Stimulation of Microbial Growth by Regulation of Redox Potential

Background

Microorganisms gain chemical energy for sustenance through electron-transfer reactions such as respiration, fermentation, and photosynthesis. We previously proposed an electrochemical cultivation method to increase the cell density of specific bacteria (e.g., iron-oxidizing bacteria); this method involved the supply of electrons as the energy source from an electrode to the bacteria. In general, since electron-transfer reactions depend on redox potential[1)], it has been estimated that every microorganism has the optimal redox potential required for its growth. However, no electrochemical cultivation method has been proposed so far to control growths and activities of microorganisms by regulating and maintaining the redox potential in culture media. Therefore, the requirement to regulate the redox potential in culture media by electron transfer between an electrode and an electron mediator led us propose the novel electrochemical cultivation system for stimulating microbial growth by creating the optimal redox potential required for growth without electron supply to the microorganism as proposed previously (Fig1).

Objective

We aim to develop a novel method to stimulate the growth of microorganisms by regulating the electrochemical redox potential.

Principal Results

1. Confirmation of decrease in redox potential with the growth of sulfate-reducing bacterium

Sulfate-reducing bacterium[2)] "*Desulfovibrio desulfuricans*" was used as the representative of environmental microorganisms. It was confirmed that the redox potential (E) in the culture medium decreased from -0.1 V to -0.5 V (vs. Ag/AgCl) with the growth of the sulfate-reducing bacterium, without any electrochemical regulation.

2. Effect of the regulation of electrochemical redox potential on the growth of sulfate-reducing bacterium

Electrochemical cultivation of the sulfate-reducing bacterium was performed by constantly maintaining the redox potential between +0.4 V and -0.8 V using quinone compound as the electron mediator (Fig2). When the redox potential was maintained above -0.45 V, the growth curve was quite similar to the one without the regulation of the electrochemical redox potential. However, it was revealed that maintenance of the electrochemical redox potential below -0.6 V enabled early initiation of the growth of the sulfate-reducing bacterium. These results suggested that regulation of redox potential can preferentially stimulate the growth of specific microorganisms. This is the first report that clarifies that optimal redox potential facilitates microbial growth.

3. Selective cultivation of specific bacteria by the regulation of electrochemical redox potential

Electrochemical cultivation of various types of bacteria (mixed culture) was performed at E = +0.4 V, -0.1 V, and -0.6 V. It was clarified by denatured gradient gel electrophoresis (DGGE) that dominant species of bacteria changed by varying applied potential (Fig3). Furthermore, the sulfate-reducing bacteria grew preferentially and became dominant when the electrochemical redox potential was maintained at -0.6 V, as clarified in Fig2.

On the basis of these results, we propose a novel cultivation method, which is different from the conventional cultivation method, for stimulating the growth of specific bacteria by regulating the electrochemical redox potential in culture media.

Future Developments

The principle that the regulation of redox potential affects microbial growth will be clarified.

1) Redox potential: a measure of the tendency of a given system to donate or accept electrons
2) Sulfate-reducing bacterium: a category of strictly anaerobic bacteria that utilize sulfate for respiration
   Activities of these bacteria are responsible for biotechnological removal of pollutants from the environment.

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Reference

S. Hirano, et al., 2008, "Electrochemical control of bacteria (Part XI) -Regulation of sulfate-reducing bacteria by redox control-" CRIEPI report (V07018) (in Japanese)

