Review Article

Trends in Biotechnology and Ties with Chemical Engineering

Seyed Nezameddin Ashrafizadeh*, Zahra Seifollahi

Research Lab for Advanced Separation Processes, Department of Chemical Engineering, Iran University of Science and Technology, Narmak, Tehran 16846-13144, Iran.

***Corresponding author:** Seyed Nezameddin Ashrafizadeh, Research Lab for Advanced Separation Processes, Department of Chemical Engineering, Iran University of Science and Technology, Narmak, Tehran 16846-13144, Iran.

Received: 29 November 2021; **Accepted:** 06 December 2021; **Published:** 09 December 2021.

Citation: Ashrafizadeh SN, Seifollahi Z. Trends in Biotechnology and Ties with Chemical Engineering. Journal of Biotechnology and Biomedicine 4 (2021): 169-186.

Abstract

Biotechnology is a broad field that deals with the exploitation of living organisms to develop products beneficial for sustainable development. Biotechnology develops cellular and molecular processes to produce products and technologies that can help improve human life. This technology has a variety of applications that play a major role in human well-being. In this article, after defining and describing biotechnology and providing a brief review of the history of this technology, its important and effective applications are addressed and eminent recent publications have been thoroughly reviewed. Explaining the relationship between biotechnology and other scientific disciplines, especially chemical engineering, has been one of the objectives of this article. In addition, according to the authors' approach regarding the familiarity of the student community with this technology, present article has been written with fluent composition and avoidance of expressing specialized details.

Keywords: Biotechnology; Biofuels; Biology; Biopharmacy; Chemical Engineering; Genetics

1. Introduction

The word biotechnology is formed from the two words of living (meaning life or living system) and technology. Biotechnology has been constantly advancing in recent years. The field of biotechnology deals with applying scientific and engineering principles in the production or conversion of some materials with the help of biological agents (microorganisms, plant and animal cells, enzymes, etc.). In this way, goods and services in agriculture and animal husbandry (such as improving the quality of plants and animals), food, pharmaceutical, medical and other industries are provided. The breadth and diversity of biotechnology applications has made its definition and description a bit difficult and varied. Some consider it synonymous with industrial microbiology and the use of microorganisms, while some define it as equivalent to genetic engineering [1]. Some other sources provide a broader definition of biotechnology and refer to it as applied biology [2]. Biotechnology comes from sharing the sciences of chemistry, biology and engineering. Figure 1 shows a schematic view of this concept.

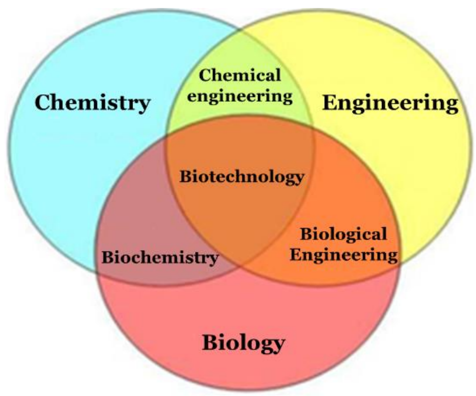

Figure 1: Biotechnology related sciences

Compared to biology, molecular biology, genetics, chemical engineering or biochemistry, biotechnology is not a basic or applied science whose scope can be easily defined. Biotechnology includes common fields of different sciences that have been created by the overlap and intersection of these sciences with each other. Biotechnology can be likened to a tree whose roots are rooted in ancient sciences such as biology, especially molecular biology, genetics, microbiology, biochemistry, immunology, chemistry, chemical engineering, botany, zoology, pharmacology, computer, etc. The branches of this tree, which are more or less newly grown, and each time with their growth create more sub-branches, are very numerous and diverse. In fact, the branches of this tree represent different technologies and applications that arise from its roots and trunk [3].

The division of biotechnology into different branches also differs according to the views of different experts and scientists, and in the most common classification, they use the intersection and connection of different sciences with biotechnology and thus name a branch of biotechnology. Two instances are medical biotechnology, which arose from the sharing of biotechnology with medical science, and agricultural biotechnology, which shows the application of biotechnology in agriculture. Thus, we can name pharmaceutical biotechnology, microbial biotechnology, marine biotechnology, forensic biotechnology, environmental biotechnology, food biotechnology, bioinformatics, industrial biotechnology, oil biotechnology, diagnostic biotechnology, etc. [4]. In fact, biotechnology requires a wide range of engineering knowledge and basic sciences. The prerequisites and outputs of this technology are schematically shown in Figure 2 [3].

