Preface

All I know is just what I read in the papers.
Will Rogers

The quote above is quite intriguing to me and reflective of this text. Everything in this text can be found either directly or with "extrapolation" or "deduction" from the books and papers one can find to date. The most influential books to this time are the *"Biochemical Engineering Fundamentals"* by J.E. Bailey and D.F. Ollis, *"Elements of Chemical Reaction Engineering"* by H.S. Fogler, *"The Engineering of Chemical Reactions"* by L.D. Schmidt, *"Chemical Reaction Engineering"* by O. Levenspiel, *"Bioprocess Engineering—Basic Concepts"* by M.L. Shuler and F. Kargi, and many others. All these texts and others have formed part of this text. In no intention this text is compiled to replace all these great textbooks of the time. A mere rearrangement and/or compiling is made in this text to give you the reader an opportunity to understand some of the basic principles of chemical and biological transformations in bioprocess engineering.

The computer age has truly revolutionized the literature, beyond the literature revolution brought about by the mass production or availability of paper and distribution of books via library. The explosion of the shear amount of literature, birth of interdisciplines and disciplines or subject areas in the past decades has been phenomenal. Bioprocess Engineering is one that born of biotechnology and chemical engineering. With the maturing of Bioprocess Engineering as a discipline, it evolves from an interdisciplinary subject area of Biology and Chemical Engineering, to a discipline that covers the engineering and engineering science aspects of biotechnology, green chemistry, and biomass or renewable resources engineering. As such, textbooks in the area are needed to cover the needs of educating the new generation of fine bioprocess engineers, not just by converting well-versed chemical engineers and engineering-savvy biologists to bioprocess engineers. I hope that this textbook can fill this gap and brings the maturity of bioprocess engineering. Yet, some of the materials in this text are deep in analyses that are suited for graduate work and/or research reference.

The key aspect that makes Bioprocess Engineering special is that Bioprocess Engineering as a discipline is centered around solving problems of transformation stemmed from cellular functions and biological and/or chemical conversions concerning the sustainable use of renewable biomass. The mechanism, rate, dynamic behavior, transformation performance and manipulations of bioprocess systems are the main topics of this text.

Chapter 1 is an introduction of bioprocess engineering profession including green chemistry, sustainability considerations and regulatory constraints. Chapter 2 is an overview of biological basics or cell chemistry including cells, viruses, stem cell, amino acids, proteins, carbohydrates and various biomass components, and fermentation media. In Chapter 3, a survey of chemical reaction analysis is introduced. The basic knowledge of reaction rates, conversion, yield, stoichiometry and energy regularity for bioreactions are reviewed. The concepts of approximate and coupled reactions are introduced, providing the basis of understanding for the metabolic pathway representations later in the book. Mass and energy balances for reactor analyses, as well as the definitions of ideal reactors and commonly known bioreactors are introduced before an introduction to reactor system analyses. The biological basics and chemical reaction basics are followed by the reactor analysis basics in Chapters 4 and 5, including the effect of reaction kinetics, flow contact patterns and reactor system optimizations. Gasification (of coal and biomass) is also introduced in Chapter 5. How the ideal reactors are selected, what flow reactor to choose and what feed strategy to use are all covered in Chapter 5.

Chapters 6, 7, 8, 9, 10 and 11 are studies on bioprocess kinetics. In Chapter 6, you will learn the collision theory for reaction kinetics and approximations commonly employed to arrive at simple reaction rate relations. Kinetics of acid hydrolysis, of an important unit operation in biomass conversion, is introduced as a case study. In Chapter 7, we turn to discuss the techniques for estimating kinetic parameters from experimental data, breaking away from the traditional straight line approaches developed before the computer age. You can learn how to use modern tools to extract kinetic parameters reliably and quickly without complex manipulation of the data. In Chapters 8 and 9, we discuss the application of kinetic theory to catalytic systems. Enzymes, enzymatic reactions and application of enzymes are examined in Chapter 8, while adsorption and solid catalysis are discussed in Chapter 9. The derivation of simplified reaction rate relations, such as the Michaelis–Menten equation for enzymatic reaction and LHHW for solid catalysis, is demonstrated. The applicability of these simple kinetic relations is discussed. In Chapter 9, you will learn both ideal and non-ideal adsorption kinetics and adsorption isotherms. Is multilayer adsorption the trademark for physisorption? The heterogeneous kinetic analysis theory is applied to reactions involving woody biomass where the solid phase is not catalytic in §9.5. Chapter 10 discusses the cellular genetics and metabolism. The replication of genetic information, protein production, substrate uptake, and major metabolic pathways are discussed, hinting at the application of kinetic theory in complicated systems. In Chapter 11, you will learn how cell grows: cellular material quantifications, batch growth pattern, cell maintenance and endogenous needs, medium and environmental conditions, and kinetic models. Reactor analyses are also presented in Chapters 8 and 11.

In Chapters 12 and 13, we discuss the controlled cell cultivation. Continuous culture and wastewater treatment are discussed in Chapter 12. Exponential growth is realized in continuous culturing. An emphasis is placed on the reactor performance analyses, using mostly Monod growth model in examples, in both Chapters. Chapter 13 introduces fed-batch operations and their analyses. Fed batch can mimic exponential growth in a controlled manner as opposed to the batch operations where no control (on growth) is asserted besides environmental conditions.

Chapter 14 discusses the evolution and genetic engineering, with an emphasis on biotechnological applications. You will learn how cells transform, how cells are manipulated, and what some of the applications of cellular transformation and recombinant cells are. Chapter 15 introduces the sustainability perspectives. Bioprocess engineering principles are applied to examine the sustainability of biomass economy and atmospheric CO_2. Is geothermal energy a sustainable or renewable energy source? Chapter 16 discusses the stability of catalysts: activity of chemical catalyst, genetic stability of cells and mixed cultures, as well as the stability of reactor systems. Sustainability and stability of bioprocess operations are discussed. A stable process is sustainable. Multiple steady states, approach to steady state, conditions for stable operations and predator–prey interactions are discussed. Continuous culture is challenged by stability of cell biomass. In ecological applications, sustainability of a bioprocess is desirable. For industrial applications, the ability of the bioprocess system to return to the previous set point after a minor disturbance is an expectation. In Chapter 17, the effect of mass transfer on the reactor performance, in particular with biocatalysis, is discussed. Both external mass transfer, e.g. suspended media, and internal mass transfer, e.g. immobilized systems are discussed, as well as temperature effects. The detailed numerical solutions can be avoided or greatly simplified by following directly from the examples. It is recommended that examples be covered in classroom, rather than the reading material. Chapter 18 discusses the reactor design and operation. Reactor selection, mixing scheme, scale-up, and sterilization and aseptic operations are discussed.

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