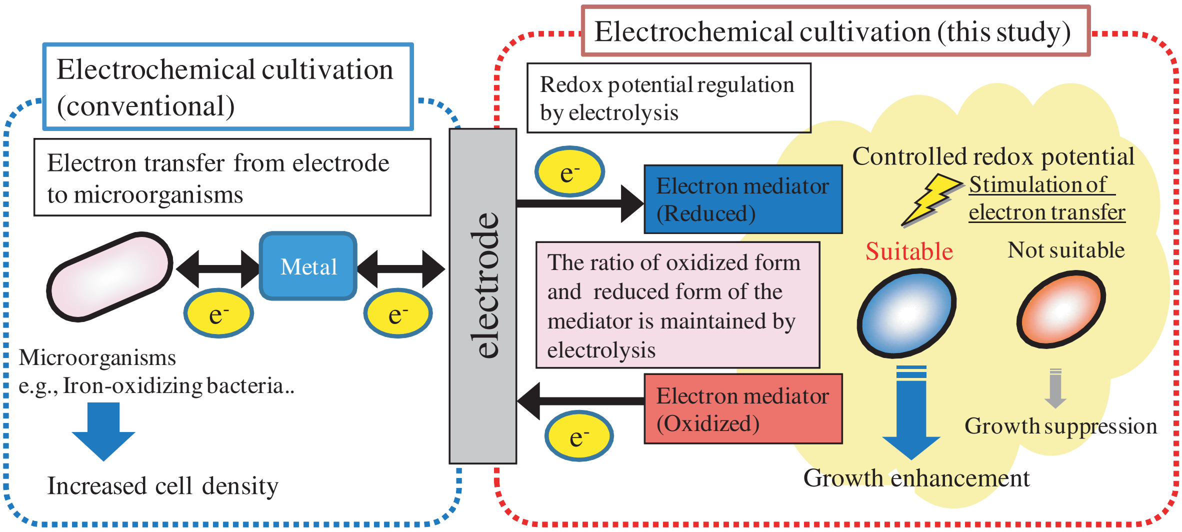

Fig.1 Stimulation of bacterial growth by regulation of redox potential using electrolysis

The cultivation method in this study establishes an optimal redox potential for the growth of a specific microorganism by electron transfer between an electrode and an electron mediator in culture medium. This method is based on a new concept to stimulate microbial growth by regulating the redox potential by electrolysis.

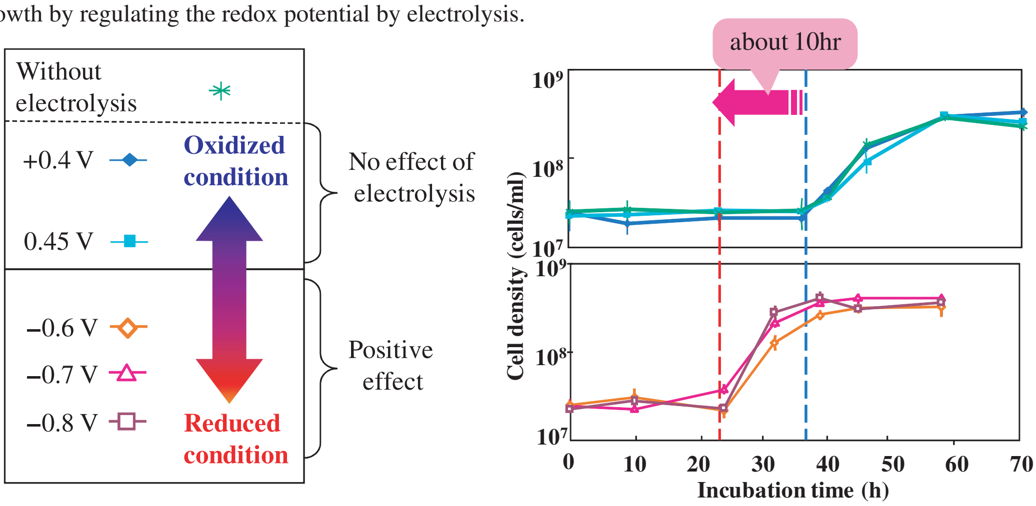

Fig.2 Effect of the regulation of redox potential on the growth of sulfate-reducing bacterium

There is no effect of electrolysis on microbial growth when the redox potential is maintained between +0.4 V and –0.45V (top right). The growth of the sulfate-reducing bacteria initiated approximately 10 hours earlier when the redox potential in the culture medium was maintained below –0.6 V than when the electrochemical redox potential was not regulated, in which case growth initiation takes approximately 37 hours.

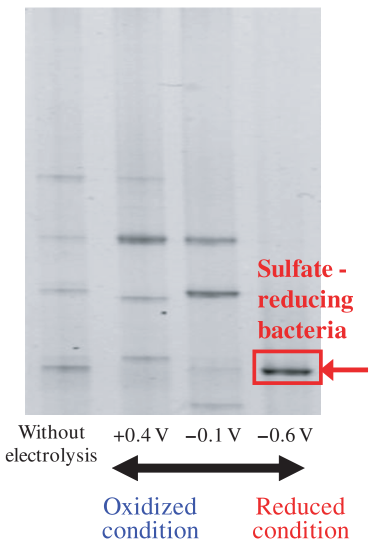

Fig.3 Enrichment of specific bacteria by the regulation of redox potential

Mixed cultures containing various types of environmental microorganisms were cultivated at controlled redox potentials (+0.4 V, –0.1 V, and –0.6 V). Depending on the applied redox potential, density of existing microbial species varied, and sulfate-reducing bacteria were enriched dominantly at –0.6 V (red arrow), which is the optimal redox potential for their growth.

[Each band refers to individual species of microorganism]