CO_2 as feedstock in microbial cultivations: Gas fermentations matched to microbial requirements and technical feasibility

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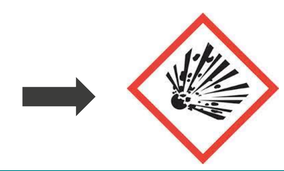
Introduction

Utilizing CO_2 as a feedstock for microbial cultivation offers a sustainable approach that reduces greenhouse gas emissions while producing valuable bio-based compounds (1). *Cupriavidus necator*, a hydrogen-oxidizing bacterium, uses the Calvin-Benson-Bassham (CBB) cycle to fix CO_2 into organic molecules, with H_2 as an electron donor and O_2 as the terminal electron acceptor (2). However, the combination of H_2 and O_2 brings with it the risk of explosive gas mixtures. Gas fermentation must therefore be optimized to match microbial requirements and technical capabilities (Table 1).

Microbial requirements

Table 1. Gas composition ranges for cultivating *C. necator*.

H_2 limitation (non-explosive)	$H_2 \leq 4\%$ + atm. O_2 (21%)
O_2 limitation (non-explosive)	$H_2 > 4\%$ + LEL of O_2 (4.8%)
Optimum (Explosive)	H_2: O_2: CO_2 = 70%: 20%: 10%



Technical feasibilities

Under non-explosive O_2 levels (4%), biomass concentration (cell dry weight, CDW) can be increased by increasing the system's pressure and k_La, based on models (Equation 1, 2).

$$OTR = k_L a\,(C^*_{O2} - C_{O2}) \quad (1)$$

$$X = \frac{OUR}{q_{O2}} \quad (2)$$

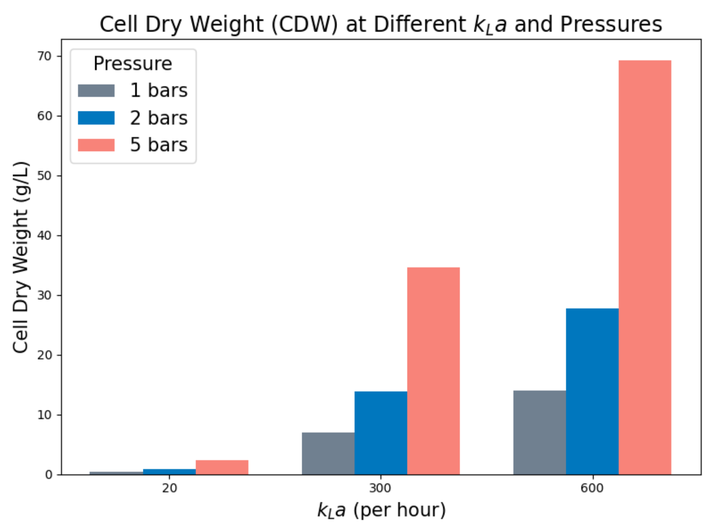


Figure 1.

PHB accumulation over time

In the presence of nitrogen, biomass was formed (CDW), after nitrogen depletion PHB (poly-3-hydroxybutyrate) was accumulated, the CDW was enhanced by increasing the k_La of the fermentation.

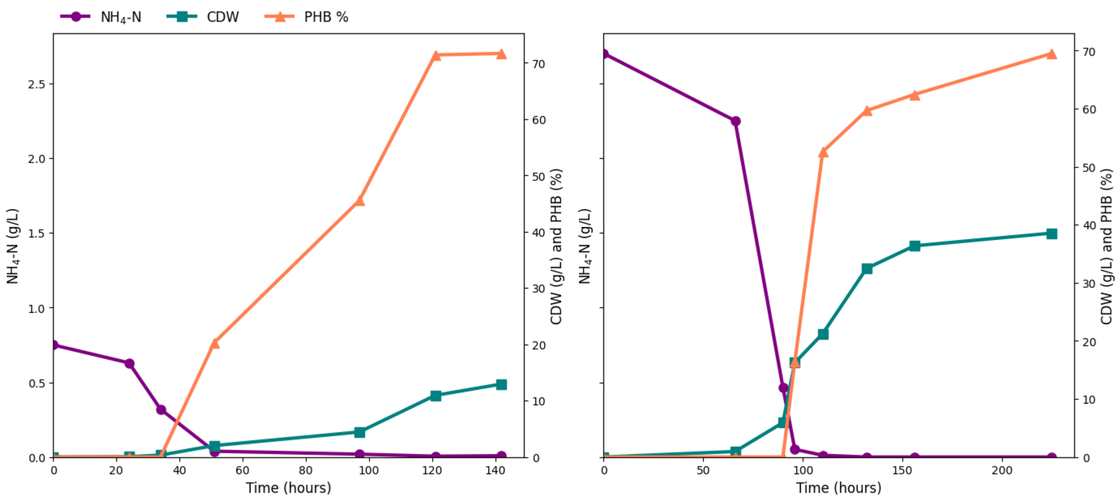


Figure 2.

PHB production

CDW: 13.5g/L → PHB: ~70%

Starting cond.
H_2 93%
O_2 2%
CO_2 5%

1L flask (k_La = 20h^{-1})

CDW: 42.5g/L → PHB: ~70%

Starting cond.
H_2 40%
O_2 2%
CO_2 5%

1.2L stired tank reactor (k_La = 110h^{-1})

Conclusions

- Achieved biomass concentration of up to 13.5g/L in a flask-scale cultivation with a k_La of 20h^{-1}.
- Reached biomass concentration of up to 42.5g/L in a lab-scale bioreactor cultivation with a k_La of 110h^{-1}.
- 70% PHB accumulation of the total biomass, resulting in the production of 29.8 g of PHB

References

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(2) Lauterbach, L., & Lenz, O. (2019). How to make the reducing power of H_2 available for *in vivo* biosyntheses and biotransformations. *Current Opinion in Chemical Biology*, 49, 91-96.

PROJECT: ConCO$_2$rde

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