Industrial vs Food Enzymes: Applications and Future Prospects

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Abstract

The domain of food process technology and environmental engineering is facing one drastic challenge over another. Scientific ingenuity and deep scientific knowledge are reshaping and revamping the entire environmental engineering scenario. Stringent environmental regulations, environmental disasters and loss of environmental biodiversity are urging the scientific domain to gear forward towards newer innovations of science. In this well-researched treatise, the author delineates immense potential and application of industrial enzymes in environmental pollution control. The scientific challenge of this treatise is immense and far-reaching. Scientific judgement and deep scientific understanding of enzyme engineering, biotechnology and the interconnected areas of environmental engineering science are deliberated in minute details. The background of this chapter involves a detailed discussion of industrial enzymes, enzymatic processes, potential applications of enzymes and enzymatic treatment to improve water quality and a detailed discussion of aromatic and other organic pollutants. The immense success and the vast potential of industrial enzymes in environmental protection are delineated in details. Other discussions include the vexing issues of pesticide residues, cyanide wastes, heavy metals, solid wastes and surfactants removal with the help of enzymes. Enzymatic treatment for the manufacture of value-added substances such as food processing wastes is delineated with deep insight and scientific introspection. This chapter also gives a wide glimpse on the field of environmental sustainability, biotechnology and enzyme engineering. Human scientific determination, mankind's vast vision and technological motivation will all lead a long way in this chapter towards the true challenge and scientific emancipation of environmental protection and sustainability.

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16.1 Introduction

Enzyme engineering and biotechnology are moving towards an avenue of immense scientific ingenuity and vast scientific cognizance. Science and technology of environmental protection are witnessing a new era of scientific rejuvenation. Frequent environmental disasters, loss of ecological diversity and worldwide strict environmental regulations have goaded the global scientific fraternity to surge forward towards innovations and challenging future. Biodegradability of environmental engineering processes is a global issue today. With such immense caution in mind and at such a crucial juxtaposition of human civilization and human scientific endeavour, environmental engineers and biotechnologists are reshaping and rebuilding the entire domain of enzyme science and engineering. This technology is not unique yet needs to be developed. In this chapter, the author pointedly focuses on the immense rigour and the wide scientific ingenuity behind environmental engineering applications of enzymes. Engineering science and technology are today surpassing vast and versatile visionary boundaries. Biotechnology and enzyme engineering are witnessing immense and drastic challenges. In such a juncture, biotechnology and process engineering needs to be re-envisioned and re-envisaged. The author of this chapter repeatedly focuses on the vast scientific potential and sagacity of science in applications of industrial enzymes (Sarrouh et al. 2012).

16.2 Objective

Scientific vision and deep scientific understanding are the veritable pillars of this widely observed study on industrial enzymes and environmental protection. Environmental regulations and concerns for ecological biodiversity are revolutionizing the scientific fabric of environmental engineering science and protection of environment (Sarrouh et al. 2012). Technology and engineering need to be readdressed and rebuilt as human civilization and human scientific research pursuit plunges into the deep depths of scientific cognizance and scientific validation. Enzyme engineering stands tall in the midst of scientific vision and deep scientific fortitude. Enzyme acts as a catalyst in many biochemical processes. The scientific endeavour has crossed all scientific frontiers and scientific sagacity (Sarrouh et al. 2012). Science and engineering are today surpassing wide and vast visionary boundaries. Enzyme engineering and science are gaining new heights as vision and scientific rejuvenation enters into a new age. In this chapter, the author mainly focuses on the wide and vast applications of industrial enzymes, mainly its realization of water treatment

applications and emancipation of environmental sustainability. Success of human scientific endeavour in environmental protection is in a dismal state. Environmental catastrophes and groundwater contamination are immense burden towards the scientific and academic endeavour. Environmental calamities are a bane towards human scientific and academic rigour. Such situation has directed the scientific community to dive deep into the murky depths of the science of groundwater remediation along with enzyme engineering. Enzyme science and biotechnology are the next-generation scientific research pursuit. The primary aim and objective of the treatise is to bring forward to the reader the wide scientific panorama of enzyme engineering particularly industrial enzymes. The challenges of science and engineering of enzymes are immense and far-reaching and are opening new doors of innovation in years to come (Sarrouh et al. 2012).

16.3 Scope

Biotechnology and enzyme engineering are in today's human scientific progress moving through aisles and avenues of scientific vision and scientific hindrances. The wide scope of this study goes beyond scientific imagination and scientific adjudication. Environmental pollution control today stands in the crossroads of immense difficulties, catastrophe and deep scientific understanding. Environmental engineering today is in a state of immense disaster and in veritable catastrophe (Sarrouh et al. 2012). Environmental regulations and stringent restrictions have directed the scientific community to gear forward towards innovations and scientific excellence. In such a critical juncture of scientific history, scientific vision and time, the scope of biotechnology, enzyme engineering and environmental science goes beyond hindrances and scientific frontiers. In this treatise, the author reiterates the synergy between enzyme engineering, industrial enzymes and environmental engineering science. Technology is today highly strained due to frequent environmental disasters (Sarrouh et al. 2012); thus there is a need of alternate technologies other than environmental engineering tools. Industrial enzymes can be a veritable tool towards environmental pollution control. The scope of scientific endeavour in industrial enzymes is immensely wide and far-reaching. Environmental engineering needs to be re-adjudicated and re-envisaged with respect to zero-discharge norms and water reuse. The challenge, the vision and the struggles of science are today replete with immense hurdles as environmental engineering moves from one difficulty towards another. The scientific ingenuity in environmental pollution control needs to be widely revisited as regards wastewater treatment and drinking water treatment. This treatise reviews the success of enzyme engineering tools in environmental protection. Scientific vision, scientific ingenuity and vast scientific profundity are the forerunners towards zero-discharge norms in environmental engineering (Sarrouh et al. 2012).

16.4 Scientific Doctrine Behind Industrial Enzymes

Industrial enzymes and its vast applications are today challenging the wide scientific firmament and the scientific domain. Biotechnology and enzyme engineering are changing the global scientific landscape. In this section, the author deeply comprehends the wide success of industrial enzyme application, the doctrine behind it and the vast scientific understanding behind enzyme engineering. Technology of enzyme engineering and biotechnology are highly challenged as engineering science moves from one barrier over another. Human mankind's immense scientific ingenuity and girth, technological motivation and scientific validation will go a long and effective way in the true emancipation of sustainability today. Global environmental sustainability is today linked with scientific endeavour in basic sciences such as enzyme engineering and biotechnology. This synergy between environmental sustainability and industrial enzyme application is opening up new doors of innovation and scientific instinct in decades to come (Weiss et al. 2013).

16.4.1 What Are Enzymes?

Enzymes are macromolecular catalysts. Enzymes enhances and catalyses chemical reactions (Sarrouh et al. 2012). The molecules at the beginning of the process upon which enzymes may act are called substrates, and the enzyme converts these into different molecules called products. Technology and engineering science of enzyme engineering and biotechnology are today in the verge of vast scientific rejuvenation and scientific understanding. Enzymes are the catalysts for the future, and enzyme engineering today stands as a veritable pillar of deep scientific discernment and scientific wisdom (Sarrouh et al. 2012; Weiss et al. 2013). Enzymes are protein molecules which work as catalysts (Sarrouh et al. 2012). Enzymes enhances chemical reactions in the body, but are not used up in the process. Almost all biochemical reactions in living things in human mankind need enzymes (Sarrouh et al. 2012). With an enzyme, chemical reactions go much faster. The substances at the beginning of the reaction are called substrates. The substrates at the end of the reaction are the products. Enzymes turn them into products (Sarrouh et al. 2012). Technology is highly challenged today with the progress of scientific rigour. In this chapter, the author deeply elucidates the immense scientific success and the vast scientific potential of enzymes in industrial application with a clear objective of greater realization of science and technology (Sarrouh et al. 2012; Weiss et al. 2013). Enzymes are made of large molecules from many amino acids. Technology and intricacies of enzyme chemistry are challenging the future trends of research. The deep scientific vision, the scientific adjudication and the futuristic vision of enzyme engineering will surely open up new chapter in the field of biochemical engineering and biotechnology today (Sarrouh et al. 2012; Weiss et al. 2013).

