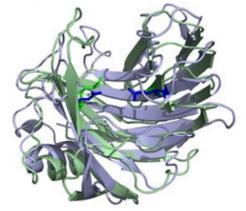


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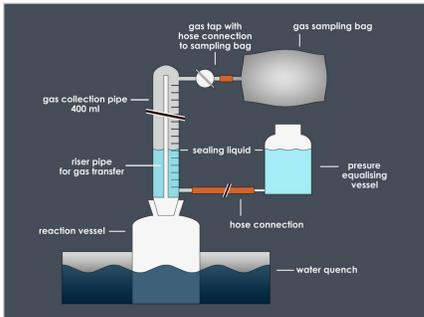
Introduction

The present work was carried out within the framework of the project "FABES-Modul" (<http://www.biogas-network.de/abgeschlossene-projekte/fabes>). It aimed at creating a more cost-effective and universally applicable enzyme preparation in order to improve the methane production in biogas processes by the use of waste material with a suitable, extensive enzyme spectrum for lignocelluloses degradation. With waste, cost-intensive microorganism cultivation for enzyme production can be saved and industrial waste can be utilized. Thereby biogas substrates can be converted more efficiently. It contributes to higher resource efficiency in biogas processes by using biorecycling of biocatalytic by-products. As catalytic active by-products the secondary raw materials of edible mushroom production and the faeces of herbivores were proven. It is known that the named by-products contain a high variety of enzymes such as xylanase, pectinase, and cellulase.



Xylanase + Glucanase, Gilbert 2010

Experimental setup



Biochemical Methane Potential – Laboratory trials

- Mesophilic fermentation process
- VDI Directive 4630
- Retention time 30-35 d
- Inocula: Hay/Straw: biogas plant (Pülling)
Maize silage/Faeces: sewage plant (Wandsdorf)
- Organic Dry Matter (ODM)-Ratio 0,4
- 500 ml fermentation vessels
- Determination of samples in triplicate
- Gas measured: CH₄, CO₂, O₂
- Statistic: Dunnett's test per IBM SPSS Statistics 20

By-product processing for generation of enzyme preparations

By-products of mushroom cultivation

- By-products of shiitake cultivation, selected by enzyme assays
(Enzyme-containing raw material)
- (1) Chopping
- (2) Water extraction
- (3) Filtration
(Enzyme extract)
- (4) Ultrafiltration (UF, e.g. 1:10)
- (5) Conditioning with stabilizing agents (SA)
(Enzyme preparation)

Faeces of herbivores

- Rabbits of the hybrid breed „Zika“
- Hard faeces, faeces mixture from female hares (1-2 years old) and young animals (10-12 weeks old)
- Soft faeces from appendix of culled young animals, generated by pressing out the appendix manually
(Enzyme-containing raw material)

Results By-products of mushroom cultivation

Enzyme-containing raw material

Using chopped residue of shiitake cultivation (used growth substrate after harvesting of the edible parts of fungi) the methane yield could be significantly ($p < 0,05$) increased by adding 10 or 50 g residue to one kilogram of a mixture of chopped hay and straw. For the sample with the highest enzyme concentration the highest lignocellulose degradation was measured. In particular the hemicellulose decomposition could be intensified. A negative impact was achieved using thermophilic conditions.



22 mg protein/g

Enzyme extract

A mechanically treated and lignocellulose-rich mixture of hay and straw was determined. By application of 50 g enzyme extract/kg fresh hay and straw an enhancement of 24 % was obtainable on a significant level ($p < 0,01$). If the original material is used, only marginal effects can be achieved. Lignocellulose degradation could be increased by enzyme application, notably the hemicellulose utilization. Additionally, an improvement of the biogas or better methane production was realizable in thermophilic processes.



