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Bioreactor with in situ water electrolysis for protein production

Abstract

Water electrolysis can be applied in cultivation of hydrogen-oxidizing bacteria by performing electrolysis directly in a bioreactor. This makes possible the conversion of electricity from renewable sources, CO_2 of atmospheric air, water and some nutrients into biomass with high protein content, providing sustainable alternative for conventional plant and animal protein sources.

Hydrogen-oxidizing bacteria

Hydrogen-oxidizing bacteria (e.g. *Cupriavidus necator*, *Rhodococcus opacus*, and *Hydrogenobacter thermophilus*) are capable of autotrophic growth by using hydrogen as an electron donor and oxygen as an electron acceptor to fix carbon dioxide to build up their biomass. Bacterial biomass has high protein content (50–83%), and it can be used as an ingredient in human and animal nutrition.

Bioreactor cultivation with in situ water electrolysis

Hydrogen and oxygen can be supplied to the bacteria by performing electrolysis directly in the bioreactor, where the bacteria are cultivated. In situ water electrolysis allows efficient hydrogen and oxygen utilization by the bacteria, due to better mass transfer of gas to aqueous solution, than in the case of external gas supply. Also flammable mixtures in the reactor headspace can be avoided to some extent. In addition to H_2 and O_2, CO_2 and nutrients needed for growth are supplied to the reactor. A laboratory scale test setup for in situ electrolysis cultivation of hydrogen-oxidizing bacteria is illustrated in Figure 1.

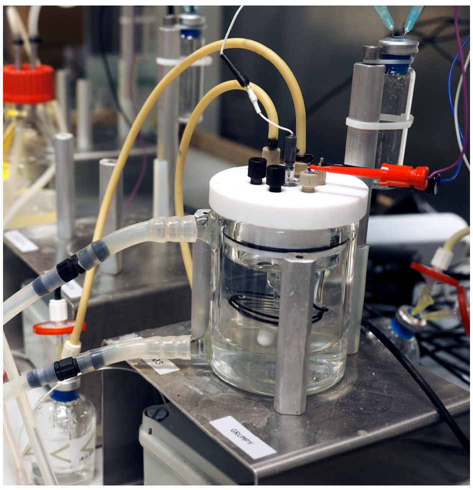

Figure 1. Laboratory scale test setup for in-situ electrolysis cultivation of hydrogen oxidizing bacteria.

Protein from electricity, air, water and nutrients

An electricity-to-biomass efficiency of 54% has been achieved by applying in situ water electrolysis, which would correspond to approximately 10 % solar-to-biomass efficiency (assuming 18% efficiency for photovoltaics). For comparison, the annual average efficiency of crops do not typically exceed 1%, and efficiencies during the growing seasons can reach only 3.5–4.3%. Bacteria have also very fast growth rate; their biomass doubling time is typically 20-120 minutes, while e.g. soybean has doubling time 1–2 weeks. Due to high conversion efficiency and fast growth, bacterial protein production requires significantly less water and land area compared to the conventional protein sources.

By applying direct air capture (DAC) of CO_2 by adsorption/desorption process with in situ water electrolysis, bacterial protein can be produced basically only from electricity, air water and some nutrients. The scheme of this concept is illustrated in Figure 2. The concept is still in research stage, but in the future, it may provide a solution to environmental impacts of conventional agriculture, such as greenhouse gases, fresh water use, land use, and pollution caused by fertilizers and pesticides. Optimization of electrode materials, cultivation medium and conditions, bioreactor construction, and process modeling and control are under research by the authors.

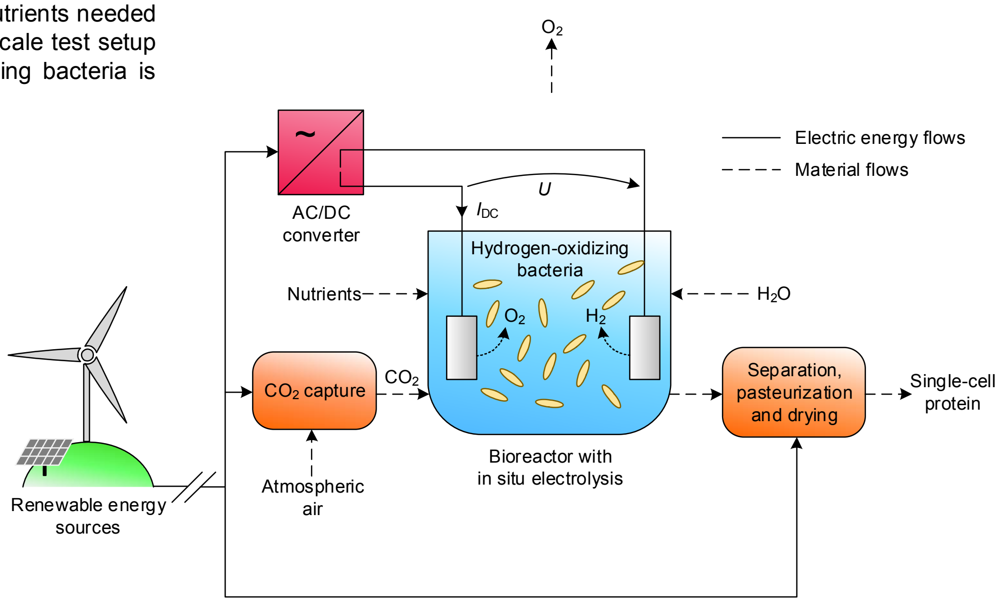

Figure 2. Scheme of the concept of producing microbial protein from electricity, water, air, and nutrients

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