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## Abstract

Tissue engineering deals with the development and growth of cells to obtain functional tissues or organs. In this process, a porous material known as a scaffold is designed to support the cells to grow in the desired form. This designed structure is incubated inside a bioreactor which provides adequate nutrient supply for the cells to grow. The major challenge in tissue engineering is to model a bioreactor and the scaffold which support high-density cells so that adequate nutrient can be delivered to inner regions to obtain significant cell growth. Mathematical modeling of such processes is essential to understand the entire mechanism. In order to stay closer to reality, the scaffold material is assumed to be elastic in nature. Correspondingly, some mathematical models of different bioreactors consisting deformable porous scaffold are developed to analyze the fluid flow and nutrient transport. Living biological cells are assumed to adhere to the solid matrix of scaffold firmly. This allows us to consider the cell phase and the scaffold skeleton phase as single combined solid phase. Fluid flow and deformation of the solid phase in the scaffold region are modeled based on the biphasic mixture theory. Navier-Stokes equation accounts for the free fluid in the bioreactor. Advection-diffusion-reaction equation governs the concentration of a nutrient in the scaffold region whereas advection-diffusion equation governs the nutrients in the free fluid.

In order to obtain the solution, the governing equations are reduced according to the geometric configuration of the model with suitable characteristic parameters. Lubrication theory is used depending on the low aspect ratio of the bioreactor width to the length. The reduced system of equations is solved analytically, semi-analytically or using numerical methods. Semi-analytical treatment on the mathematical model includes Laplace transformation to deal with the time dependency of the governing fluid flow equation and consequently, Durbin's algorithm is used to retrieve the time-dependent variables. Our typical aim is to obtain the dependence of key parameters of the bioreactor on the hydrodynamics and the nutrient supply. This allows one to optimize the required amount of nutrient concentration inside the scaffold region for the cells to obtain uniform growth and reduce the cell death. Correspondingly, the current mathematical model enables one to optimize the solid phase deformation to aid cell proliferation and avoid physical damage to the deformable scaffold. Moreover, a general criterion is developed to regulate the nutrient concentration inside the scaffold to avoid the formation of necrosis region or starvation zone. The criteria provide an idea to adjust the fluid volume flux supply in the lumen to obtain optimum and required cell growth in the scaffold region. In this way, the mathematical modeling approach may help in directing the future experiments to achieve optimum results by providing the obtained theoretical data.

**Keywords:** Tissue engineering; Deformable porous media; Biphasic mixture theory; Nutrient transport; Lubrication approximation; Perturbation methods; Asymptotic solutions; Contois equation; Sherwood number; Laplace transformation.