【Grant-in-Aid for Scientific Research (S)】

A Study of Science and Process Construction of Microbial Gas-phase Reaction

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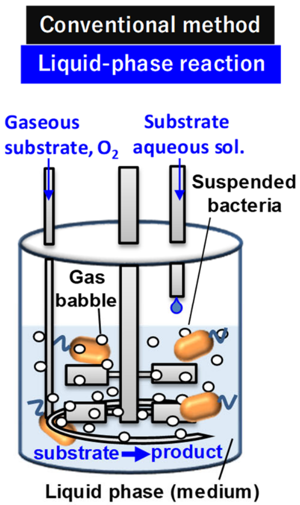
Project Information	Project Number : 24H00043 Project Period (FY) : 2024-2028 Keywords : microorganism, gas-phase reaction, metabolic analysis, breeding, bioproduction

Purpose and Background of the Research

●Outline of the Research

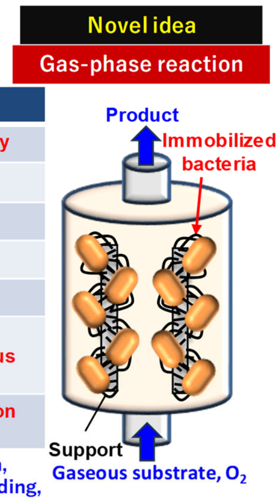
We will reveal metabolic and signaling switches and changes in substrate uptake mechanisms, redox status, and stress responses by different environmental factors (molecular transport, oxygen concentration, water content, etc.) between gas and liquid phases in several bacterial species. Through gene expression, metabolite, and metabolic flow analyses, bacterial strain suitable for gas phase reactions will be designed and created. We will construct highly effective microbial gas-phase reaction systems and establish their scientific principles, bringing innovation to bioproduction.



Diffusion rate in the gas-phase: 10,000 times of the liquid phase

Reaction	In liquid	In gas
Bubbling/mixing	necessary	unnecessary
O_2 supply	inefficient	efficient
Contamination risk	high	low
Harvesting	complex	simple
Scale up	difficult	easy
Volumetric efficiency	high	low →continuous reaction
Waste/Inhibitor	release from cells	accumulation →washing

metabolite analysis, pathway design, genetic engineering, molecular breeding, bioreactor construction



① Substrate uptake mechanism, redox status, stress responses、metabolism change
② Creation of bacteria and products suitable for gas-phase microbial reactions
③ Design and construction of highly efficient microbial gas-phase reaction systems

Figure 1. Total image of the study

●Background of the Research

The principal investigator discovered AtaA, a protein that exhibits strong and nonspecific adhesion properties, and devised a novel bacterial immobilization method, as well as microbial gas-phase reaction, in which rapid reactions can be attained without agitation or aeration. Then, a novel gas-liquid interfacial reactor that is 4 to 10 times more efficient than the liquid phase was designed and constructed.

●Originality and creativity of the research

This research is a very challenging attempt to overturn the conventional idea that microbial reactions are carried out in liquids. There have been no reports on the creation of bacterial strains suitable for gas-phase reactions or the research of their products in papers or even in conference presentations. There are studies on deodorization and microbial conversion using biofilms formed on the liquid phase side of packed bed carriers and gas-liquid interfaces. There are also papers claiming gas-phase reactions using bacteria encapsulated in gels. However, it was shown that they cannot be called gas-phase reactions because gel has the high water content.

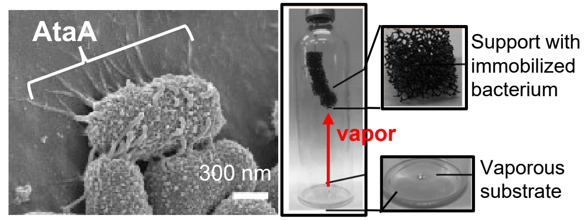


Figure 2. Bacterial cells immobilized on a material surface with AtaA (left) and an image of a microbial gas-phase reaction (batch reaction) (right)

Expected Research Achievements

● What are this study trying to reveal?

We will reveal the following three points. (1) "What environmental factors differ in the gas and liquid phases, and how do they cause changes in metabolism, substrate uptake mechanisms, redox status, stress responses, etc.?", 2) "What are breeding of bacterial strains and their products suitable for microbial gas-phase reactions?", and 3) "What is a highly efficient microbial gas-phase reaction process?

● To what extent will they be pursued in this study?

Several bacterial species that have been successfully immobilized by AtaA are used with various gaseous substrates, such as benzene/toluene vapor, acetic acid vapor, and CO_2/H_2, are used. We will comprehensively examine metabolites, membrane lipid composition, and gene expression to determine the metabolism, redox state, and stress responses that differ between liquid- and gas-phase reactions. We will also clarify how gaseous substrates are taken up, metabolized, and converted to target products in bacterial cells, and in silico design bacteria that efficiently produce target products in the gas phase. Finally, bioreactors and bioprocesses will be designed to achieve microbial gas-phase reactions that are tens to hundreds of times more efficient than liquid-phase reactions.

● Developments, impacts, etc. that lead to social life

Microbial production of useful chemicals such as biofuels and biodegradable plastics from the greenhouse gases CO_2 and CH_4, or from gasified waste and biomass, will contribute to solutions to global warming, waste reduction, and zero emission.

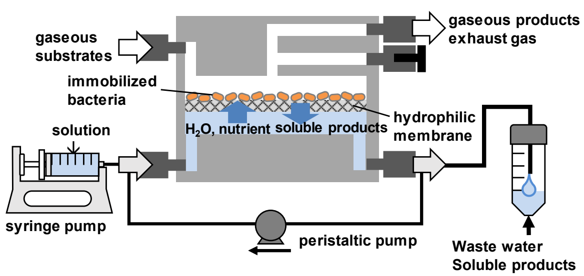


Figure 3. An example of microbial gas-phase bioreactor

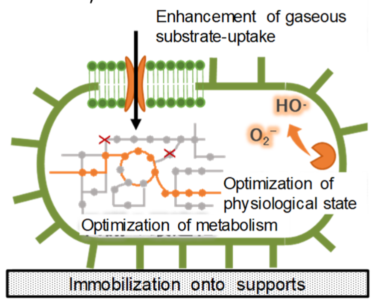


Figure 4. Creation of bacteria for gas-phase reaction

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