Numerical Simulation and Experimental Validation of a Rotating Bioreactor for Mimicking Microgravity Effect

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Restrained by scarce chance and high cost of a space flight experiment, rotary bioreactors are developed for microgravity effect mimicking in ground-based laboratory. The operating mode of a rotating bioreactor and features of fluid dynamics and mass transportation in the bioreactor play an important role in influencing experimental results, which could cause inconsistent or contradictory data. For establishing adequately controlled experimental conditions, a new rotating bioreactor system was designed, and its applicability was verified by numerical simulation and cell biological experiments.

For the numerical simulation, the Eulerian multiphase model was chosen to simulate the movement and distribution of the particles in the rotating bioreactor, regarding the particles as pseudo-fluid. The pseudo-fluid was discretized to analyze the trajectories of the particles. Simulation results help to optimize the experimental conditions and provide predictions to guide experimental design.

For biological experiments, MC-3T3-E1 cells and Cytodex-3 microcarriers were inoculated in the bioreactor, cell adhesion rate was measured, and the cell growth rate under different rotating conditions was assayed. The results were compared with that in commercialized RCCS (Synthecon, USA) to further validate the simulation and prediction. The results demonstrate that the experimental conditions can be optimized by rationally setting speed, carrier/cell ratio, and culture liquid density/viscosity in the new bioreactor system for a controllable microgravity effect simulation experiment. It is found that the simulating results show good agreement with the experimental ones in cell proliferation kinetics. The study aims to set up a software and hardware platform for investigating the effects of microgravity on mammalian cells by integrating numerical simulation method and cell biological experiments.

References

[1] F. Consolo, et al. Computational modeling for the optimization of a cardiogenic 3D bioprocess of encapsulated embryonic stem cells. Biomech Model Mechanobiol. 2011

[2] Ohwon Kwon, et al. Oxygen Transport and Consumption by Suspended Cells in Microgravity: A Multiphase Analysis. Biotechnology and Bioengineering. 2008. Vol. 99, No. 1

[3] Cynthia M. Begley, et al. The Fluid Dynamic and Shear Environment in the NASA/JSC Rotating-Wall Perfused-Vessel Bioreactor. Biotechnology and Bioengineering. 2000. Vol. 70, No. 1