6-15 mg protein/ml

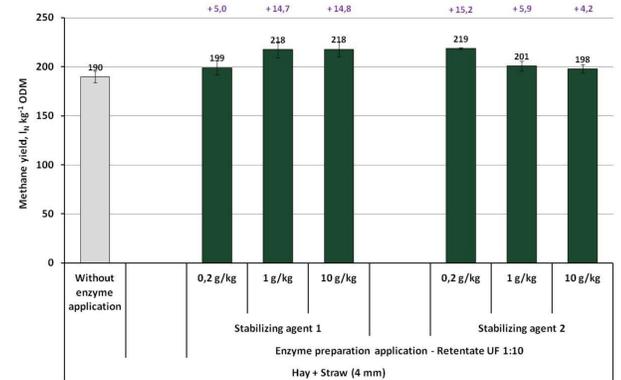
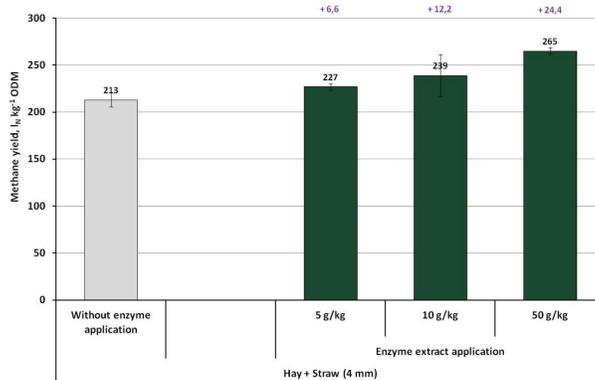
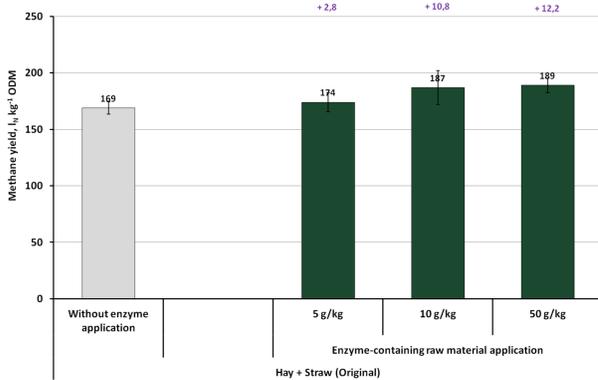
Enzyme preparation

By concentrating the enzyme extract the enzyme content and activity could be enhanced, consequently a lesser amount of preparation was necessary to achieve significant ($p < 0,001$) increases in methane yield, compared with applications of enzyme extract. The sample with 0,2 g enzyme preparation per kg mechanically treated hay and straw had the highest methane value and surplus of methane. A rise of enzyme concentration of the preparation with stabilizing agent 2 leads to an inhibition in gas production.

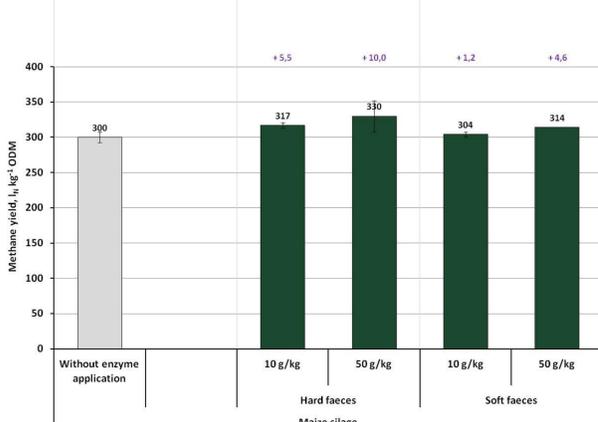
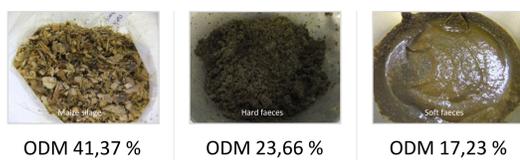


SA1: 20 mg protein/ml

SA2: 36 mg protein/ml



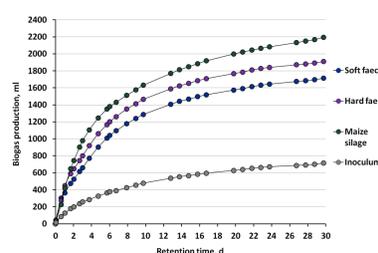
Results Faeces of herbivores



Enzyme-containing raw material

Different faeces of herbivores were tested regarding methane potential and potential as enzyme-containing additive for biogas processes.

In comparison with maize silage the methane value of hard and soft faeces, respectively, was lower. Values of 275 and 252 l_N kg⁻¹ ODM were measured (see figure below).



As additive hard faeces seems to have a potential. The methane yield of maize silage could be enhanced up to 10%. An high amount of faeces is necessary for realizing an improvement in biogas production, therefore investigations in terms of extracting and concentrating the enzymes have to follow.

Conclusion

It could be shown that by-products or rather enzyme preparations generated from by-products of mushroom (wood-decaying fungus) production can significantly increase the methane yield of hay and straw in mesophilic batch-tests.

The enhancement of methane yield is associated with the lignocellulose degradation. The studies demonstrated that with increasing enzyme concentrations the degree of decomposition of hemicellulose and cellulose and thus the methane production increased.

New enzyme sources for improving the biogas process could be found. The biorecycled by-products can substitute commercial enzyme preparations.

A utility patent exists for the use of by-products of mushroom production to stabilize and enhance biogas production.