16.4.2 What Are Industrial Enzymes?

Enzymes are biological molecules that enhance chemical reactions (Weiss et al. 2013). In enzymatic reactions, the molecules at the beginning of the process, called the substrates, are converted into different molecules called products. Since enzymes are highly selective for their substrates and speed up only a few reactions from among many different possibilities, the set of enzymes made in a cell determines which metabolic pathways occur in that cell. Science of industrial enzymes is highly advanced today and replete with deep scientific vision and scientific understanding. Like all catalysts, enzymes lower the activation energy for a reaction, thus increasing the rate of reaction. As a result, products are formed faster and reactions quickly reach their state of equilibrium. The enzyme industry is the result of a rapid development seen primarily over the past four decades, thanks to the ever-growing and promising development of modern biotechnology and biological sciences. The majority of currently used industrial enzymes are hydrolytic in action. Various carbohydrates, primarily amylases and cellulases, represent the largest group (Weiss et al. 2013). The chemical process industries, dominated by the detergent, starch, textile and fuel alcohol industries, account for the vital consumption of industrial enzymes. Deep scientific discernment, the challenges of scientific innovation and the vision of science are the forerunners towards the larger aeon of research pursuit in enzymes (Weiss et al. 2013).

16.4.3 What Are Food Enzymes?

Science and technology are moving towards a visionary realm at a drastic pace surpassing scientific frontiers. Food provision and provision of pure drinking water are major components towards the success of human civilization and human scientific progress today. Food and water securities are the grave concerns of human civilization and human scientific endeavour. Enzyme engineering is a challenging domain of engineering science and scientific research endeavour today. The crisis and catastrophe of water science and technology needs to be reorganized and re-envisaged with the passage of scientific history and time (Sarrouh et al. 2012; Jube and Borthakur 2006). Plant enzymes can increase the digestion of food and the delivery of nutrients to the blood even if you have a challenged digestive system (Sarrouh et al. 2012). Technological vision, scientific motivation and the wide vision of engineering science will all lead a long and effective way in the true realization of scientific truth behind enzyme engineering today (Sarrouh et al. 2012; Weiss et al. 2013). Enzymes are present in all living animal and plant cells. Three broad classifications of enzymes are:

1. Food enzymes (Sarrouh et al. 2012; Weiss et al. 2013)
2. Digestive enzymes (Sarrouh et al. 2012; Weiss et al. 2013)
3. Metabolic enzymes (Sarrouh et al. 2012; Khan et al. 2009;Jube and Borthakur 2006)

Food is possibly the area where chemical processing has the deepest and visionary roots. Technology and science of enzymes are the torchbearers towards a greater realization of scientific vision in today's research pursuit. Human civilization's immense scientific grit and determination, the vast technological vision and the scientific excellence will all lead a long and visionary way in the true realization of applied science of enzymes today. Process improvement or design and implementation of novel approaches will be veritably performed and more so in recent years. The author discussed the scope of harnessing for more efficient biocatalysts, through screening, structural modification and immobilization of enzymes. Food processing through the use of biological agents is historically a visionary approach. Scientific vision, vast technological validation and the marvels of enzyme science are the pallbearers towards a newer visionary aisle of scientific research today.

16.4.4 Scientific Doctrine and Scientific Cognizance in the Domain of Industrial Enzymes

Technological and scientific profundity and validation are today forerunners towards a newer era in human civilization and human scientific rejuvenation. Industrial enzymes and its applications are challenging the entire scientific landscape (Sarrouh et al. 2012). Scientific vision, scientific adjudication and fortitude are the utmost needs of research forays and research emancipation. Industrialists were among the first to recognize and vastly exploit the great potential of enzymes, for they realized if reactions could be speeded up, or production processes could be performed in lesser time, or at lower temperature or pressures, using cheaper starting materials (Sarrouh et al. 2012). Biotechnologists and biochemical engineers are immensely contributing towards the true realization of enzyme engineering in human society. Scientific ardour and vast scientific emancipation are the necessities towards a greater scientific cognizance of enzyme science in this century. In this chapter, the author pointedly focuses on the deep scientific vision and scientific introspection in the field of enzyme engineering with the sole purpose of furtherance of science (Sarrouh et al. 2012; Shannon et al. 2008).

16.5 Industrial and Analytical Applications of Enzymes and Future Perspective

Scientific wisdom and scientific cognizance are the forerunners of cutting edge research in enzyme science today. Validation of science and scientific motivation are the future challenges of science and technology. Human mankind's vast emancipation in the science of biotechnology, scientific and technological prowess and the wide futuristic vision will all go a long and effective way in changing the scientific landscape and scientific ingenuity. Technological and scientific validations are the backbones and veritable supports of today's scientific endeavour. Human civilization's immense scientific and engineering prowess, the vision and challenge

of science and the futuristic vision of biotechnology and enzyme engineering are the forerunners towards the true emancipation of science today. Scientific excellence, scientific ingenuity and wide scientific understanding are the forerunners towards a greater visionary future in biotechnology, bioengineering, enzyme engineering, industrial enzyme applications and biological sciences (Khan et al. 2009).

16.6 Biocatalysis, Industrial Enzymes and the Visionary Future

Biocatalysis can be broadly defined and envisioned as the use of biological molecules (usually enzymes) to catalyse specific chemical reactions. Enzymes are complex protein molecules and are produced by living organisms to catalyse the biochemical reactions required for life. Although enzymes are formed within living cells, they can continue to function in vitro, and their ability to perform very specific transformations is making them increasingly useful and important in industrial processes (Sarrouh et al. 2012; Khan et al. 2009). Science and engineering of enzymes are overpowering vast and versatile visionary scientific frontiers. Technological vision and scientific fortitude are the need of the hour in the futuristic vision of enzyme engineering and chemical process engineering. Human scientific research pursuit in biotechnology and enzyme science is today encompassed with deep scientific vision and scientific discernment. Biocatalysis is a major segment of biotechnology. Biotechnology is defined by the European Federation of Biotechnology as "the integration of natural sciences and organisms, cells, parts thereof, and molecular analogues for products and services" which can be translated to "a technology which employs practical applications of living organisms or the components of living organisms"(Sarrouh et al. 2012; Khan et al. 2009; Weiss et al. 2013). Technology is so far-reaching and groundbreaking in today's world of scientific regeneration. Human mankind's immense scientific prowess, technological profundity and the wide futuristic vision will all lead a long and visionary way in the wide emancipation of enzyme engineering (Sarrouh et al. 2012; Khan et al. 2009).

Biocatalysis can be broadly defined as the use of enzymes to catalyse specific chemical reactions (Sarrouh et al. 2012; Khan et al. 2009). Enzymes are complex protein molecules. The wide world of science and engineering are slowly evolving into new dimensions of scientific thought and scientific regeneration. Scientific progeny and scientific destiny are assuming immense importance as human civilization and human scientific research pursuit attains new dimensions of scientific vision. Although enzymes are formed within living cells, they continue to function in vitro (in the test tube), and their ability to perform very specific chemical transformations is making them increasingly pivotal and important in industrial processes (Sarrouh et al. 2012; Khan et al. 2009). Most of us use biocatalysis around the home often without realizing. Technology and engineering are moving from one visionary direction towards another. In this chapter, the author deeply elucidates the immense scientific potential, the wide vision and the deep scientific forbearance behind enzyme engineering applications. In the past, many sectors of the chemical

process industry were more restrained in embracing this technology, largely because enzymes were perceived as being too delicate to survive the extreme conditions in the reaction vessels. Engineering science, enzyme engineering and bioengineering are gaining new dimensions as science moves from one revolutionizing paradigm over another (Sarrouh et al. 2012; Khan et al. 2009; Weiss et al. 2013).

