
# ENHANCING THE PROCESS OF BIOLOGICAL $CO_2$ HYDROGENATION BY INVESTIGATING THE ROLE OF PACKING MATERIALS

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## Introduction

The transition to sustainable energy is urgent due to the finite nature of fossil fuels and their role in global warming. The Paris Agreement highlights the need to reduce $CO_2$ emissions and adopt sustainable solutions. Biogas, derived from organic waste, offers a promising alternative but has a low calorific value due to $CO_2$ content. Upgrading biogas to biomethane, which can replace natural gas, is crucial. Europe has adopted technologies like membrane separation and chemical scrubbing for this purpose. This study examines the impact of different packing materials on Trickle Bed Reactors (TBRs) for efficient biomethanation and their flexibility for intermittent operation.

## Materials and Methods

The experiments used two custom-made stainless steel TBRs, each with a 1 L volume. Reactor 1 (R1) was filled with activated carbon pellets, and Reactor 2 (R2) with Raschig rings. Both operated at 55 ± 1°C, maintained by thermal jackets. A synthetic gas mixture of 20% $CO_2$ and 80% $H_2$ was supplied via peristaltic pumps. Nutrients came from recirculated digestate, refreshed twice weekly. Gas Retention Time (GRT) was tested from 12 hours to 45 minutes. The process was also validated under intermittent gas supply, with interruptions of 1 to 3 weeks to simulate real scenarios.

## Results

In the first experimental assay, GRT was gradually reduced, as shown in Figure 1. Both packing materials showed efficient biomethanation up to a GRT of 2 hours, with K1 Raschig Rings (R2) achieving $CH_4$ purity up to 99%. At a GRT of 1 hour, R1 experienced a significant drop in $CH_4$ concentration but later recovered. R2 was only mildly affected and quickly stabilized. Further reducing the GRT to 45 minutes caused instability, with R1 showing low $CH_4$ concentration and R2 collapsing, as illustrated in Figure 1.

In the second experimental assay, a GRT of 1 hour was used during gas mixture supply periods. Figure 2 shows that both reactors recovered after a 3-week starvation period. R1 established a more robust microbial community, unaffected by starvation, and quickly reached high methane purity upon reactivation. In contrast, R2 needed adjustment time after 1- and 2-week starvation periods but eventually also achieved high methane purity.

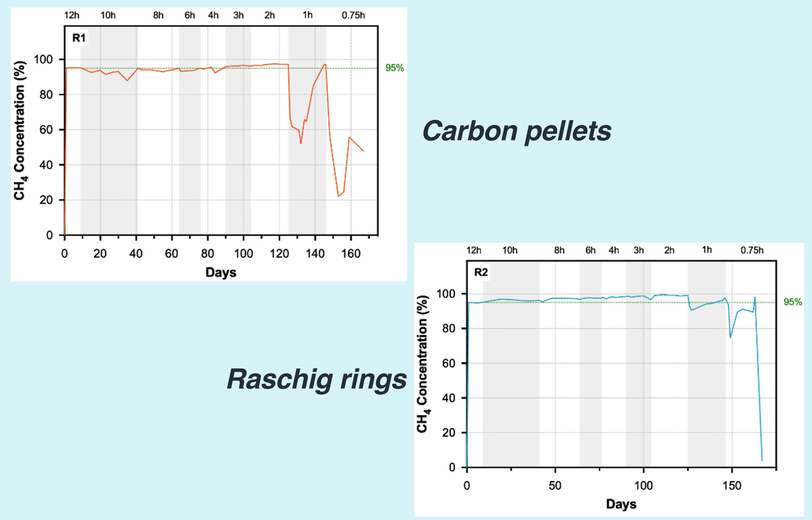


**Figure 1.** Methane concentration at the output gas during the different Gas Retention Times.

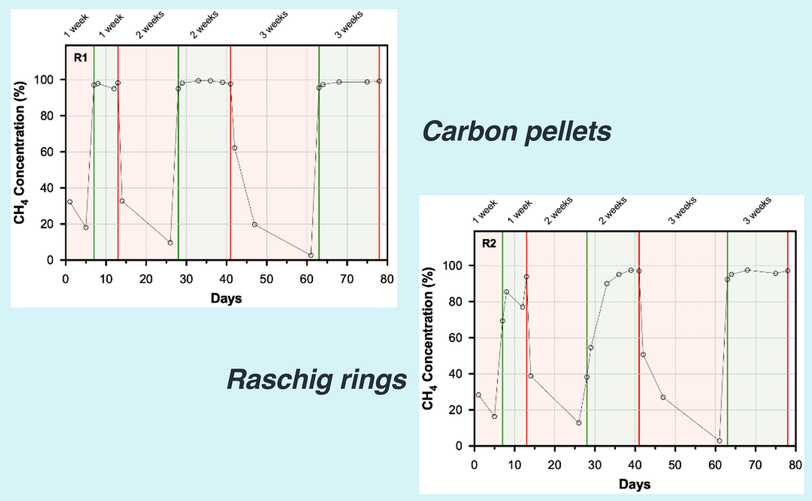


**Figure 2.** Process performance under intermittent provision of $CO_2$ and $H_2$.

### The BioUpgrade project

The project BioUpgrade intends to demonstrate the new technology for the first time in Europe in pilot conditions at the biogas production plant in Nigrita, Greece (BIOENERGY NIGRITAS SA). The implementation of the project will be carried out in cooperation with the Waste Management and Bioprocessing Laboratory of the Soil and Water Institute of ELGO-DIMITRA.

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