Public End Report DEI124024 “Carbon Capture and Utilization (CCU) door productie van eiwit uit CO2 en groene stroom”

Project owner: dsm-firmenich

Project period: 1 april 2025 – 30 april 2025

Background and goal:

Single Cel Proteins (SCP), proteins produced by microbes, are considered a sustainable source of proteins that lower land use and CO2 emissions. Current SCP processes have the disadvantage that they use natural gas or sugar as raw material.

Dsm-firmenich R&D team developed a SCP production process on ethanol as main carbon source to produce high crude protein content yeast cells. The product and process development were guided by an internal techno-economic analysis (TEA). From this analysis it became clear that productivity in the fermentation is a critical variable for cost effectiveness. To enable a higher overall productivity in fermentation, the mass transfer rate for O_2 needs to be increased to a target level. For that purpose, a future fermentation process is envisaged with extra oxygen introduction.

Additional Computational Fluid Dynamics (CFD) modelling was performed on the O_2 sparger design and its best positioning in the pilot fermenter which confirmed the targeted OTR is within reach, assuming a certain and constant bubble size.

A Pilot Setup Plan was written to describe the intended approach for the evaluation of Air Liquide’s O_2 injection technology in the pilot facility to be able to intensify the fermentative production of Single Cell Protein (SCP) and thereby reduce the cost price (COGS). The fermentation technology to be scaled up was performed with yeast using ethanol as main carbon source.

In the next step, after establishment of the base-line performance, different settings for the O_2 injection (e.g. applied top pressure, air flow rate, O_2 flow rate, Dissolved oxygen (DO) setpoint, ethanol feed profile) were tested and evaluated for its performance to increase the oxygen transfer rate (OTR) and thereby the SCP productivity.
As final step, optimal process settings derived from the earlier runs were chosen to perform two complete fermentations to demonstrate the beneficial effect of the O_2 injection technology on the OTR and SCP productivity. One of these fermentation batches was processed towards SCP product.

For an impression on the set-up of the O_2 supply system introduced in the pilot fermenter see Figure 1 and Figure 2.

