Biogas yields – from laboratory into practice

Inter-laboratory campaign | Standard biogas yields

Workshop "Conundrum of Biomethane Potential Tests"
10th June, Leysin (Switzerland)

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Content

KTBL

- KTBL – an introduction
- The KTBL/VDLUFA inter-laboratory campaign "Biogas"
- Standard biogas yields for agricultural AD plants used in Germany

KTBL – an introduction

Kuratorium für Technik und Bauwesen in der Landwirtschaft
Association for Technology and Structures in Agriculture

- Non-profit organisation
- Located in Darmstadt (south of Frankfurt)
- 60 employees
- Government-financed by German Federal Ministry of Food and Agriculture
- Objective of KTBL is the knowledge transfer from science to practice for the agricultural sector

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KTBL – an introduction (2)

Target groups

- farmers, politics, administration, advisory services, research, industry…

Tasks

- Collect and process costing data
- Description of state of the art
- Evaluation of new technologies (economic and ecological assessment)
- Initiation and coordination of R&D projects
- Provision of scientific and technical advisory statements to policy and administration
- Contribution to national and international regulations

Approach is coordinated with a large ***network*** of 400 honorary members in KTBL-working groups

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Products and services – e.g. biogas

Publications, e.g.

Conferences and Workshops, e.g.

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Products and services (2) – e.g. biogas

Online tools (free of charge)

e.g. **Biogas economic calculator** (in German)
http://daten.ktbl.de/biogas/startseite.do#start

e.g. **European Feedstock Atlas** (EU-Project)
http://daten.ktbl.de/euagrobiogasbasis/

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For what do I need fermentation tests?

For (agricultural) biogas production:

- the analytical assessment is difficult because of the complex nutritional composition of the substrates
- quality of substrate varies (carbohydrates, protein and fat content correlates with the energy content, biogas quality and digestibility)
  - plant relatability is largely determined by the substrate costs (substrate costs can make up to 60% of the annual operating costs)
- reliable information are needed for the system design/planning (e.g. ratio of fermenter size / volume load to CHP performance) or
- needed for efficient plant operation (amount of daily substrate feed-in to achieve full CHP performance (full load hours) or repowering actions

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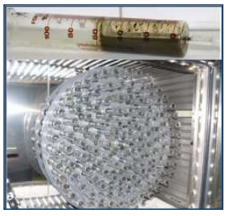
Methods of biogas potential test

- Batch tests are mainly used for such biogas yield tests
  - material is mixed with a seeding-sludge
  - incubation normally at mesophilic conditions
  - test ends if no relevant gas production takes place (30 - 35 d)
  - different experimental approaches/set up (sample volume between 100 ml - 15 l)
- Continuous fermentation tests are normally used for the simulation of operating parameters (volume load, hydraulic retention time, process stability, etc.)
- In general, the experimental potential test are realised according the VDLUFA method "Determination of biogas and methane yield in fermentation tests" (2011) or the VDI guideline "fermentation of organic substances" No. 4630 (2014)



Minimum test conditions

- Use of appropriate gas-tight and temperature-controlled reactors
- Use of proper inoculum (high buffering capacity, low gas potential)
- Mixing ratio of inoculum: tested substrate (oDM-based): > 2 : 1
- Inoculum parallel as reference sample
- At least one standard substrate (e.g. micro-crystalline cellulose) as control of the inoculum
- Fermentation temperature 37°C ± 2°C

Source: Oechsner, Paterson: Methanertrag aus Biomasse - Übertragbarkeit von Laborergebnissen in die Praxis, 2013

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Minimum test conditions (II)

- 3 repetitions for each tested substrate
- measure biogas production as often as possible
- determine methane content by every gas sampling
- Duration of fermentation test at 25 days
- Abort criterion: <0.5% of the previous gas amount of at least 3 days
- methane yield related on oDM of input
- Volatile compounds correction of oDM value (alcohols, acids)
- Standardization of gas values (0°C, 1013 hPa), water vapor

Source: Oechsner, Paterson: Methanertrag aus Biomasse - Übertragbarkeit von Laborergebnissen in die Praxis, 2013

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KTBL/VDLUFA Inter-Laboratory Campaign "Biogas Yields"

- Since 2006, KTBL and VDLUFA NIRS GmbH are organising the inter-laboratory campaign for biogas tests. The campaign is professional assisted by a KTBL working group (Chair: Dr. Hans Oechsner)
- The campaigns were done in 2006 - 2008 (research project), 2011 and 2013. Since 2014, its done on a annual basis (incl. a given certificate about the successful participation for each lab.)
- Scope is biogas and methane yield, methane content and also determination of DM, oDM, fatty acids and alcohols (optional).
- Samples are micro crist. cellulose, silages (maize, grass, grain), draff. In 2014, digestate was implemented for testing residual gas potential test
- Aim
  - identifying sources of variation of measurement results in the determination of biogas yields and residual gas potential
  - optimizing the analytical methods and minimize the coefficient of variation for future gas revenues
  - improving the database for standard biogas yields.

