CO_2-to-Food: Converting simple chemicals to feed the world

Dr. Lisa Marie Schmitz
Universität Tübingen
Department of Geosciences
Environmental Biotechnology Group

The pressure on agricultural land and its natural resources is increasing. In July 2024, the United Nations (UN) already recorded 8.16 billion people on Earth, with the global population currently growing by around 80 million each year. With an increasing world population, the demand for food is steadily increasing.

Protein is an essential source of nitrogen and amino acids for both humans and animals. Today, meat, animal products, and plants are the primary sources of dietary protein. However, their production by current agricultural practices is not sustainable and is on the brink of collapsing with an increasing world population. Already, around 9% of the global population suffers from famine. In addition, around two billion people lack essential vitamins and minerals due to insufficient dietary diversity. This can severely impact health, leading to a weakened immune response, cognitive impairments, and developmental delays in children. Meeting the growing demand for food and nutrients with conventional agriculture alone seems almost impossible. Today, half of Earth's habitable surface - about 4.8 billion hectares - is used for agriculture. In addition, the food sector accounts for 26% of the roughly 50 Gt of CO_2 equivalents emitted annually worldwide. Expanding agriculture further leads to increased deforestation, resource utilization, and rising greenhouse gas emissions, exacerbating climate change.

Microbial protein is a promising addition and alternative to conventional food sources. It refers to protein-rich, edible microbial biomass (e.g., from bacteria, yeasts, filamentous fungi, or algae) that is cultivated under controlled conditions, such as in bioreactors. The targeted enrichment of the biomass with micronutrients can further enhance its nutritional value. Most commercial production processes for microbial protein products on the market use sugars as raw material, which does not circumvent traditional agriculture. The simple organic compound acetate is an ideal cultivation substrate since it can be derived from CO_2 and renewable energy, supporting a circular economy. The Power-to-Vitamin (PtV) process couples water electrolysis to a two-stage bioprocess system. In the Stage A bioreactor, CO_2 is reduced to acetate with H_2 as an electron donor by the acetogenic bacterium Thermoanaerobacter kivui under strictly anaerobic conditions. The acetate is continuously transferred to a Stage B bioreactor and aerobically converted into protein- and vitamin B9-enriched microbial biomass of the yeast Saccharomyces cerevisiae. The yeast biomass obtained from Stage B provides the recommended daily allowance of vitamin B9 (~400 µg d-1) already at a serving size of ~6 g dry weight per day. By this, our system provides a product fulfilling two primary goals: (1) protein provision for nutrition security; and (2) guaranteeing adequate vitamin B9 levels for optimal health.