Energie mit Zukunft.
Umwelt und Verantwortung.

DBI GTI
Gastechnologisches Institut

Hydrogen as climate-friendly energy source produced by fermentative microorganisms

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Background

The increasing global demand for energy from fossil fuels is opposed by the shortage of resources. In addition, the environment is reinforced polluted by the use of fossil energy sources. A climate-friendly, renewable, energy dense and carbon-neutral alternative provides hydrogen. One possibility to produce hydrogen is by anaerobic fermentation in a two stage process [1-6].

Technology

- The dark fermentation process can be divided into four biochemical phases (fig. 1) [7, 8]
  - Hydrolysis
  - Acidogenesis (exhaust gas: CO_2 and H_2)
  - Acetogenesis
  - Methanogenesis (exhaust gas: CO_2 and CH_4)
- The single-stage fermentation process is mostly established in practice (agricultural biogas plant).
- Advantages of the two-stage process (*fig. 1*):
  - The bacterial species involved in hydrogen and methane formation prefer different environmental conditions, which have to be applied.
  - Utilization pathways of hydrogen (fuel cell) and methane (upgrading, grid-injection) can be used.

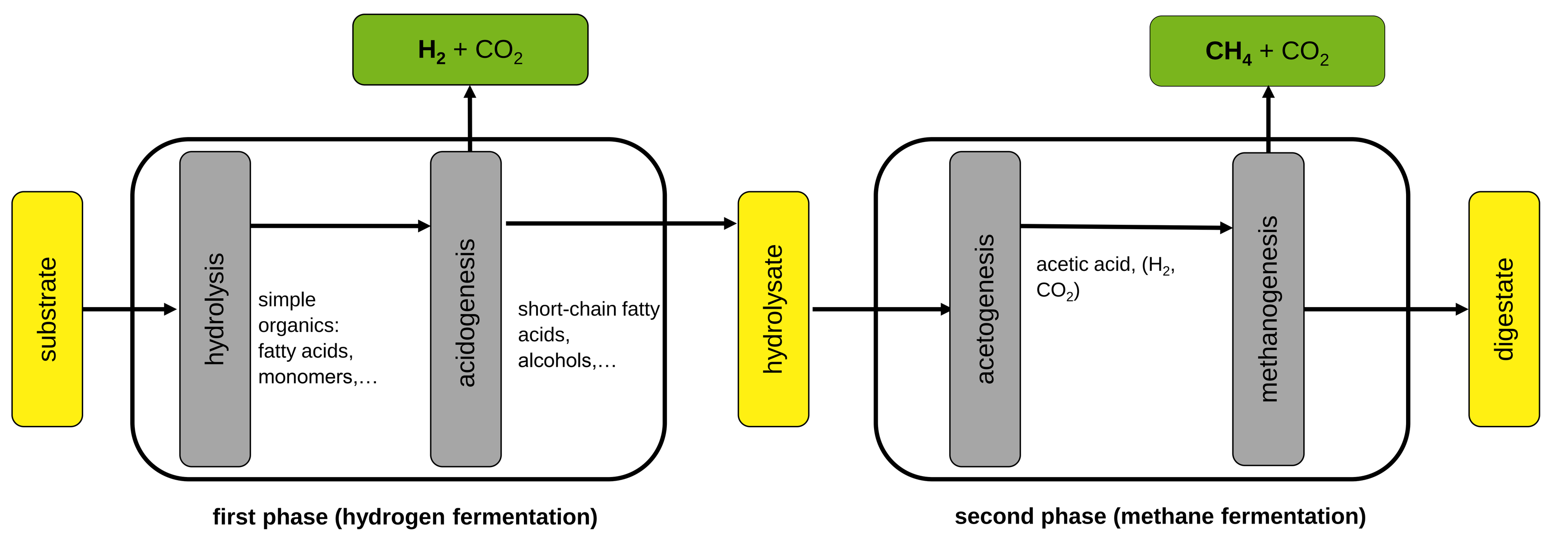

Figure 1. Simplified scheme of biohydrogen and biomethan (biogas) production

Experimental Investigation

- First experimental investigations are carried out in the laboratory at DBI in the research project "MehrH2", FKZ MF120051 [9].
- In a formerly established process setup (pilot-plant, figure 2) the continuous and simultaneous production of biohydrogen (up to 30 vol%, figure 3) and biomethane (50 to 60 vol%) was achieved [10, 11].