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Some inter-Laboratory campaign results

- About 30 till 33 national and international laboratories participate at each inter-laboratory campaign
- The assessment of each campaign and the following discussion with the experts of the KTBL working group encourage the participating parties to search internally for errors in their procedure which results in constantly improvement of the test results
- The standard deviation of repetition (s_r) of the inter-laboratory has increased during the years (test results are more accurate)

s_r	2014	2013	2011	2008	2007
Cellulose	14	16	23	30	23
Maissilage	14	24	27	29	34

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Some inter-Laboratory campaign results

- The standard deviation of comparison (CV_R) between the participating laboratories has also improved during the campaigns (example biogas yield)

CV_R	2014	2013	2011	2008	2007
Cellulose	4,6	5	3,4	8	10
Maissilage	5,7	8	9	10	12

- Differences in the results of the labortaories do not refer to kind and size of the experimental set-up; problematic are often
  - Methode of result assessment
  - Conversion into standard specifications (norm conditions)
  - Determination of CH_4 yield from concentrations (water vapour, head space volume, CO_2 loss)

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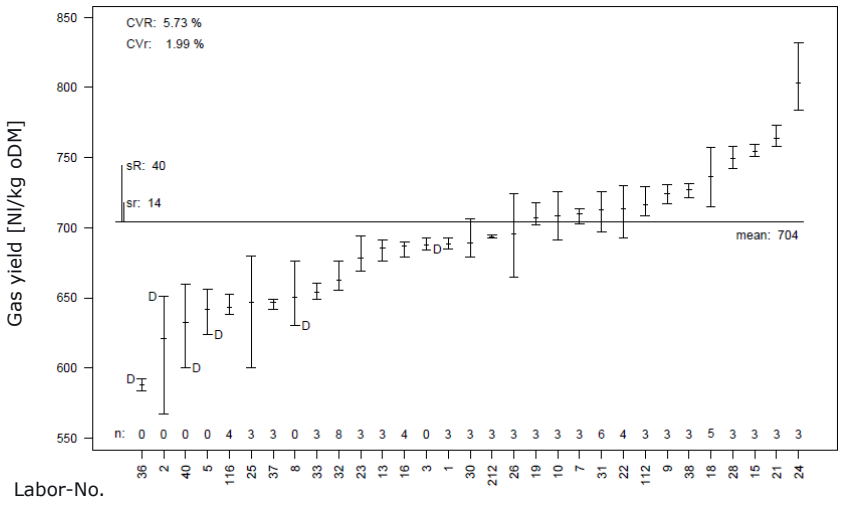
Some inter-Laboratory campaign results

Example from campaign evaluation (2014): biogas yield determination (sample maize silage) with at least 3 repetitions per lab.



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Transferability – batch tests / AD plant

Paramater	Batch set up	AD plant
Digester volume	100 ml – 15 l	> 2,000 m³
Operation	No change of biomass during test	Daily exchance of biomass, recirculation possible
Biol. Process	Degradations phases run after another	Degradations phases run at the same time
Volume load	Up to 50 g oDM / l*d at beginn of test	2 – 5 (10) g oDM / l*d
Retention time	35 d	More than 100 d
Substrate	Normally single biomass, representative, homogenised	Substrate mixture with diff. composition, quality often not specified
Measurement	exact weighing of imput, accurate determindation of biogas amount and quality	Imprecise weighing and gas counter, gas quality often not measured

Source: Oechsner, Paterson: Methanertrag aus Biomasse - Übertragbarkeit von Laborergebnissen in die Praxis, 2013

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Standard biogas yields of KTBL

- The achievable biogas yield in the biogas plants are influenced by the composition of the substrates as well as by the process itself. In practice, the estimation of the expected gas production were often based on individual experience. This lead to very different plant dimensions for initial conditions.
- Therefore the KTBL working group "biogas yields" was convened in 2004
- Aim was to collect laboratory results of different biogas substrates from different institutions / (biogas)laboratories
- The standard values are based on the results of batch potential test
- By evaluating a huge no. of lab. results, which were produced under comparable conditions at laboratory scale fermentation tests, and the incorporative knowledge of the experts, a list with statistical reliable biogas yields could be generated

