, Hawaii, USA, and were characterized for their fiber compositions following ANKOM methodology at University of Hawaii at Mānoa. The Biomethane yield potential test of selected biomass samples was conducted following the Hohenheim Biogas Yield Test (HBT) method at University of Hohenheim, Germany.

Energy crops differed significantly (by crop type and plant parts) in composition and in methane yield during AD, and thus, require either different pretreatment conditions or conversion technologies to maximize the energy recovery

Growing Pennisetum purpureum at the resaerch station Waimanalo, Hawaii (http://www2.hawaii.edu/~khanal/biofuel/feedstock.html)

Partner:
University of Hawai'i at Mānoa,

Project duration:
Jan. 2016 – Aug. 2016

Procurement of the large scale research unit "Biogas-CHP"

On behalf of the Rectorate, the State institute of agricultural engineering and bioenergy assumes the management of the company and the coordination of the research projects at the biogas plant "Unterer Lindenhof". This research unit is owned by the University of Hohenheim. In 2016, the extension of the plant was a special task of the state institute.

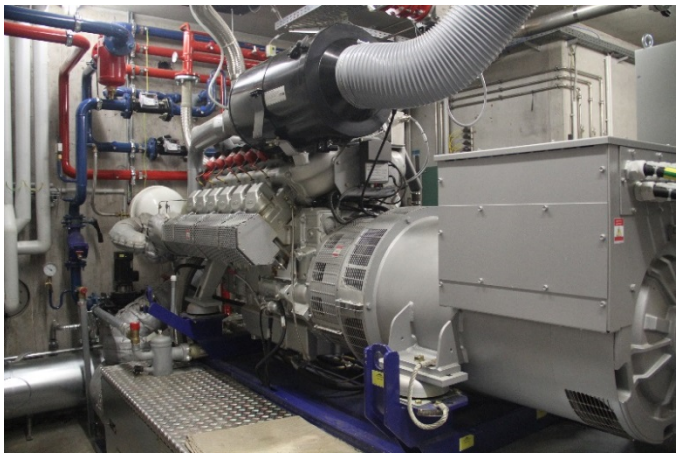
In 2016, numerous technical adjustments were made to the biogas plant. For example, the new CHP unit, which has an electrical output of 355 kW, was installed in the middle of January to the end of February. For this purpose, it was necessary to replace the entire periphery of the CHP (gas control section, activated carbon filter and measuring instrument). The new cogeneration plant now allows investigations into the integration of bioenergy into virtual power plants and demand-oriented electricity and heat production. Due to the simultaneous adaptation of the central control of the system, hourly precision performance curves can be specified and their effects on efficiency, emissions, maintenance costs, etc. can be investigated. This leaves the research biogas plant a highly topical reallaboration.

In the exchange of the CHP, the feed-in management of the produced electricity was also changed. Thus, a "full feed" was converted to a "surplus feed"; i.e. That the site is now supplying electricity to Lindenhöfe and only the excess electricity is fed into it.

Up to now, the liquid substrates were stored in 6 open containers of 500m³ after separation from the secondary fermentation store. In 2016, for the sake of aging and environmental protection, together with the university building authorities as well as the regulatory authorities, the demolition of 4 existing reservoirs and the planning of a new digestate storage with a volume of 4,800 m³ was pushed forward. At the same time, the over 45-year-old liquid manure system of the Lindenhöfe site had to be re-planned with the corresponding control system. The construction project will be implemented in 2017. The new digestate storage is expected to have a shelf life of fermentation products of 270 days from autumn 2017 onwards. At the same time, the gas storage volume has considerably increased so that the day-to-day operation of the CHP unit can be better adapted to the requirements and the research tasks.

Dr. sc. agr. Andreas Lemmer

Dr. sc. agr. Hans-Joachim Nägele



New gas CHP at the research biogas plant with an electrical output of 355 kW

Funding:
University of Hohenheim

Project duration:
proposed 2014 - realisation 2016

The chemistry laboratory of the state institute of agricultural engineering and bioenergy

Dipl.-Biol. Annette Buschmann

Jacqueline Kindermann

Inga Buschmann

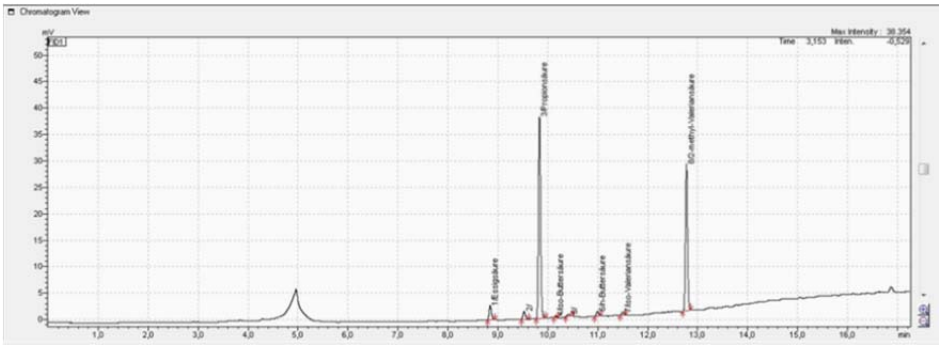
The process-biological assessment of ensiling processes, anaerobic digestion or for the biological production of platform chemicals requires an exact knowledge of the intermediates formed in the process as well as the input and output substances. The necessary analyses are carried out in the chemical laboratory of the State institute for agricultural engineering and bioenergy. Laboratory analysis has been continually developed over the last few years, as modern equipment could be procured from university and third party funds. The following devices and evaluation methods are available:

Two gas chromatographs (GC) for determining the contents of volatile fatty acids in the digester substrate, important parameters for assessing the biological stability of the biogas process,

A high-pressure liquid chromatograph (HPLC) with the aid of which fatty acids (including lactic acid), alcohols as metabolites of the biogas process, as well as especially non-volatile compounds, e.g. various sugars can be analyzed, a fully automatic titration system for determining the buffer capacity of Fer-menterinhalt, a high-performance analyzer for simultaneous analysis of total carbon (TC), inorganic carbon (TIC) as well as total nitrogen (TN) in aqueous samples plus the TC content in solid samples a pulping and distillation system for the determination of total nitrogen and ammoniacal nitrogen, both aqueous and solid samples by Kjeldahl method.

Nearly all devices are equipped with an auto sampler, which, after the sample preparation, enable a fully automatic determination and thus significantly increase the sample throughput.

In 2016, the focus of the analytical spectrum broadening was on the expansion of HPLC to determine the mannitol content of silages. The amount of alcohols formed during the ensiling has a considerable influence on the silage losses as well as the drying losses during TS determination. In contrast to other silages, mannitol can be the largest alcohol fraction in sugar silages in the silage. To date, there has been no method by which this alcohol can be determined in silages. By expanding the existing HPLC by a second column (calcium column) with flux HPLC water, the necessary equipment requirements were created. Since the determination of the sugars and alcohols is disturbed by the ferric acids formed, these must be removed from the sample by means of an anion exchanger before analysis. By developing this new analytical method, together with the equipment manufacturers, the analysis of the laboratory was again expanded in 2016.



Chromatogram of GC analysis of a digester sample taken from the biogas plant "Unterer Lindenhof"

Co-organized Conferences

- Biogas Info Tage (Biogas information Days)
  13.-14.01.2016
  Ulm fair, Ulm, organised together with Renergie Allgäu e.V.
- ALB Fachtagung - „Melktechnik“ (Symposium “Milking Technology”)
  3. März 2016
  University of Hohenheim, Stuttgart, organised together with ALB Baden-Württemberg
- ALB Fachveranstaltung - „Aktuelles aus der Hohenheimer Agrarforschung“ (ALB Symposium “News of The Hohenheim Agricultural Research”)
  13. April 2016
  German museum of agriculturre, organised together with ALB Baden-Württemberg
- ALB Fachgespräch - „Ferkelerzeugung“ (ALB Technical Discussion-”Pig Production”).
  24. November 2016
  Erbach-Dellmensingen, organised together with ALB Baden-Württemberg
- International Biogas & AD Training Course
  11.-15.04.2016, Stuttgart, University of Hohenheim, organised together with IBBK

International Guest Scientists to the State Institute

- Aida Sandybaeva
  „Influence of magnetic fields on the kinetics of biogas production“
  Technical State University named by I.Razzakov
  Kyrgyzstan
- Bilhate L. Chala
  “Effect of TE application on bio-methane yield and process stability of digestion of coffee pulp and husk”
  University of Hohenheim, Institute of Agricultural Engineering, Agricultural Engineering in the Tropics and Subtropics (440e)
- Edmond Demollari
  “Evaluation and optimization of indicator parameters of biogas production from agricultural waste ”
  Agricultural University of Tirana
  Albania
- Irina Miroshnichenko
  “Methane yield tests of Russian substrates" and "Investigations on the process stability during fermentation of nitrogen-rich substrates”
  Agricultural State university of Belgorod
  Russia
- Surendra K.C.
  “Co-digestion of animal manure and agricultural residues for enhanced methane production “
  University of Hawai´i at Manoa
  USA

Social Media

Dr. sc. agr. Hans-Joachim Nägele
Creation of the website: http://www.bioenergieforschungsplattform-bw.de
commissioned by the Ministry of Rural Affairs and Consumer Protection Baden-Württemberg

Graduate Theses 2016

Doctoral Theses

Jonas Lindner
Optimierung der primären Gärung bei zweistufigen Biogasanlagen. Dissertation, University of Hohenheim.
http://opus.uni-hohenheim.de/volltexte/2016/1242/pdf/20160222_Dissertation_Lindner.pdf

Michael Mutombo Mukengele
Biochemical composition of biomass and its impact on the prediction of the specific methane yield potential. VDI-MEG.

Staff of the State Institute who partake in a doctorate within the faculty of agricultural sciences are scientifically supervised by the Senior Head of the State Institute, Prof. Dr. Thomas Jungbluth.

Master Theses

Bing, S.
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Illi, L.
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Luff, K.
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