Figure 2. Pilot biogas plant - 2 m³ scale

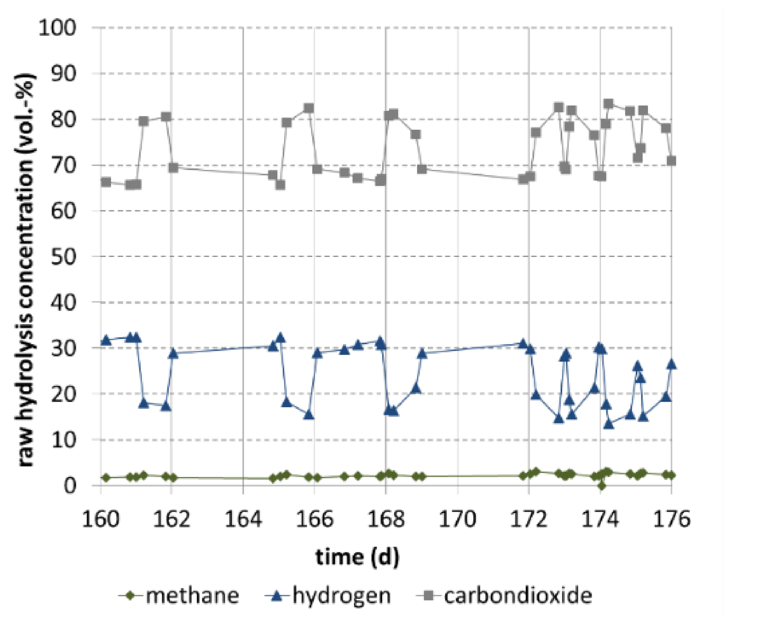

Figure 3. Raw-gas concentration (hydrolysis)

Optimization of the established process-setup

- Adaptation and optimization of the established process-setup by integration of a third stage for thermal treatment of the digestate was conducted in lab-scale-design (fig. 4).
- Analysis of process parameters:
  - online: temperature, gas quantity
  - offline: gas-quality (CH_4, CO_2, H_2, O_2, H_2S), pH, FOS/TAC

