Enrichment of syngas-converting mixed microbial consortia for ethanol production and thermodynamics-based design of enrichment strategies

Background: The production of ethanol through the biochemical conversion of syngas, a mixture of H₂, CO and CO₂, has been typically studied using pure cultures. However, mixed microbial consortia may offer a series of benefits such as higher resilience and adaptive capacity, and non-sterile operation, all of which contribute to reducing the utility consumption when compared to pure culture-based processes. This work focuses on the study of strategies for the enrichment of mixed microbial consortia with high ethanologenic potential, investigating the effect of the operational conditions (pH and yeast extract addition) on both the ethanol yield and evolution of the microbial community along the enrichment process. The pH was selected as the main driver of the enrichment as it was expected to be a crucial parameter for the selection of carboxydotrophic bacteria with high ethanologenic potential. Additionally, a thermodynamic analysis of the network of biochemical reactions carried out by syngas-converting microbial consortia was performed and the potential of using thermodynamics as a basis for the selection of operational parameters favoring a specific microbial activity was evaluated.

Results: All enriched consortia were dominated by the genus Clostridium with variable microbial diversity and species composition as a function of the enrichment conditions. The ethanologenic potential of the enriched consortia was observed to increase as the initial pH was lowered, achieving an ethanol yield of 59.2 ± 0.2% of the theoretical maximum in the enrichment at pH 5. On the other hand, yeast extract addition did not affect the ethanol yield, but triggered the production of medium-chain fatty acids and alcohols. The thermodynamic analysis of the occurring biochemical reactions allowed a qualitative prediction of the activity of microbial consortia, thus enabling a more rational design of the enrichment strategies targeting specific activities. Using this approach, an improvement of 22.5% over the maximum ethanol yield previously obtained was achieved, reaching an ethanol yield of 72.4 ± 2.1% of the theoretical maximum by increasing the initial acetate concentration in the fermentation broth.

Conclusions: This study demonstrated high product selectivity towards ethanol using mixed microbial consortia. The thermodynamic analysis carried out proved to be a valuable tool for interpreting the metabolic network of microbial consortia-driven processes and designing microbial-enrichment strategies targeting specific biotransformations.

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