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In-situ Multiphase Compartmentalised Substrate Shuttle Bioreactor for Protein and Platform Chemicals

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A wide range of useful chemicals and products are produced by microorganisms, however these process use feedstocks which could be used as food. There is significant interest in the utilization of bacterial processes for the production of “green” or sustainable chemicals which are not dependent on feedstocks which compete with the production of food. One promising avenue is to use hydrogen and carbon dioxide based microbial metabolisms, often called C1 metabolism, as this route would be independent of the traditional energy and carbon supplying substrates such as molasses which could be used a human foodstuff. Hydrogen can be produced electrolytically from renewable energy sources which have variable and intermittent energy output such as wind power and thus could be used in areas where wind output is grid constrained for electricity production. A number of hydrogen and carbon dioxide related metabolic pathways have significant challenges to due to either feedstock incompatibilities or feedstock /product inhibition which hinder either the industrial exploitation due to explosion risks at larger scales or low product/ feedstock concentration which increases the cost of product recovery.

One commonly proposed microbial route is the use of hydrogen oxidizing microorganisms such as *Cuprovidius necator* to produce products such as proteins or bioplastics. However as indicated with the original name of “Knallgas” or “bang gas “ for this metabolic pathway, the scale up of this particular process faces significant challenges due to the flammability of hydrogen and oxygen. The flammability of hydrogen is particular problem as this extends over a very wide range (4-75% H2 in air) and has a low ignition energy for combustion, 10% of that required by petrol. Therefore to reduce the risk of explosion, the reactor will need either to be operated under low concentration of either substrate or oxygen. However this approach would probably result in reduced process productivity as the microorganisms would always be under either low substrate or oxygen availability. In this project, the substrate shuttle reactor concept uses a novel configuration of a membrane separated bioreactor design to overcome these challenges.

Another C1 metabolic route that could be exploited for “green” chemical platform chemicals the production of volatile fatty acids such as acetic acid from hydrogen and carbon dioxide using bacteria such as *Clostridium aceticum.* This process would have reduced flammability issues but would face challenges due to the relative low product concentrations and the decrease in-reactor pH due to the production of an acid product. To increase productivity and reduce the addition of alkali then the continual removal of product e.g. via membrane extraction would offer significant advantages. As there are a number of aerobic microorganisms that can be used for the production of lipids, single cell protein, and bioplastics which use acetic acid and thus if these metabolisms were coupled with anaerobic acetic acid production from hydrogen, a safe process could be implemented. It could be potentially possible to produce a range of foodstuffs, oils and single cell protein which would be independent of the traditional food production systems.