16.7 Up-To-Date Insight on Industrial Enzyme Applications

Industrial and household catalysis today involves more and more dependence on enzymes. This is absolutely not surprising since enzymes are able to catalyse all kinds of chemical reactions. The wide vision of enzyme science, the futuristic scientific endeavour and the fruits of industrial enzyme applications will lead a long and effective way in the true visionary emancipation of biotechnology today (Sarrouh et al. 2012). Today, enzyme engineering is surpassing feasible visionary frontiers. Technology needs to be restructured and redefined as industrial enzymes gain newer heights (Sarrouh et al. 2012). Global enzyme engineering scenario is far-reaching and needs to be restructured and revamped with the progress of scientific rigour. Technological vision, scientific rigour and the futuristic vision will be the pallbearers in the true emancipation of environmental engineering science. Human mankind is in a state of immense scientific regeneration today. The global water scenario is totally grave and needs attention. Groundwater arsenic and heavy metal contamination has devastated the scientific landscape (Sarrouh et al. 2012). Technology is baffled and science retrogressive with the passage of history and time. The global scenario in enzyme engineering and biotechnology is wide and bright. Industrial catalysis can perform conversions in minutes or even seconds, which would take hundreds of years without their interference. Furthermore, they catalyse reactions, which are difficult to perform by chemical methods (Khan et al. 2009; Weiss et al. 2013). Since all these features are generally displayed at room temperature under mostly in aqueous conditions, the research towards the use of biocatalysts is mainly driven by the necessity of using varied sustainable technologies for the production of chemicals through green routes and complex active ingredients in a pharmaceutical and agro-biochemical context (Khan et al. 2009). Science and vision in the field of biochemical engineering, bioengineering and biotechnology are gaining wide heights and surpassing feasible frontiers with the passage of history and time (Khan et al. 2009; Weiss et al. 2013).

There is a present-day concept of “white biotechnology” which remains a challenge since new biocatalytic processes have to compete economically with the well-established chemical processes that have been optimized for years (Sarrouh et al. 2012; Khan et al. 2009; Jube and Borthakur 2006; Weiss et al. 2013). Although many complicated chemical reactions can be efficiently performed by biocatalysts, industrial conditions are usually different from those in nature with respect to substrate concentrations, shearing forces, temperature and organic solvents. Therefore, most enzymes found in soil and water may display the desired activity, but are generally not suited for industrial use. Engineering science of biotechnology is

complicated and needs to be reframed. Today's revolutionary technology is the world of biotechnology and enzyme engineering (Sarrouh et al. 2012; Weiss et al. 2013). Science of biotechnology, enzyme engineering and bioengineering are vast and versatile. Scientific vision, scientific cognizance and scientific profundity are the today's forerunners towards a greater realization of enzyme engineering science in decades to come (Khan et al. 2009; Jube and Borthakur 2006).

Nanoscience and nanotechnology are revolutionary areas of science today. This scientific paradigm needs to be re-envisioned and revamped with the passage of history, scientific fortitude and time. Nanotechnology has begun to find potential and promising applications in the area of functional foods opening up a whole new domain of research and development initiatives. Nanotechnology used in food can be classified into four broad areas:

1. Agriculture: Nanocapsules for delivery of pesticides, fertilizers and other agrichemicals more efficiently, nanosensors for monitoring soil conditions, nanochips for identity preservation and nanosensors for detection of animal and plant pathogens (Weiss et al. 2013)
2. Food processing: Nanocapsules to improve bioavailability of nutraceuticals, nanoencapsulated flavour enhancers, nanoparticles as gelation agents and nanoemulsions and particles for better availability and dispersion of nutrients (Weiss et al. 2013)
3. Food packaging: Antibodies attached to fluorescent nanoparticles to detect chemicals or food-borne pathogens, biodegradable nanosensors, nanoclays and nanofilms (Weiss et al. 2013)
4. Supplements: Nanosize powders to increase absorption of nutrients, cellulose nanocrystal composites as drug carrier and nanoencapsulation of nutraceuticals (Weiss et al. 2013)

Weiss et al. (2013) discussed with cogent insight nanotechnology in the food industry. The challenge and the vision of science today go beyond scientific imagination and instinct. Scientific foresight, sagacity and scientific doctrine of nanotechnology are the pallbearers towards a newer era of enzyme engineering. Extreme surface-to-volume ratios of the particles are characteristic of nanoscaled materials (Weiss et al. 2013). The wide vision of engineering science, the scientific grit and determination and the immense success of scientific research pursuit are the pallbearers towards a newer doctrine of food nanotechnology today. The surface-to-volume ratio is the basis of the special applications and also the cause of the possible risks with nanomaterials. This present overview deals lucidly with the four main areas of use in the food industry: packaging, process technology, microbiology and ingredients. Scientific vision of food nanotechnology is highly advanced today. Technology validation, the scientific girth and scientific truth are the forerunners towards a wider scientific approach of nanotechnology in present-day human civilization (Weiss et al. 2013).

16.8 Industrial Enzymes: Classification and Selection Criteria

The role of enzymes in many processes has been known for a long period of time. Their existence was associated with the history of ancient Greece where they are extensively using enzymes from microorganisms in baking, brewing, alcohol production, cheese making, etc. With intense and deep scientific knowledge and understanding in purification of enzymes, the number of applications has increased manifold, and with the availability of thermostable enzymes, a number of new possibilities for industrial processes have emerged. Technological vision, the wide scientific objectives and validation and the futuristic vision of enzyme engineering will all lead a long and visionary way in the true realization of biotechnology and true emancipation of enzyme engineering in decades to come. Technology and science of human mankind are torchbearers towards a greater visionary scientific understanding today. In such a critical juncture of scientific history, human history and visionary time, the world of biotechnology and bioengineering needs to be reframed. The International Union of Biochemistry and Molecular Biology (IUBMB) classified enzymes into six major groups (classes), according to the type of reaction they catalyse (Khan et al. 2009; Weiss et al. 2013).

1. Oxidoreductases: All enzymes catalysing oxidoreduction reactions belong to this class. The substrate that is oxidized is regarded as hydrogen donor (Sarrouh et al. 2012; Weiss et al. 2013).
2. Transferase: Transferases are enzymes which transfer a group, e.g. a methyl group or a glycosyl group, from one compound (generally regarded as donor) to another compound (generally regarded as acceptor) (Weiss et al. 2013).
3. Hydrolases: These enzymes catalyse the hydrolytic cleavage of C-O, C-N, C-C and some other bonds, including phosphoric anhydride bonds (Weiss et al. 2013).
4. Lyases: Lyases are enzymes cleaving C-C, C-O, C-N and other bonds by elimination, leaving double bonds or rings or conversely adding groups to double bonds (Khan et al. 2009; Whitehurst and Oort 2010).
5. Isomerases: These enzymes catalyse geometric or structural changes within one molecule (Weiss et al. 2013).
6. Ligases: These are enzymes that catalyse the joining together of two molecules coupled with the hydrolysis of a diphosphate bond in ATP or a similar triphosphate (Weiss et al. 2013).