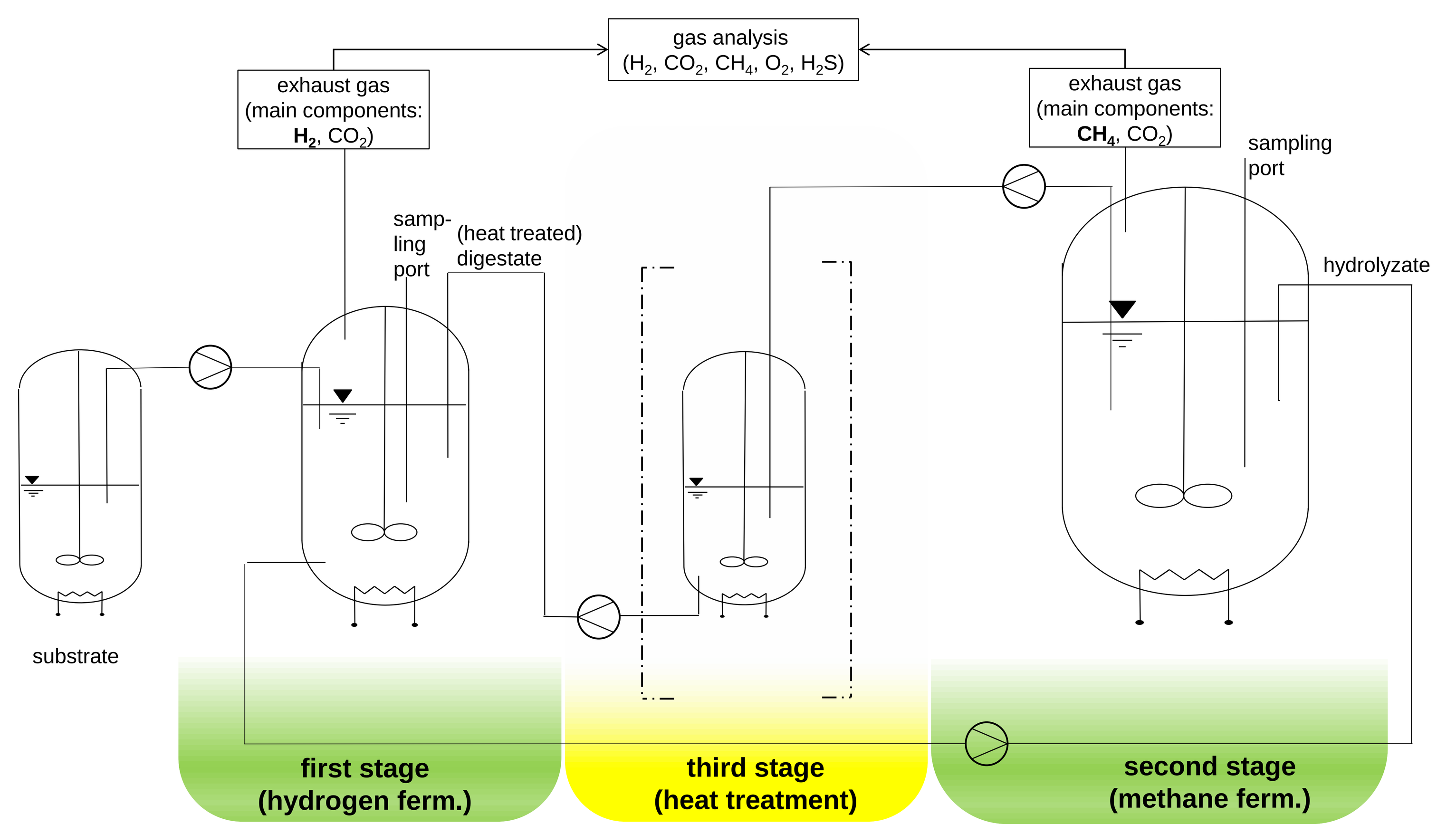

Figure 4. Experimental setup for optimization of the established process-setup

Results

- Integration of third stage (heat treatment) caused increase of hydrogen ratio up to 49 vol% (figure 5, ★)