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Extract of standard value table

Substrat	Eigenschaften (Substrat-zustand, Behandlung, Herkunft)	Richtwert TM % FM	oTM % TM	Biogasertrag l_n/kg oTM	Biogasertrag m^3_n/t FM	Methan-gehalt %	Methan-ertrag l_n/kg oTM
Wirtschaftsdünger[1)]							
Geflügelmist	abhängig vom Stroh-Kot-Verhältnis, wenig gelagert	40	75	500	150	55	280
Rindermist		25	85	450	100	55	250
Rindergülle	mit Futterrest	8,5	80	380	25	55	210
Schweinegülle		6	80	420	20	60	250
Nachwachsende Rohstoffe							
Maissilage		35	95	650	210	52	340
CCM		65	98	730	470	52	380
Sorghumsilage		28	90	610	150	52	320
Getreide-GPS	mittlerer Kornanteil	35	95	620	200	53	330
Grünroggensilage		25[2)]	90	600	140	53	320
Sonnenblumen-silage		25	90	520	120	57	300

From: KTBL booklet No. 107 „Gasausbeute in landwirtschaftlichen Biogasanlagen", 3. Vol. 2015

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Standard biogas yields of KTBL (2)

- The standard values for biogas gas yields have been very well accepted by the various players in the sector (from farmers to bankers)
- So a uniform and solid standard for estimating the biogas yield for agricultural biogas plants have been established over the years

1. Auflage 2005

2. Auflage 2010

3. Auflage 2015

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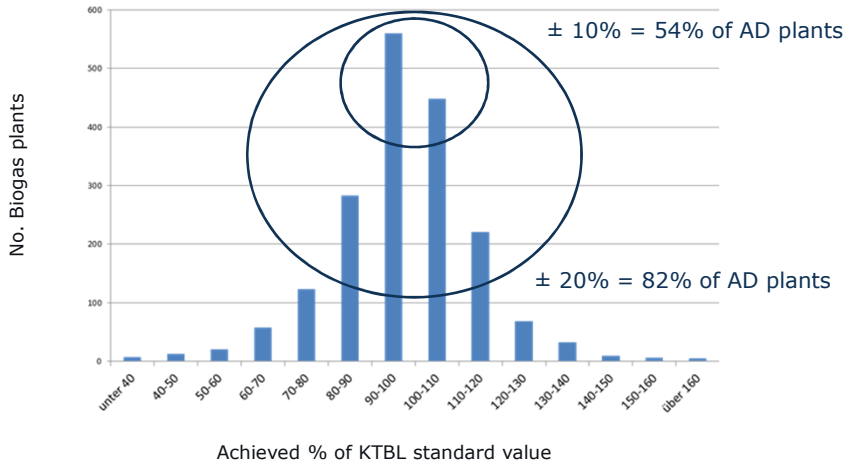
Transferability into practice

Relative substrate utilization grad of 1,854 investigated biogas plants referring to the KTBL standard values



Quelle: Hölker (2012); Faustzahlen Biogas (KTBL 2013)

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Transferability into practice

Possible deviation factors of standard values

- Sample taking
- Substrate characteristics varying depenting on kind, orgin, harvesting conditions, storage conditions, etc.
- Process relevant factors like biomass mixture, biol. conditions, retention time, reactor load, nutients shortage
- Gas yield determination failure on AD plant (informations from plant operater)
  - Conversion into standard specifications based on gas volume measurement (overestimation up to 20%)
  - Calculation based on power production values (overestimation up to 10%) [correct grad of CHP efficiency, consideration of accurate ignition oil amount]
  - Accurate recording of biomass imputs (weighing, oDM)

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Summary

- With the VDLUFA method "Determination of biogas and methane yield in fermentation tests" (2011) and the VDI guideline 4630 "fermentation of organic substances" (2014) sound methods for the uniform performances of fermentation tests are available
- The inter-laboratory test biogas with its initiation to internal error analysis leads clearly to the continuous improvement of the set-ups and results
- The standard deviation of comparison between the laboratories participating the inter-laboratory test has improved during the last years (the next campaign of KTBL/VDLUFA inter-laboratory test biogas will start in September 2015)
- Reliable standard biogas yields are a practicable a good option for the estimation of the methane yields necessary for plant design and operation

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