Each enzyme described receives a classification number, known as “EC”(enzyme commission of the IUBMB), which is composed of four digits:

1. Class
2. Subclass within the class
3. Specific chemical groups that participate in the reaction
4. The enzyme itself

16.9 Genetically Engineered Enzymes

The wide and significant progress in genetics and process engineering enables the enzyme industry to offer products with improved properties and often at reduced costs. A research endeavour claimed that genetic engineering enables us to select host organisms and cultivation conditions that are safe to the manufacturing personnel, to the user of the product and to the environment at large. The vast challenges and the vision of science in biotechnology are changing the wide scientific landscape. Scientific and technological profundities of human scientific endeavour are veritably challenging the scientific scenario. In this chapter, the author rigorously points out the unique emancipation of enzyme engineering as a whole. Science and technology of genetic engineering are huge pillars with a definite and wide vision of its own. Technology needs to be reframed and re-envisioned with the course of history, scientific profundity and time. The challenge, the success and the scientific pinnacles are the forerunners of scientific success and scientific regeneration. Human mankind is in the path of new scientific rejuvenation and scientific vision. Genetic engineering today is witnessing drastic changes and the global water issues are linked to the progress of enzyme engineering, biotechnology and genetic engineering. Human mankind today stands in the midst of immense scientific ingenuity and deep adjudication. Scientific temperament and scientific candour should be enhanced today in view of the global water needs. Heavy metal groundwater contamination is challenging the wide scientific fabric. Genetically engineered enzymes need to be re-envisioned and revamped with the march of human civilization and human mankind.

16.10 Industrial Enzymes: Production and Application and the Wide Vision of the Future

Industrial enzymes are extensively produced by fermentation using microorganisms such as bacteria or fungi under carefully controlled conditions. Scientific vision and scientific profundity are of utmost importance in scientific endeavour today. Human mankind's immense scientific prowess is in a state of deep scientific rejuvenation and scientific truth. Today science and engineering of industrial enzymes are surpassing wide and vast scientific frontiers. Biotechnology, bioengineering and enzyme engineering need to be re-envisioned and redefined with each step of scientific history and time. In practice, the great majority of microbial enzymes come from a very limited number of genera, of which *Aspergillus* species, *Trichoderma* species, *Bacillus* species and *Kluyveromyces* species predominate (Weiss et al. 2013). Most of the strains used have either been employed by the food industry for many years or have been derived from such strains by mutation and selection. Technology and science of bioengineering and its futuristic vision are the torchbearers towards a greater emancipation of biotechnology today.

Most of the highly used microorganisms have been genetically modified to overproduce the desired activity and not to produce undesired side activities.

Technological motivation, scientific validation and deep scientific vision are the pallbearers towards a greater realization of biotechnology today. Science and engineering are moving from one paradigm towards another in today's world. Enzyme engineering and biotechnology are the revolutionizing domains of science and engineering.

16.11 Vision of Science and Scientific Understanding of Global Food Engineering Applications

Global environmental protection today stands in the midst of scientific vision and scientific fortitude. Environmental engineering needs to be reorganized as human scientific endeavour moves from one paradigmatic shift towards another. The challenge is immense and goes beyond scientific imagination and scientific truth. In this chapter, the author rigorously points out the immense scientific needs and the scientific vision behind industrial enzyme application. Global environmental protection today is linked with global water crisis. Heavy metal groundwater contamination today is in a state of immense scientific disaster. Science has few answers to the global groundwater contamination issue. This chapter gives a wider overview on the scientific success and the scientific destiny of global groundwater remediation issue. Global food engineering applications and global water research and development initiatives today stand in the midst of deep scientific introspection and vast insight. Human scientific vision and sagacity in heavy metal water decontamination are the challenges of science and technology today. Technology and engineering science of food engineering applications and water challenges are restructuring the vast scientific landscape. In this chapter, the author rigorously points out towards the scientific success, the deep scientific profundity and the foresight in enzyme applications in human endeavour. The challenge goes beyond vast scientific ingenuity and technological truth as science and engineering move towards a newer era.

16.12 Frontiers of Enzyme Science and Engineering

Enzyme engineering is surpassing visionary frontiers as scientific vision and scientific fortitude assume greater heights. Biotechnology and enzyme engineering are witnessing a new era in the field of science and technology. Technology is veritably challenged as enzyme engineering gains newer dimensions. Science and engineering are visionary pillars with a vast and definite vision of its own. In this chapter, the author rigorously points out the immense potential, the wide vision and the success of enzyme engineering in environmental protection. Global environmental engineering issues and global water shortage problems are today challenging the entire scientific landscape and plunging the scientific domain towards the murky depths of introspection and validation. Global water issues and global energy issues are the vexing problems of our present-day human civilization. Technology and science are in a state of immense scientific struggle and scientific adjudication. Frontiers of

science and engineering such as enzyme engineering and biotechnology are witnessing a new era in the field of scientific vision and scientific profundity. The frontiers of enzyme engineering need to be more targeted towards the science of environmental engineering, water use and reuse, water pollution and industrial pollution control. Environmental engineering also involves groundwater heavy metal remediation and provision of clean drinking water. Human needs such as water and power are of utmost importance with the progress of scientific and academic rigour. Biotechnology needs to be re-enshrined and readdressed as regards biological treatment of industrial wastewater. In this chapter, the author repeatedly urges upon the success and scientific potential of industrial enzymes in treatment of industrial wastewater. Scientific frontiers and scientific validation are the pillars of future endeavour in biotechnology and enzyme engineering.

16.13 Frontiers of Biotechnology and Deep Scientific Understanding

Frontiers of the science and engineering of biotechnology are veritably surpassing visionary boundaries. The vision behind biotechnology and enzyme engineering is immense and groundbreaking. Technology needs to be readdressed and re-envisaged as human scientific research pursuit evolves into a new age of science and engineering. In this treatise, the author rigorously points out the immense potential and immense present-day success in industrial enzyme application in environmental engineering science. Scientific understanding and wide scientific vision are the pillars of this treatise. Biotechnology is today moving towards visionary directions. The frontiers of biotechnology today are the science of genetic engineering. Global water research and development initiative today stand in the midst of immense vision and comprehension. Heavy metal and arsenic poisoning are a bane to human civilization. Technology of enzyme engineering needs to be restructured and revamped with the march of this scientific age. Arsenic drinking water poisoning is a pivotal issue in developing and developed countries around the world. Technology and science have veritably no answers to the burgeoning crisis of arsenic drinking water poisoning in South Asia mainly in Bangladesh and India. Scientific understanding and scientific sagacity are the necessary pillars of groundwater remediation today. Water disinfection, water desalination and water reuse should be the overarching goals of global water and bioengineering research and development initiatives. Biotechnology and bioengineering are the two opposite sides of the coin today. Frontiers of science and frontiers of biotechnology are today replete with vision of science and its challenges and academic rigour. The world of environmental engineering today is involved in immense catastrophe and unimaginable environmental disasters. Industrial wastewater purification is at a state of deep crisis. In such a vexing situation, global water scientific forays and bioengineering assume immense importance.