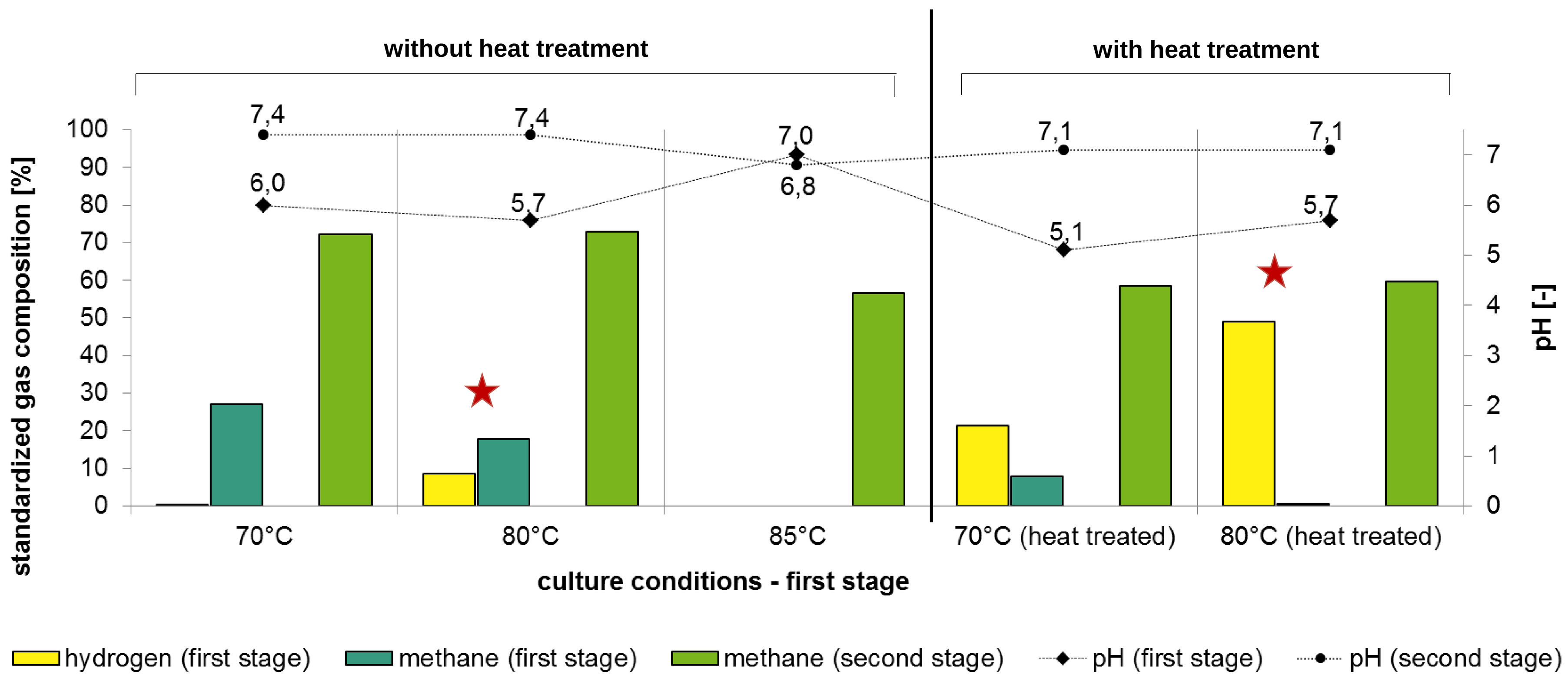

Figure 5. *Standardized gas composition of first and second stage*

- Improvement of hydrogen content (+20 vol%), molar hydrogen yield (+0.3 mole/mole[glc]) and hydrogen yield (+151 L/kg[suc]) compared to pilot scale experiments (figure 6)

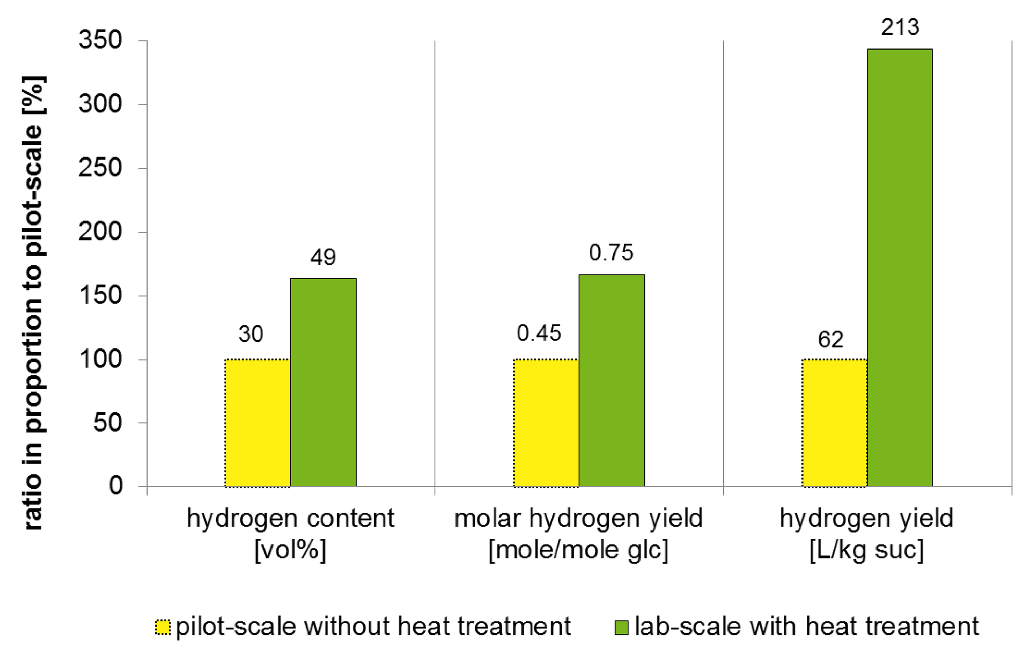

Figure 6. Optimization due to thermal treatment in lab-scale experiments compared to pilot scale (bar labels show absolute values)

- Adjustment of process parameters (table 1)

Table 1. Determined and validated optimum process parameters

parameter	first stage	second stage	third stage
substrate	carbohydrates	hydrolysate	-
inoculum	mesophilic fermented sludge fed on sucrose		-
T	thermophilic: 80 °C	mesophilic: 40 °C	100 °C
pH-value	5.0 - 6.0	7.0 - 7.5	-
retention time	to be optimized	to be optimized	0 min
loading	to be optimized	-	-
recirculation	heat treated digestate	hydrolyzate	digestate

Conclusions

A continuous process with associated parameters for the simultaneous production of biohydrogen and biomethane was established by DBI. The integration of an additional heat treatment strongly enhanced the process stability and efficiency. So the hydrogen content raised up to 49 vol% (formerly 30 vol%) and the molar hydrogen yield up to 0.75 mole/mole[glc] (formerly 0.45 mole/mole[glc])
Potential for optimization is the active control of the fermentative pathways by variation of the ratio hydraulic retention time and loading rate within the first stage. The optimized parameters should furthermore be validated at the already established pilot scale process.

Literature

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