

# Hohenheim Biogas Yield Test

## Comparing Theoretical Yields with Actual Batch Yields

*The objective of this paper is to evaluate two approaches for calculating theoretical methane yields by comparing them with yields from batch biogas experiments. To compute the theoretical methane yield the chemical composition was used on the one hand, and the ruminal digestibility of the substrates on the other. The comparison showed that using the chemical composition resulted in higher methane yields for all substrates than those of the batch experiments. If the digestibility is additionally taken into the calculation, carbohydrates are overestimated and fats and proteins underestimated.*

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### Keywords

Biogas, renewable energy, digestion, theoretical biogas yield, biogas yield, pure substances, batch-experiments, Hohenheimer Biogas-Yield-Test (HBT)

The feedstock for biogas plants is mainly composed of carbohydrates, fats and proteins, in varying proportions. The specific methane yields of a chemical compound can be theoretically evaluated if one knows its chemical formula [1, 2, 3]. Single fractions, namely carbohydrates, fats, and proteins were used in lab scale batch digesters for determining their specific biogas and methane yields' potential. These results were compared with the theoretical methane yields, calculated by means of two different models previously described.

### Material and Methods

For determining the practical biogas and methane production rates in lab scale, a batch process called „Hohenheim Biogas yield Test“ [4] was used. By means of this anaerobic digestion test, one can determine the specific biogas and methane yields, the biologic degradation rate, as well as the degradation velocity of the substrates. The substrates were digested for duration of 35 days under mesophilic temperature conditions of 37 °C.

For all substances the theoretical biogas and methane yields were calculated using Buswell's chemical formulae model [5], except for protein for which the comparable Boyle's formula [6] was used. The chemical

formulae of proteins [7] were estimated by determining their amino acids contents. For fats, formulae were estimated by determining their fatty acids composition [8].

Moreover, the theoretical methane yields were also calculated using the digestibility of the raw chemical composition of the feedstock. The digestibilities of the chemical composition's groups were associated to the biogas potential and their methane contents [9]. Those separate results were summed up to get the total theoretical biogas yields of the substrates.

### Results and Discussion

#### *Methane yields from the lab scale experiment*

One can notice in *Figure 1* that carbohydrates were degraded very fast. After seven days of digestion, 90 % of the total biogas production from starch was attained. Cellulose degradation occurred at a much lower rate and it took 11 days to reach 90 % of the total methane production. Cellulose and starch yielded respectively 0,392 and 0,349 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. Starch had a slightly lower methane yield than the other carbohydrates. All of the carbohydrates being studied were generally easily degradable materials; nevertheless, they had low methane productions compared to fats and proteins (*Table 1*).

*Tab. 1: Methane yields and content of the substrates measured in the lab*

Nutrient class	Substrate	Methane yields [Nm <sup>3</sup> CH <sub>4</sub> /Kg oTS]	Methane content [%]
Carbohydrates	Starch	0,349	45
	Starch	0,392	48
Fats	Sunflower oil	0,861	67
	Coconut oil	0,807	67
Proteins	Gelatine	0,437	62
	Casein	0,457	63

*Tab. 2: Methan content calculated with Buswell and Keymer and in measured in the laboratory*

Stoffklasse	Substrat	Theoretical methane contents Biogas [%]	
		Chem. composition after Buswell	Digestibility model after Keymer/Baserga
Carbohydrates	Starch	50	50
	Starch	50	50
Fats	Sunflower oil	72	68
	Coconut oil	71	68
Proteins	Gelatine	63	69
	Casein	65	70

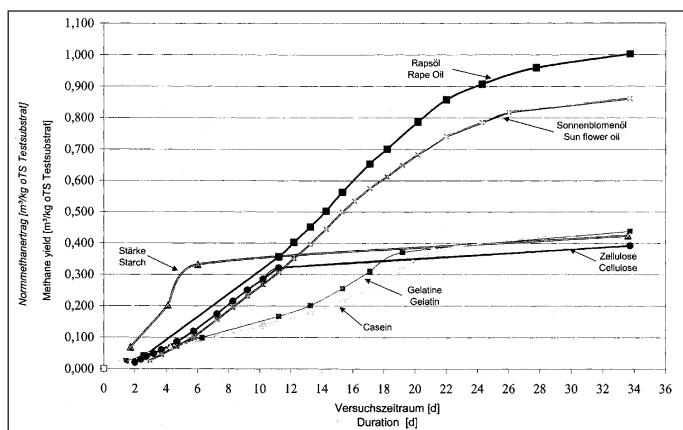


Fig. 1: Process of the methane formation of selected substrates from the groups of materials of carbohydrates, fats and proteins in the batch-biogas test with a retention time of 34 days

Fats were relatively slowly degraded in comparison to carbohydrates and proteins; their digestion was retarded for two days and characterized by low gas production rates. Sunflower oil required 24 days of digestion to reach the degradation rate of 90 %. Sunflower oil attained a methane yield of 0,861 Nm<sup>3</sup>CH<sub>4</sub>/kg VS in the HBT batch experiment. Rape seed oil yielded 1.00 Nm<sup>3</sup>CH<sub>4</sub>/kg VS over the digestion time of 35 days. Fats reached very high methane contents of 67%.