16.14 Recent Scientific Advancements in the Area of Industrial and Food Enzymes

Scientific advancements and scientific enrichment are the visionary orders of today. Application of industrial enzymes has revolutionized the scientific fabric and the wide scientific arena. Technological vision, scientific objectives and the wide scientific barriers will all lead a visionary way in the true emancipation of enzyme engineering and biotechnology today. Alcade et al. (2006) discussed with deep far-sightedness environmental biocatalysis. Modern biocatalysis is developing new techniques to improve a wide range of enzymatic processes, which effectively reduce energy and raw material consumption and generate less toxic by-products. The challenge of human scientific endeavour lies in the hands of environmental engineers and scientists. Biocatalysis is also achieving new advances in environmental engineering fields from enzymatic bioremediation to the synthesis of renewable and clean energies (Alcade et al. 2006). Technological advancements are moving from one challenging paradigm over another. In this chapter, the author deeply ponders over the immense scientific potential, scientific girth and scientific determination in the pursuit of science of biocatalysis (Alcade et al. 2006). Technology and science of enzyme engineering are the frontier areas of scientific endeavour today. Human mankind's immense scientific girth and determination and a scientist's definite vision will go a long and visionary way in the true realization of enzyme engineering science today. Modern biocatalysis is developing new and innovative tools to improve a wide range of production processes, which reduce energy and raw material consumption and generate less toxic industrial wastes (Alcade et al. 2006). Biocatalysis is evolving into new dimensions of scientific research pursuit and a new era of scientific regeneration and vision. Biocatalysis is also advancing towards enzymatic bioremediation and the synthesis of renewable and clean energies and biochemical cleaning of dirty fossil fuels (Alcade et al. 2006). This treatise discusses these widespread issues, pointedly focusing on new advances in recombinant DNA techniques for future biocatalyst development, as well as resulting in furtherance of science and engineering of industrial enzymes (Alcade et al. 2006). Environmental biocatalysis is the other scientific pillar and scientific pinnacle of this treatise. Advances in both catalysis and biocatalysis are determinant in reducing the environmental footprint of chemical engineering and petroleum-based techniques. Scientific vision and scientific cognizance are the forerunners of biocatalysis applications today. In the 1970s the main scientific vision was towards white biotechnology. Slowly green chemistry grew its momentum and biotechnology became a part and parcel of green chemistry. Scientific vision, sustainability science and holistic green chemistry are the torchbearers towards an effective green chemistry today. Environmental biocatalysis and environmental microbiology are the other two vast areas of scientific research pursuit today. Human civilization is witnessing immense challenges as regards biotechnology and genetic engineering (Alcade et al. 2006).

Here comes the question of green chemistry and sustainable engineering. Green chemistry is defined as the development and application of chemical processes and

products to reduce or eliminate the use and generation of substances hazardous to human health and the human environment. Technological challenges are far-reaching as scientific endeavour moves forward. Biocatalysis constitute a sustainable alternative to conventional organic synthesis, offering appropriate and relevant tools for the industrial transformation of natural or synthetic materials under mild reaction condition and low-energy requirements. Alcade et al. (2006) deeply comprehended these vexing issues of environmental sustainability and the progress of endeavour associated with it. The authors touched upon bioremediation of recalcitrant compounds, microbial bioremediation and the applications of enzymes for clean energy production. The science of bioremediation is of immense importance with the progress of scientific and academic rigour. This chapter deeply discusses the wide and vast scientific rigour in the field of bioremediation (Alcade et al. 2006). Ruggaber and Talley (2006) deeply discussed the issue of enhancing bioremediation with enzymatic processes in a well-researched review. The use of extracellular enzymes has been a standard in many industries for many years; only recently, they have been applied for bioremediation of recalcitrant substances (Ruggaber and Talley 2006). Technology of bioremediation assumes immense importance with the progress of scientific and academic rigour. Research forays demonstrate the immense importance of enzymes in bioremediation. The authors in this paper widely delineate the immense scientific potential, the scientific cognizance and the success of science of bioremediation (Ruggaber and Talley 2006).

Enzymatic processes encompass two traditional categories of chemical and biological treatment systems since they widely involve chemical reactions based on the action of biological catalysts. The vision and challenge of enzyme engineering are today opening new doors of deep scientific ingenuity (Ruggaber and Talley 2006). Kumar et al. (2014) delineated lucidly global market scenario of industrial enzymes. The vision of enzyme engineering and biotechnology is opening up new dimensions of scientific research trends. Enzymes are known to be effective biocatalysts for a wide range of applications (Kumar et al. 2014). Scientific vision is challenged today in the field of bioengineering, bioprocess engineering and the vast world of biotechnology. The applicability of biocatalysts as technical and feed enzymes totally revolutionized the global market scenario. The scenario needs to be readdressed with the passage of history and time. This chapter gives a wide overview of enzymatic applications of different classes in multiple industries with exploring the present and future research trends. Scientific profundity, scientific girth and scientific cognizance are the challenges in the field of enzyme engineering. Current applications are focused on three different markets including food processing and beverages and animal feed industry. This chapter touches upon technological improvements and the growing demand of application of industrial enzymes (Kumar et al. 2014). The authors also ponder upon the ever-growing concern for environmental protection and the increasing applicability of industrial enzymes. Binod et al. (2013) reviewed industrial enzymes and the present and future perspectives of its application in India. Enzyme technology is witnessing drastic and dramatic challenges and is a well-established branch of biochemical science. The challenge and vision lie in its phase of maturation and deep evolution. This

paper delineates the status of research and development in enzyme research and the future research trends. The authors also deliberated on the commercialization of industrial enzyme application. Enzymes involved in biotransformation are also discussed in lucid details in this paper. The authors also touched upon biotechnological innovation, commercial processes, the global market of industrial enzymes, research and development initiatives in India and the vital concept of SWOT analysis (Binod et al. 2013). Enzyme engineering is so advanced in the present century. Large-scale microbial production started in the 1960s. The industrial enzyme business is steadily increasing, thanks to improved production technologies, engineered enzyme properties and new application fields (Binod et al. 2013). Adrio and Demain (2014) discussed cogent insight microbial enzymes with special focus towards tools for biotechnological process. Industrial bioprocesses are the frontiers of biotechnology today. Scientific fortitude, scientific vision and scientific profundity are the veritable pillars of biotechnology and enzyme engineering today. Current applications are focused on many different markets including pulp and paper, leather, detergents and textiles, pharmaceuticals, chemical, food and beverages, biofuels, animal feed and personal care. More versatile enzymes are the utmost need of the hour for future scientific research pursuit. The authors deliberated on microbial enzymes with the pivotal role of furtherance of science of biotechnology. The technology is evolving into newer future directions and wider future research directions (Adrio and Demain 2014). The authors discussed enzyme discovering, metagenomic screening, microbial genomes, extremophiles and the effective strategies to improve properties of microbial enzymes (Adrio and Demain 2014). Kenealy and Jeffries (2003) discussed with deep insight enzyme techniques for pulp and paper in a review of recent developments in this field. Science and engineering of enzymes are surpassing visionary boundaries. In this review, the author gives insight into the immense success in the application of enzymes in pulp and paper domain (Kenealy and Jeffries 2003). The pulp and paper industry is applying novel, ecologically robust technologies in its manufacturing processes. Many interesting enzymatic applications have been widely researched in the literature. The vision of technology, scientific motivation and scientific determination are of utmost need as human civilization and human scientific endeavour moves towards a newer scientific paradigm. The authors reviewed in this paper new applications of enzymes in pulp and paper industry and how the new and innovative technology can be implemented to scientific endeavour. This review also deeply suggests how existing enzymes may be used by process engineers and chemical technologists to improve the unit operations and unit processes in pulp and paper manufacture. Biotechnology has huge scientific potential and deep scientific vision. It has the potential to increase the quality and supply of feedstocks for pulp and paper, reduce manufacturing costs and create novel high-value products. Science and engineering of enzymes are veritably ushering in a new era in scientific fortitude and deep scientific vision. Novel enzyme technologies can ameliorate environmental issues and further the cause of deep scientific emancipation in enzyme technology. Due to the pulp and paper industry being capital-intensive with facilities specific to the task, new and innovative technologies must either reduce expenses or enhance existing

process design. Science and engineering are two huge pillars with a definite vision of its own. The authors also touched upon environmental and manufacturing benefits, innovation and implementation in pulp and paper manufacturing processes. The treatise also delineates enzyme use in bleaching, xylanases in prebleaching, novel xylanases and also other enzymes in pulp bleaching (Kenealy and Jeffries 2003).

