Electrochemical Regulation of Microbial Growth
– Mechanism of Growth Stimulation by Redox Potential Control and its Application –

Background

Microorganisms gain chemical energy for sustenance through electron-transfer reactions such as respiration, fermentation, and photosynthesis. In general, since electron-transfer reactions depend on redox potential, it has been hypothesized that every microorganism has an optimal redox potential for growth. We previously demonstrated an electrochemical cultivation method to stimulate growths and activities of microorganisms by electrochemically maintaining a constant redox potential in culture media. However, the mechanism through which redox potential affects microbial growth had not been clarified and the potential of electrochemical cultivation to enrich specific microorganisms in a complex mixture had not been examined.

Objective

The purpose of this study is to analyze the effect of electrochemical control of redox potential on microorganisms to reveal the mechanism for stimulating the growth of microorganisms and to apply this novel cultivation method to cultivate environmental microorganisms.

Principal Results

1. Effect of the electrochemical control of redox potential on microorganism

To reveal the growth stimulating mechanism, sulfate-reducing bacterium "*Desulfovibrio desulfuricans*" was selected as a model organism to examine the effect on respiratory reactions which produce the energies required for growth and metabolism. It was revealed that maintaining the optimal redox potential for *D. desulfuricans* activated the rate of sulfate respiration by 1.5 times and increased the amount of transcription of genes for sulfate respiration by 2 to 7 times. On the basis of these results, the mechanism through which electrochemical control of the redox potential stimulates respiration reaction, increases energy production, and activates microbial growth was estimated (Fig1).

2. Enrichment of environmental microorganisms by electrochemical control of redox potential

An environmental sample (lake community) containing various types of microorganisms was split and cultivated under 24 distinct electrochemical conditions. Depending on the electrochemical conditions, significant enrichment of particular microorganisms was achieved. In a typical case, we were able to enrich a bacterium which made up less than 0.1% in the natural lake community, although it was difficult to achieve using conventional cultivation methods (Fig2).

3. Development of commercial type of electrochemical cultivation system

To popularize this novel cultivation method, we developed a commercial model of the electrochemical cultivation system (Fig3). It was expected this commercial system will help to cultivate microorganisms with electrochemical control of redox potential.

Future Developments

Electrochemical cultivation will be applied to survey useful microorganisms for bioprocesses and make these operations more efficient.

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Reference

"Electrochemical control of bacteria (Part X, XII, XIII)" CRIEPI report (in Japanese)

-Development of prototype cultivation system for electrochemical cultivation- CRIEPI report (V07011)

-Effect of redox control on sulfate reducing bacteria- CRIEPI report (V08040)

-Effect of electron mediators and redox potential on the flora of environmental microbes- CRIEPI report (V08038)

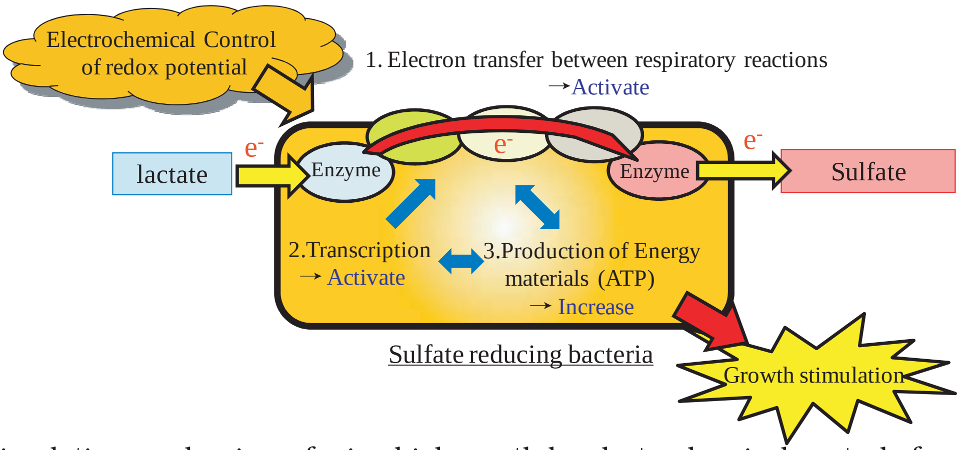


Fig.1 Stimulation mechanism of microbial growth by electrochemical control of redox potential

Electrochemical control of the optimal redox potential for microbial growth induced three types of biochemical changes in sulfate-reducing bacteria: 1. Stimulation of the rate of respiratory reaction, 2. Transcriptional activation of genes for respiration, 3. Increase of energy material required for growth and metabolism. These changes could be involved in stimulation of microbial growth by electrochemical regulation of redox potential.

