

# Preface

Immobilizing body at a particular position is a mechanism of meditation that concentrates complete energy and allows its linear alignment from head to toe.

Chapter 1: The concept of enzyme immobilization first arose in 1916 when it was found that enzymes could perform catalysis even in a fixed state with movement only at the active site. Technology has evolved tremendously since then, particularly with respect to immobilizing matrices. Enzyme immobilization has solutions to various problems related to the industrial, agricultural and environmental sectors, and it has a higher number of patents across the world than any other technology known to date. However, the connectivity to their arrival in the market and patents filed is not very appreciative. An immobilized enzyme has various heightened and additional properties with respect to its soluble state, such as higher stability, more reusability, longer storage time, a broad range of activities in the presence of various physical and chemical factors, as well as easier product recovery. Chapter 1 is the compiled summary of the innovative research carried out in the field over the last 100 years.

Chapter 2: Immobilized enzymes have a broad range of applications, including synthesis of complex drug intermediates; chemical synthesis without toxic by-products under mild conditions; remediation of polluted water, air and soil; and disease diagnosis and its treatment. Enzyme immobilization is preferable to other known technologies due to the convenience of enzyme handling, the ease of product recovery, the possibility of enzyme reusability, the stability under extreme physical and chemical conditions, the ease of shipment and the fact that it is applicable for all reactor types and enables easier process control. There are numerous protocols for enzyme immobilization and several modifications are emerging to make it adaptable for any process. However, it is still a technique of trial and error; this is supported by the fact that enzyme behavior could not be predicted with the given matrix being implemented when a number of enzymes with similar structures that were from the same family were investigated. It has been found from a number of studies that the immobilizing matrix plays a key role in the properties

of the immobilized enzyme. Chapter 2 is the compiled summary of recent developments in immobilization techniques with respect to the types of matrices and the immobilization methods. Furthermore, it also discusses immobilizing enzymes in the absence of a matrix, and the associated properties.

Chapter 3: There are a number of enzyme sources, among the most important of which are bacteria, fungi, plants and animals. Structural studies of enzymes from any of these sources have found a similarity of more than 70 % with an almost negligible difference at their active sites. Bacterial and fungal sources are widely used for various industrial processes such as the production of organic acids, amino acids, antibiotics, food and beverages, including alcohol, cleaning supplies, clothing, paper products, transportation fuels, agrochemicals, monitoring devices, and pharmaceuticals, as well as in disease diagnosis and chemical feedstock. This is a result of the ease with which they can be cultured and the associated high enzyme recovery. With the evolution in purification protocols and improvement of novel chromatographic techniques as well as instrumentation, the concept has moved for enzymes usage from microbial to plant sources. Furthermore, plant enzymes have good catalytic properties and are high in abundance. Plant carbohydrases and proteases are the main enzyme classes which are found to have extensive industrial applications. Financial statistics of the global market have revealed that there is tremendous requirement for enzymes. Therefore, enzymes obtained from the best source for a particular process would accelerate it by several fold. In addition, enzymes from plant sources have additional benefits due to the generation of huge biomass, which is of economic significance. Chapter 3 is the compiled summary of the physiological and industrial significance of enzymes from plants. Furthermore, it also discusses the usage of leftover biomass for various applications.

Chapter 4: Enzymes are now known to be the important constituents of our daily diet due to their capabilities for treating several diseases. It has been found that eating highly processed food laden with preservatives is not good for health as it hampers the body's immune mechanisms and diverts energy to the production of only digestive enzymes. This can lead to the development of several serious diseases such as cancer, cardiac arrest, and autoimmune diseases (allergies and arthritis). There are several medications known that use enzymes for the treatment of various diseases. However, the popularity of enzyme therapy has been limited for various reasons, the most important of which are the state and route of administration. Soluble enzymes are prone to degradation inside the body due to various factors, as well as to immunogenicity. Enzyme immobilization has the solution by employing biocompatible matrices. Immobilized enzymes have enormous applications in bioanalytical and biomedical fields including in biosensors, disease diagnosis, bioreactors in the removal of waste metabolites and the correction of inborn metabolic deficiencies, development of controlled release drug delivery systems, prediction of species-dependent metabolic pathways, large-scale synthesis of drug and xenobiotic metabolites. Furthermore, immobilized enzymes are helpful in making drugs pharmacologically more active by conjugating with various side groups. Chapter 4 is the compiled summary of the biomedical and bioanalytical

applications of immobilized enzymes as well as a discussion of their efficacy compared with other techniques known to date.

Chapter 5: Environmental pollution is responsible for about 12.6 million deaths across the world, annually (WHO), which is much higher than any other cause. Developing countries (which constitute one fourth of the world's population) are at major risk from environmental pollution due to their unstable economy, political instability, low productivity, high rate of damage to ecosystems and almost negligible budget towards public health. Children are at a higher risk than adults as they have a higher metabolic rate, due to which they can ingest larger concentrations of pollutants and retain them for longer durations. Furthermore, pollutants such as lead and mercury can have toxic effects even before child is born, when it is living inside the mother's womb, since pollutants can easily cross the placenta. It has been found that poor sewage systems have worsened the situation by several fold. It has been estimated that about 30–50 % of solid wastes are not collected and disposed of properly, which creates ideal breeding conditions for mosquitoes, rodents and other disease-bearing organisms. Furthermore, the leaching of waste materials from unsealed dumpsites into soil and drinking water supplies as a result of poor landfill management has increased the severity. There is an urgent need for effective waste management *via* cheaper technology. Immobilized enzymes have solutions for the remediation of various pollutants, especially from water and air. Chapter 5 is the compiled summary of various immobilized enzymes being used in the treatment of waste water and polluted air.

This book is the outcome of long hours of immobilizing myself onto the chair. It has an emphasis on simplicity so as to reach all classes, whether from the field or not. I am very thankful to my Ph.D. supervisor, Prof. Arvind M. Kayastha (School of Biotechnology, Banaras Hindu University), who introduced me to the field and for his continuous motivation, which has always made me move ahead with keen interest and enthusiasm. This book would not have been completed without the support from my family members (mummy, papa, raman, muniya, anshu and yogesh) who have spared their time to allow me to focus on book writing. Furthermore, I make a special thanks to the various living creatures around me; they have motivated me in various respects and for this I find no words to express my feelings.

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