Eggleston (2007) delineated with deep scientific insight advances in the industrial application of enzymes on carbohydrate-based materials. Enzyme engineering and biotechnology are the frontiers of science and engineering today. Scientific wisdom and scientific discernment are the pillars and supports of scientific endeavour in enzymes and bioengineering today. This chapter reviews the new era of advances in the application of industrial enzymes on renewable carbohydrate materials, including mono-, di- and polysaccharides. Intense scientific research pursuit in the genetic engineering opens up new areas of scientific innovations. Technological and scientific endeavour are replete with immense scientific validation and deep scientific comprehension. In recent times, large-scale enzyme applications on carbohydrate materials are extensively researched and reported. The author in this paper widely reports the wide application domain of industrial enzymes, the industrial application and the visionary outlook as regards bioengineering industrial applications. Chemical process technology and biochemical engineering need to be readdressed and re-enshrined with each step of scientific history, scientific vision and time (Eggleston 2007). The author widely upholds the immense potential of biocatalysis with the visionary objective of the furtherance of engineering science. The advances in industrial enzymes particularly carbohydrate-based materials are discussed in minute details. The frontiers of enzyme engineering are today ushering in newer innovations and new dimensions in research trends. The paper reviews with immense scientific imagination the success of bioengineering and enzyme engineering with a wide view of emancipation of engineering science.

Enzyme Technical Association Report (2001) deals lucidly on enzymes as a primer on its use and benefits today and tomorrow. This treatise presents a detailed overview on what enzymes do, where they are used in products in day-to-day experience and how modern biotechnology is widely opening doors that will enhance the deep scientific comprehension in industrial enzyme applications. Technology of enzyme engineering is highly advanced and highly progressive. A deep insight into industrial enzyme applications has opened new dimensions of research trends in years to come. Also, the scope of the study also involves industrial applications encompassing energy. Energy sustainability and holistic sustainable development are the pillars of immense scientific endeavour. Technology and science of enzyme engineering need to be re-envisaged and readdressed as science and vision evolve into newer future directions (Enzyme Technical Association Report 2001). OECD Report (2001) comprehended deeply the application of biotechnology and industrial sustainability. Progress in engineering science and energy sustainability are the two opposite sides of the visionary coin. Technology needs to be restructured and re-envisioned as regards wider scientific emancipation of industrial sustainability, energy sustainability and also environmental sustainability. Biotechnology provides a wider view as a tool which adapts and modifies the biological

organisms, products, processes and systems found in nature. Science of sustainability is experiencing immense scientific regeneration and scientific innovation. The World Commission on Environment and Development defined "sustainable development as strategies and targets that have the objective of meeting the needs and aspirations of the present without compromising the ability to meet those of the future". The concept of sustainability was propounded by Dr. Gro Harlem Brundtland, former prime minister of Norway. Today the science of sustainability needs to be re-envisioned and revamped with the progress of scientific and academic rigour. The report also deeply elucidates on the interface of technology, cleaner production and sustainability. The treatise also describes the interface of biomimicry and biotechnology with the only vision of scientific comprehension and nature (OECD Report 2001). Lorenz and Eck (2005) deeply comprehended metagenomics and industrial applications. The authors discussed with deep foresight the industrial perspective in the application of enzymes and the wide emancipation in the field of biocatalysis. The authors delineated with immense scientific foresight the success and immense scientific potential of metagenomics. Scientific vision, scientific fortitude and deep scientific understanding are the forerunners towards a deeper emancipation of enzyme engineering and metagenomics (Lorenz and Eck 2005). Neujahr (1984) described with immense scientific insight biosensors for environmental pollution control. Biosensors have universal applications. The range of substances of interest and the enzymes or microorganisms may differ. Biosensors are analytical applications of biologically derived catalysts (Neujahr 1984). However, many of the biosensors that have been developed for fermentation or food industries, or for critical use, may be veritably used for environmental purposes. Science, technology and engineering are moving towards a newer visionary realm and a newer visionary future today. The status of environmental protection today stands in the midst of immense scientific prudence and deep scientific comprehension. The success of scientific endeavour, the technological wisdom and the wide futuristic vision are the forerunners towards the true emancipation of enzyme engineering science today. Biosensor application is the visionary target of scientific research pursuit today. The targets for the development of biosensors started in the 1960s. Engineering science and enzyme engineering paradigm are moving towards a newer age of scientific regeneration and scientific wisdom. Biotechnology and chemical process engineering are today ushering in a new age of scientific prudence and scientific profundity. The progress of human civilization, the vast scientific rigour and the scientific regeneration are today the forerunners of the wider emancipation of enzyme engineering and biotechnology. Technological validation and scientific motivation are the veritable pillars of scientific research pursuit in applied science today (Neujahr 1984). Enzyme engineering and biosensors are the newer avenues of applied science today. Thus biosensors and its application are the areas of utmost interest in the pursuit of science and engineering. Klos-Witkowska (2015) discussed with immense foresight enzyme-based fluorescent biosensors and their environmental, clinical and industrial applications. Biosensors are the next-generation science and the pillars of enzyme engineering science today. The challenges and the targets of scientific research pursuit in biosensors are the

forerunners towards a greater emancipation of enzyme engineering today (Klos-Witkowska 2015). Mankind's vast scientific girth and scientific determination will go an ideal and visionary way towards a true realization of engineering science in today's world. Enzyme-based fluorescent biosensors and their applications in environmental protection, medical science and chemical process industry are described in details. Technology is evolving into newer directions in future research. Biosensors used in environmental protection measure toxicity effects. The course of scientific discovery and scientific vision in biosensors and enzyme engineering is evolving into a new age of scientific truth and scientific judgement. Biosensors are classified according to the transduction method. In this paper, several methods for enzyme immobilization, mainly entrapment, adsorption, covalent immobilization, cross linking and affinity interaction, are described and re-envisioned, and the use of enzymatic fluorescence biosensors in the detection of analytes is presented in lucid details (Klos-Witkowska 2015). Rao and Gianfreda (2014) described in lucid details in a well-researched treatise enzymes in agricultural sciences. This book deals with several aspects on the role of enzymes in agricultural sciences such as soil biochemistry as influenced by intra- and extracellular enzymes, soil fertility, interactions between enzymes and pesticides and/or environmental pollutants, plant growth and processes at soil-plant interfaces. Deliberation in the field of soil enzymes is a part of this book. Soil enzymes assist all activities fundamental to agricultural sciences. Accurate methodologies are of immense importance in the pursuit of science in soil enzymes and agricultural paradigm. The scientific success, the wide vision and the definite scientific targets are the forerunners towards a greater visionary future in the field of soil enzymes. A section of the book also involves enzymes and soil fertility. Soil is an important resource in the agricultural production system, and measuring its fertility is a pivotal objective in the sustainability of ecosystems. Scientific vision, scientific candour and the wide scientific profundity are the salient points in the research endeavour in soil enzymes. Another chapter in this book deals with enzymes in plant growth. Science of enzymes is moving towards visionary directions (Rao and Gianfreda 2014). The success of technology and the futuristic vision of engineering science and applied science will veritably lead a long and effective way in the true realization and true application of enzyme engineering in agricultural sciences. Agricultural sciences and sustainability are the pillars of human scientific endeavour today. The editors of the book and the authors with deep scientific intellect present a wider scientific perspective in the field of enzyme engineering.