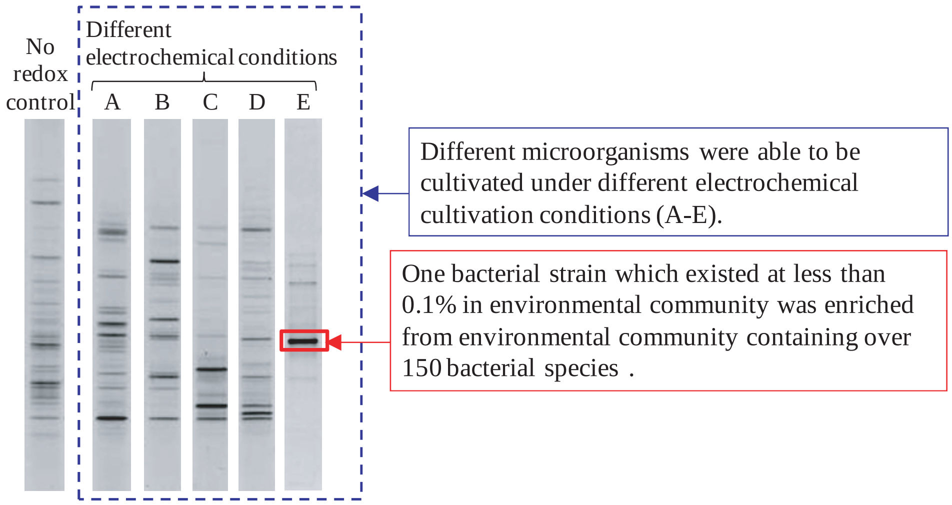
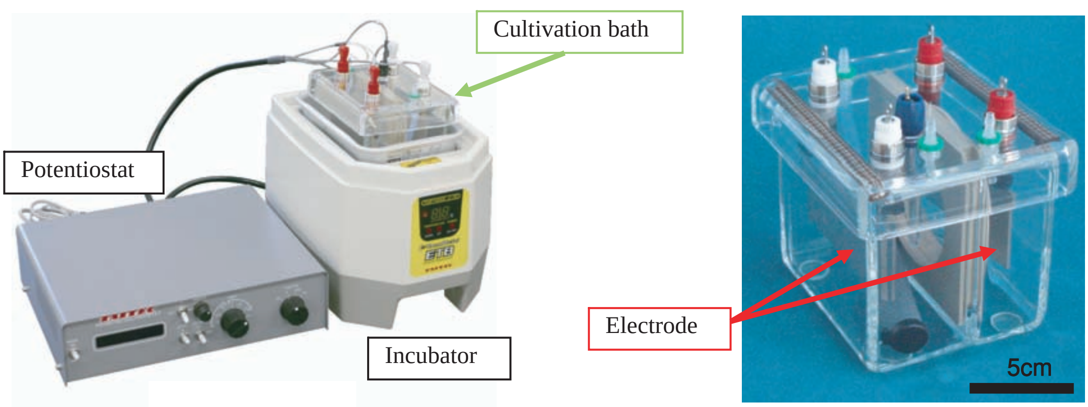


Fig.2 Electrochemical cultivation of environmental microorganism

This figure shows a result of DNA electrophoresis which reflects cultivated microbial diversity. Bands indicate major bacterial species cultivated under different electrochemical conditions. In condition E, the bacterium which existed at a ratio of less than 0.1% in environmental community (lake community) was enriched.



(a) Whole system for electrochemical cultivation

(b) Cultivation bath

Fig.3 Commercial type of electrochemical cultivation system

Electrochemical cultivation system includes potentiostat, incubator, and cultivation bath.