The degradation of proteins was slower than that of carbohydrates, but faster than that of fats. 19 days were needed to reach 90 % of the total biogas production for gelatine, while it took 21 days for casein. The highest methane yields among proteins was 0,457 Nm<sup>3</sup>CH<sub>4</sub>/kg VS obtained during the digestion of casein. Gelatine had a methane yield of 0,437 Nm<sup>3</sup>CH<sub>4</sub>/kg VS, thus being lower than the average of the substrates of the protein class.

#### Theoretical methane yields potential calculated by means of chemical formulae

The methane yields of the substrates calculated using the chemical formulae were higher than those being measured in the lab scale batch experiments (Table 1). For starch and cellulose the same methane yield potential was calculated 0,415 Nm<sup>3</sup>CH<sub>4</sub>/kg VS, since the two have the same chemical formulae (as sum). The starch and cellulose methane yields determined in the lab experiment were respectively 19 % and 6% lower to those computed with the model (Fig. 2). The methane yield potential for sunflower and rape seed oil was computed with 1,025 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. The sunflower oil lab values lay of 19 % lower than the theoretic value, while rape seed oil's lab value did not differ to the theoretic one. The calculated values for gelatine and casein were 0,504 and 0,512 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. Those values were respectively 15 % and 12 % higher than the methane yields from the batch experiment.

It has been noticed that for more complex chemical compounds, whose formulae were

inexact, the variation between the lab and the theoretic values were greater than for simple substrates with relatively simple formulae.

#### Calculation of the methane yields using the substrate's digestibility data

By taking into account the digestibility factor for each chemical compound, cellulose and starch showed a theoretical methane yield potential of 0,374 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. Through this calculation method, carbohydrates were assumed to have a methane content of 50 %. In comparison to the lab obtained values, the theoretical methane yields potential computed with this model were 7 % higher for starch and 5 % lower for cellulose (Fig. 2).

Fats showed a potential of 0,812 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. The digestibility factor used in this model disclosed an underestimation of the methane yields potential of sunflower oil and rape seed oil. The computed values were 6 % lower for sunflower oil and 23 % for rape seed oil.

Gelatine and casein had a computed methane yields' potential of 0,409 and 0,513 Nm<sup>3</sup>CH<sub>4</sub>/kg VS. Those values were respectively 12 % higher and 6 % lower than the methane yields obtained in the batch experiment.

#### Summary

As prerequisite for a better prediction of the methane yields potential is the exact knowledge of the elementary chemical composition, using the chemical formulae of feedstocks. The prediction of methane yield potential using the Buswell model leads generally to an overestimation of the methane yield, since the model assumes that the substrate is fully degradable during the digestion process.

Depending on the substrate composition, the organic matter contained in the substrate will be only partially degraded. Therefore, a correction factor, which takes into account the digestibility in the biogas digester, is needed. Since the bio-conversion of fats and proteins in rumen differs very much to that

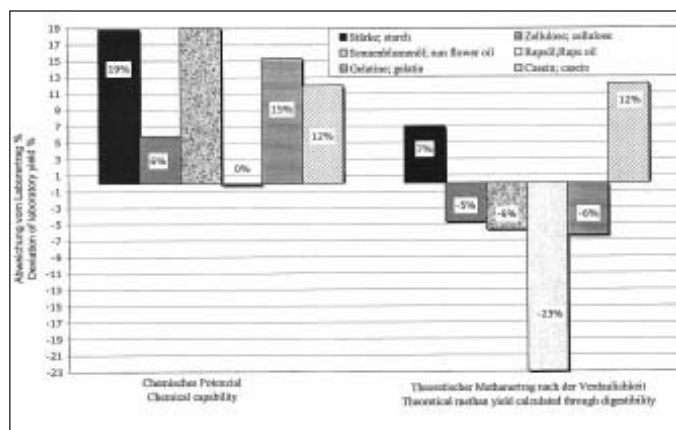


Fig. 2: Deviation of the potential methane yields, on the basis the chemical composition and digestibility, of the methane yields in the HBT

in a biogas plant, this digestibility factor derived from feed for ruminants is inappropriate, especially for substrates rich in protein and fats. Moreover, the chemical composition's sum formulae of complex substrates such as whole plants and plants' fractions are hardly determinable. Hereby models

based on macromolecules are more appropriate, though in such case pure substances are not taken into consideration.

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