16.15 Technological Vision in Applications of Enzymes

Environmental engineering science is a vast and broad area of scientific research pursuit. Rapid loss of biodiversity and stringent environmental engineering restrictions has plunged the scientific domain towards newer technologies and newer innovations. The challenge and vision of enzyme engineering science are immense and path breaking. Scientific notions, scientific vision and scientific

Table 16.1 Visionary scientific endeavour in the field of industrial and food enzymes

Visionary scientific endeavour	References
Remediation, biocatalysis and green processes	Alcade et al. (2006)
A review on bioremediation with enzymatic processes	Ruggaber and Talley (2006)
Global market trends of industrial enzymes	Kumar et al. (2014)
Industrial enzymes – current status and future perspectives in Indian context	Binod et al. (2013)
Microbial enzymes as tools for biotechnological processes	Adrio and Demain (2014)
A review of recent developments in enzyme processes for pulp and paper	Kenealy and Jeffries (2003)
Advances in the industrial applications of enzymes	Eggleston (2007)
Uses and benefits of enzymes today or tomorrow	Enzyme Technical Association Report (2001)
Applications of biotechnology in industrial sustainability	OECD Report (2001)
Metagenomics and industrial applications	Lorenz and Eck (2005)
Insights into application of biosensors for environmental pollution control	Neujahr (1984)
Enzyme-based fluorescent biosensors for environmental pollution control and industrial applications	Klos-Witlkowska (2015)
Research work on the application of enzymes in agricultural sciences	Rao and Gianfreda (2014)

forbearance are today the pillars of wide scientific barriers. The technology of enzyme engineering science is today surpassing visionary frontiers. The vision of technology and deep scientific understanding are immense and groundbreaking. Human mankind's scientific endeavour, the deep scientific candour and the world of immense challenges are all the forerunners towards a greater scientific knowledge and greater realization of energy and environmental sustainability today. Technology and engineering science of biotechnology and enzyme engineering are gaining new and immense scientific heights. This treatise pointedly focuses on the vast environmental engineering applications of industrial enzymes with the sole and visionary aim of advancements of science and technology (Table 16.1).

16.16 Recent Scientific Endeavour in the Field of Biotechnology, Genetic Engineering and Enzymes

Recent research pursuit in the domain of biotechnology is changing the vast scientific scenario as science and technology evolve into a new paradigm of enzyme engineering and biotechnology. Biotechnology is a revolutionary domain of science and technology today. Technology is today a huge scientific pillar with a definite and strong vision of its own. The wide and innovative scientific pursuit needs to be redefined and restructured as science and engineering move towards a newer era of scientific vision and scientific fortitude. Petre (2012) in a well-researched book redefines and re-envisions the science of biotechnology. The treatise presents a

well-documented view on advances in applied biotechnology. The authors delved deep into the domains of biotechnology of agricultural wastes, microbial biotechnology, molecular biotechnology and genetic engineering and finally biotechnological applications of tissue engineering. Scientific vision and scientific ingenuity are the pillars and backbones of endeavour in science of biotechnology (Petre 2012). This book gives deep insights into the success of applied biotechnology with the sole aim of furtherance of science of enzymes. The overarching goal of this chapter is to address the deep and intricate issues of applied biotechnology. Scientific vision, mission and validation are of utmost importance in the avenues of science of biotechnology. The wide scientific wisdom and deliberations begin with biotechnology of agricultural wastes. The agricultural wastes recycling with applications in agro-food industry and food processing is one of the challenges and scientific hindrances of biological sciences and biotechnology. It is also one of the technically advanced research areas in the biotechnology domain known to human civilization so far. Accumulation of winery wastes and brewery wastes is of immense scientific concern to the future of environmental protection science. Many of these lignocellulosic wastes cause immense environmental pollution. Environmental science and bioengineering or biotechnology are today connected to each other by an umbilical cord (Petre 2012). Biotechnology is today emerging into a widely visionary frontier science. Waste food reuse is another giant footstep in this entire book. The success, the wide vision and the scientific potential of waste food reuse assume immense importance in the path of human civilization and possible scientific and academic rigour. Waste food reuse is a giant step in the scientific rigour with the sole and pivotal aim in progress of science and engineering. This book is a monumental piece of work targeting the applied science of biotechnology and bioengineering and also presenting the interfaces of recent advances in applied biotechnology. The other phenomenal areas of this work are green polymers and sustainability, bioprocess engineering, downstream processing, fermentation engineering and the wider holistic domain of food processing. Microbial biotechnology is the other visionary pillar of this well-researched and well-observed treatise (Petre 2012). Khan et al. (2009) discussed with lucid and deep insight recent advances in medicinal plant biotechnology. The challenge, the vision and the targets of science are slowly advancing in this chapter. Medicinal plants are the most important source of life-saving drugs for the progress of human civilization and human health (Khan et al. 2009). Technology is highly advanced and its vision deeply challenged. Plant secondary metabolites are veritably and economically important as drugs, fragrances, pigments, food additives and a wide range of pesticides. The biotechnological tools are immensely important to select, multiply, improve and analyse medicinal plants. It is widely estimated that 70–80% of people around the world rely chiefly on traditional, largely herbal, medicines to meet their health needs and primary healthcare imperatives. In this chapter, the author deeply ponders upon the scientific success, the insight and the scientific regeneration in the field of plant biotechnology. The immense global need for herbal medicine is not only vast but groundbreaking. Various scientific innovations have been adopted for increasing bioactive molecules in medicinal plants. Scientific vision and technological motivation are the immediate need of

the hour. Recent advances in plant biotechnology are surpassing visionary scientific frontiers. This treatise unfolds the scientific intricacies in the path towards scientific emancipation in biotechnology (Khan et al. 2009). Jube and Borthakur (2006) elucidated in deep details recent advances in food biotechnology research. The vision of technology and deep scientific profundity are the veritable pillars of this well-researched treatise. Modern biotechnology involves molecular techniques that improve commercial products and processes. Technology, engineering science and scientific vision are the pillars of human scientific endeavour. Biotechnology is a relatively new and rapidly evolving branch of molecular biology. The technique of biotechnology today is changing the way civilization progresses. Biotechnology vision, the challenges of research pursuit and the vast human intellectual prowess are all today leading towards true emancipation of science and engineering. In this treatise, the author pointedly focuses on the scientific success, scientific prowess and scientific forbearance behind biotechnology applications in human society. The applications of biotechnology have also enhanced other branches of scientific endeavour through the development of new detection procedures for early diagnosis of cancer, diabetes and Parkinson's and Alzheimer's disease. The author pointedly focuses on the immense success, the deep scientific revelation and the vast scientific pragmatism behind the world of biotechnology, enzyme engineering and biological science (Jube and Borthakur 2009). Khattak et al. (2012) deeply elucidated on the subject of genetic engineering in a well-researched review. The vast and versatile vision of science and engineering are challenging the scientific firmament today. Human mankind have been deeply pursuing genetic engineering, a visionary technology which is transforming the planet. The scientific success, the scientific brilliance and the vision of tomorrow's research pursuit will certainly lead a visionary way in the true emancipation of biotechnology today. To change the intricacies and parts of human genomes is to create some desired or beneficial trait in the science of genetic engineering. In this chapter, the author reiterates the scientific vision, the scientific fortitude and the vast scientific profundity behind genetic engineering (Khattak et al. 2012). Whitehurst and Oort (2010) in a comprehensive review elucidated on enzymes in food technology. The scientific vision, the potential and the deep revelation behind enzyme engineering are presented in this chapter in deep details. The authors touched upon protein engineering, production of industrial enzymes, enzymes in dairy industry, enzymes in bread making, enzymes in brewing, meat enzymes, enzymes in protein modification and the vast world of food enzymes. Technological challenges and the scientific far-sightedness are the scientific pillars and the scientific imperatives of modern science of biotechnology and enzyme engineering today. Enzyme engineering today is witnessing immense challenges in its application in food industry. Technological vision in enzyme engineering is highly advanced today. This facet of enzyme engineering is presented in deep details in this treatise. Enzymes are proteins that vastly enhance chemical reactions. This process is defined as catalysis. Scientific analysis and scientific profundity are at its best as the author analyses the intricacies of enzyme engineering. In enzymatic reactions, the molecules present at the start of the reaction are widely termed as substrates. In the nineteenth century, Pasteur studied the fermentation of sugar to