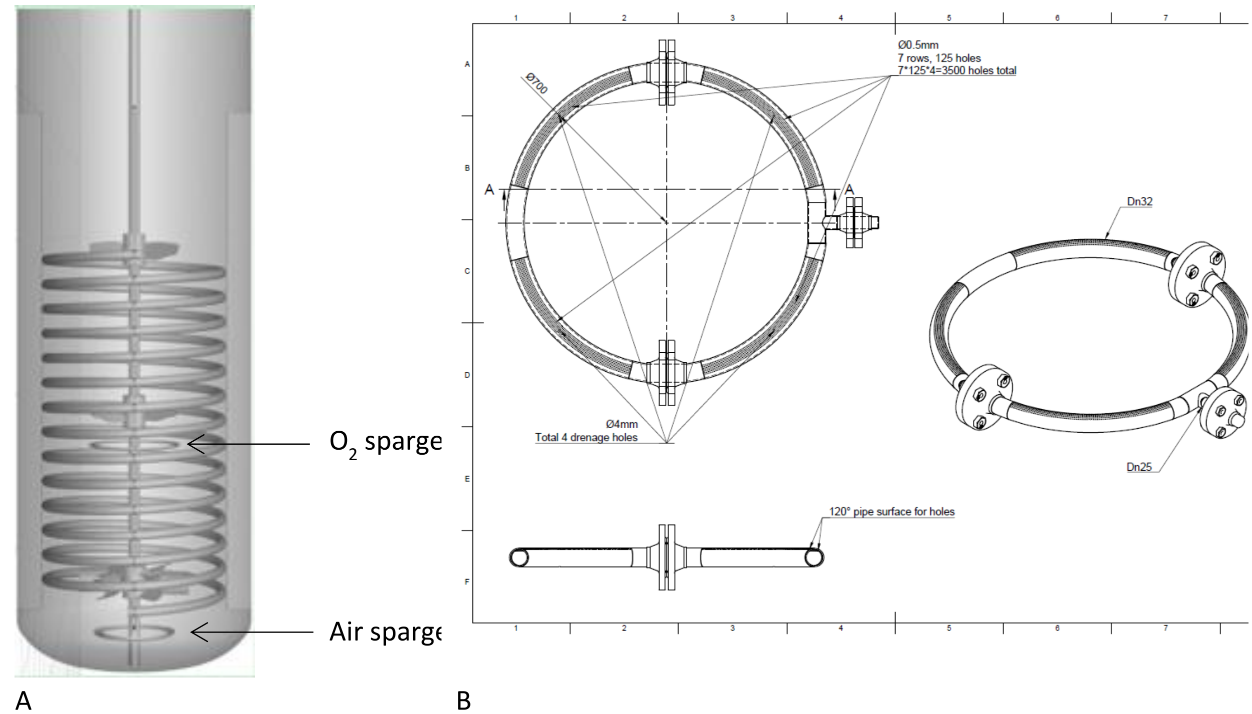

Figure 1. A: Schematic drawing of the Grenzach pilot fermenter setup with an air sparger and an extra sparger for oxygen introduction. B: Detailed drawing of the O_2 sparger, supplied by Air Liquide.

Figure 2. View for the top sight glass of the 15 m^3 fermenter in Grenzach used for the pilot evaluation.

Bottlenecks and results:

One of the major bottlenecks of the project was the interaction with the oxygen injection supplier as the timelines of their preparation where not fully aligned with our internal timelines to run the pilot campaign. Nevertheless, we managed to execute the project within the given time frame and run the campaign as planned.

Besides the planning challenges, the designed oxygen injection hardware design by the supplier with our input, didn’t met the performance specifications that were planned. We achieved around 90% of the original target and by working with the fermentation settings, we managed to optimize the current design as best as it could be. We intent to still achieved the full target in the near future, as we learned in this campaign that the design can be optimized, and that target we have set is possible to achieve.

The following points summarizes the project results and conclusions derived from them:

- The base-line process using air only was scaled and transferred successfully to the pilot facility in Grenzach, delivering similar results on yield and quality as observed on lab-scale.
- The O_2 sparger of Air Liquide could be operated safely and worked technically well, including process control.
- The modifications to the fermentation cooling system proved sufficient to match the demanded cooling.
- The performance of the O_2 sparger was below expectation, not delivering a higher mass transfer coefficient than with air and not delivering higher oxygen transfer rates than would be obtained with O_2-enriched air.
- Reduction of the antifoam in the batch medium in combination with O_2 limitation and elevated ethanol concentrations in broth increased the gas hold-up in the broth and thereby increased the oxygen transfer rate in the broth.
- Accumulation of ethanol in the fermentation broth resulted in a substantial improvement of the O_2 transfer, ~5% above the target level of xx mol/ton/h.
- A steady protocol with an OTR of xx mol/ton/h resulted in a cell productivity of xx kg/ton/h, which is xx× higher than with only air (without O_2).
- The improved productivity came along with a good yield of xx g/g and a high protein content of xx g/g at end of fermentation (average for first three batches).

Target group and perspective on implementation

The Single Cell Protein technology has great potential for the food and feed sector as protein from alternative feedstocks can increase the supply of food and feed in the world. Dsm-firmenich will support further investment opportunities and is looking into the possibilities to accelerate the upscaling of this technology

Contribution to the goals of DEI+

Single cell protein production using decarbonized feedstocks has been proven by this project to be successfully implemented at pilot scale and confirming its techno-economic feasibility. This will bring a major contribution to the decarbonization sectors as CO2 will be used as source to produce protein. It is expected that CO2 production will be used in the future to produce protein and other food ingredients, and the tested technology confirmed the feasibility of this concept.

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