alcohol by yeast. Technology and its challenges had undergone vast changes since then. Nearing the end of nineteenth century, Kuhne first coined the word "enzyme" which comes from the Greek word "yeast", to describe the activity already started by Pasteur. Thus human civilization and human scientific endeavour are in the path of newer scientific rejuvenation (Whitehurst and Oort 2010). Enzymology is the pillar of biological sciences today. Any living cell inside human beings, animals, microorganisms, plants, etc. are the site of vast biological processes called metabolism. Enzymes have a wide variety of functions inside living organisms and human cells. They are veritably important for intracellular activity. The science of enzymes is thus wide and far-reaching. Enzyme reaction engineering is a basic and fundamental way of how enzyme binds substrates and carries out the enzyme catalysis. This chapter widely revisits the entire scientific canons of enzyme engineering specifically towards greater emancipation of science and technology (Table 16.1). The function of catalysts is to enhance a chemical reaction without becoming a part of reaction products. Enzyme engineering is the success of this century along with the science of biotechnology. They are highly specific, catalysing a single chemical reaction or many reactions. The challenge of science and engineering is thus vast and versatile. In this chapter, the author repeatedly urges the scientific candour and vast scientific sagacity in the research pursuit in enzyme science. Chemical kinetics of enzymes are today intricate and groundbreaking. This chapter broadly targets the scientific success and the scientific targets of enzyme engineering with a vast and versatile vision towards the future (Table 16.1).

16.17 Prospects in Enzyme Applications

The world of science and technology is gearing forward from one paradigmatic change towards another. Human scientific vision, revelation and scientific provenance are the forerunners towards a newer aeon in the field of enzyme applications. The challenge of science and technology needs to be re-envisioned and restructured with the passage of history and the visionary time frame. Science and technology of enzyme engineering and nanotechnology are highly advanced today. Industrial and food enzymes are the necessities of engineering and scientific advancement today. The vast prospects of enzyme applications are opening up new arenas of scientific research endeavour in present-day human civilization. Enzyme engineering and biotechnology are the immense scientific needs of this century. The domain of enzyme applications is robust and groundbreaking. Copeland (2000) deeply elucidated with deep and cogent insight structure, mechanism and data analysis of enzymes. The author in this treatise deeply comprehended history of enzymology, chemical bonds and reactions in biochemistry, structure of enzymes, kinetics of enzyme reactions, reversible inhibitors, time-independent inhibition and the vast domain of enzyme catalysis (Copeland 2000). Today, there are tremendous vision and future prospects of enzyme engineering. The vast and versatile domain of enzyme science and engineering is opening new doors of scientific innovation and research pursuit. Human society, human civilization and vast research endeavour are

ushering a newer domain in global scientific regeneration. Prospects, future scientific frontiers and futuristic vision are the needs of the civilization today. Enzyme engineering and biotechnology are the pillars and scientific imperatives of today (Palit 2017a, b).

16.18 Global Water Shortage Issues and the Application of Enzymes

Science and engineering are gearing forward from one paradigm towards another. The vision of technology and scientific objectives are changing the scientific scenario and the scientific vision. Global water research and development initiatives are challenging the wide scientific firmament. The diverse domains of science and technology are revolutionizing the whole world of scientific candour and scientific sagacity (Palit 2017a, b). Enzyme engineering, environmental engineering and chemical process engineering are veritably changing the vast scientific landscape and opening up new windows of scientific regeneration in the coming decades. Technology is immensely challenged, and science veritably strained as global water crisis and water shortage devastates the scientific horizon and the panorama (Shannon et al. 2008). In this chapter, the authors rigorously points out towards the immense success and veritable potential in tackling issues in enzyme engineering and the holistic world of environmental protection. Enzyme engineering and the science of biotechnology are changing the scientific landscape and ushering in a new aeon of scientific rejuvenation (Palit 2017a, b). Global water shortage issues have plundered the scientific fabric and have challenged the intricate water research and development initiatives. Heavy metal groundwater contamination is a veritable bane towards human scientific endeavour (Shannon et al. 2008). This avenue of science needs to be widely pursued with utmost need (Palit 2015, 2016a, b). Heavy metal and arsenic drinking water contamination are the veritable challenges of our times and the present-day human civilization. Both developed and developing countries worldwide are in the difficult scientific quagmire of challenge and vision. Water science and water process engineering are the futuristic vision of tomorrow (Table 16.1).

16.19 Future Research Trends and Future Scientific Frontiers

Human civilization and human scientific endeavour today stands in the midst of scientific comprehension, vision and fortitude. Technological objectives and scientific motivation are today in a state of deep revamping. Enzyme engineering and chemical process engineering are in the road towards immense advancement and scientific instinct. The question of environmental protection and groundwater decontamination is of immense importance in the path towards scientific vision. The future research trends need to be streamlined towards application of industrial enzymes in environmental protection and wide scientific research pursuit. Human mankind's

scientific girth and determination and scientific progress are the forerunners towards a greater visionary era. In this chapter, the author pointedly focuses on the success and scientific ingenuity of industrial enzymes and biotechnology as a whole. Vision of science and deep introspection are of utmost need in the future scientific research pursuit (Palit 2015, 2016a, b). Technology and science are moving rapidly from one challenging paradigm to another. Enzyme engineering, biotechnology and chemical process technology are the pillars of scientific endeavour today. Scientific and technological validation, immense scientific prowess of human civilization and academic rigour of science will all lead towards the true emancipation of enzyme engineering today. The future research trends should be targeted towards global water challenges, bioremediation and groundwater heavy metal remediation. Science and technology of enzyme engineering should be re-enshrined and envisaged with the progress of human civilization and the academic rigour (Palit 2017a, b).

16.20 Conclusion and Scientific Perspectives

Enzyme engineering and the science of biotechnology are surpassing one visionary boundary over another. Technology today stands in between scientific vision and scientific sagacity. Enzyme engineering and biotechnology are the frontier science of tomorrow. The vision of technology, scientific motivation and deep scientific cognizance are the forerunners towards a greater understanding of science of biotechnology and enzyme engineering today. Scientific perspectives and environmental engineering frontiers are veritably groundbreaking today as science and technology enter a newer aeon. Catalysis and chemical reaction engineering today are in the midst of immense scientific regeneration. The sagacity of enzyme engineering science needs to be envisioned and addressed as human civilization and human scientific research pursuit reaches visionary realm and surpasses scientific frontiers. Biotechnology and genetic engineering are the wide visionary domains of science today. The prowess of human scientific endeavour, the greatness of human scientific and academic rigour and the wide future trends will all lead a visionary way in the true emancipation of enzyme engineering and biotechnology today. Environmental protection and industrial wastewater treatment are two major vexing domains of scientific research today. The challenge and the vision of industrial enzyme applications are groundbreaking and need to be envisioned and envisaged with the passage of history and time. The author in this treatise rigorously points out the vast scientific potential and scientific rigour in the field of industrial enzymes and the large visionary domain of biotechnology. Environmental pollution control and enzyme engineering are today's relevant branches of engineering and science which have to be veritably addressed as grave concerns for the protection of environment assume immense importance. This chapter is a wide eye-opener towards the vision and discernment in the field of enzyme engineering. Enzyme engineering and biotechnology thus will witness immense revamping and challenges in decades to come.

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