Due to the great impact of biotechnology on human well-being, most believe that this science will be one of the most powerful tools for human existence in the near future. Today, the scope of biotechnology activity is very wide and includes the diagnosis, prevention and treatment of diseases to the production of new chemicals and drugs, new food sources, environmental protection, energy conservation, etc. [3].

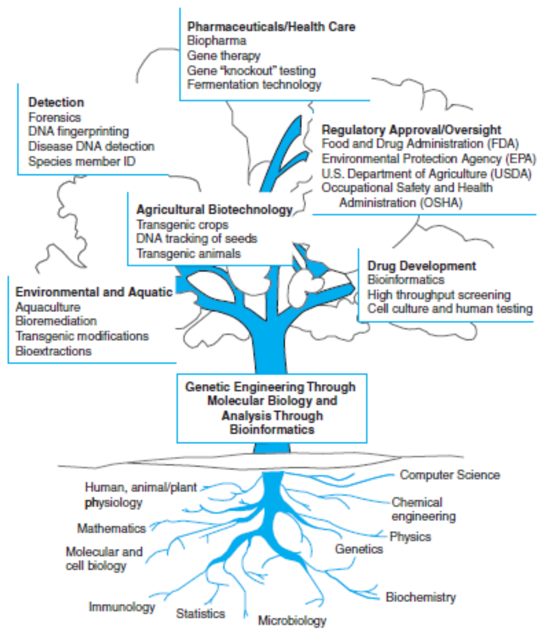

Figure 2: Diagram of requirements and outputs of the biotechnology industry [3].

2. History

The term biotechnology was first coined in 1919 by Karal Ereky, a Hungarian engineer, to mean the application of biological sciences and their interactions in man-made technologies. He is known by some as the father of biotechnology [4]. Biotechnology is not a new development, and studies by microbiologists over more than a hundred years have shown that there is a very close vital link between humans and microbes that can be both beneficial and harmful. But using this science to develop and improve human food resources is a new achievement that has just been proposed and scientists have entered a competition with each other in this field. The history of using microorganisms to produce food items such as beer, vinegar, yogurt and cheese dates back to more than a thousand years ago, but the mechanism of production of these products was unknown to anyone [5]. Observing the fact that sour milk has a much better storage capacity, man soon realized that by adding a small amount of sour milk the day before to fresh milk, he could begin the fermentation process. Ethanol was the first chemical to be produced biotechnologically to increase the alcohol content of wine and beer. Apart from distillation, biotechnology changed little from the Christian era to the first of the twentieth century, and like the advancement of other sciences, the advancement of this technology was motivated by war [1,6].

The development of biotechnology can be divided into five periods [7,8]:

- **Pre-Pasteur period, before 1865**
  The products of this period are alcoholic beverages and dairy products such as cheese and other fermented derivatives.
- **Pastor Period, 1865-1940**
  Production of ethanol, butanol, acetone, glycerol, organic acids such as citric acid and aerobic wastewater treatment are the achievements of this period.
- **Antibiotic Period, 1940-1960**
  Production of penicillin (immersion fermentation technology), various antibiotics, animal cell building technology, viral vaccines and microbial steroid transfer are some of the achievements of this course.
- **Post-Antibiotic Period, 1960-1975**
  Amino acids, protozoan proteins, enzymes, cell technology and fixed enzymes (glucose isomerization), anaerobic wastewater treatment, and bacterial polysaccharides are the results of this course.
- **New biotechnology period, years after 1975**
  The results of this course are: hybridoma technology (monoclonal antibodies), genetic engineering, production of human growth hormone, production of insulin, production of skin growth factor and etc.

The main techniques that have given rise to modern biotechnology are [9, 10]:

- Genetic engineering: This method involves changing the nature of a living genetic material and inserting it into the host organism to change its nature.
- Biochemical engineering: This technique involves maintaining the sterile conditions of optimal microorganisms in biotechnological processes to receive products such as enzymes, hormones, antibiotics, vaccines, and drugs.

The world has entered modern biotechnology with new applications of biotechnology from traditional biotechnology [11]. In the last century, due to the uncontrolled increase in population and the need for food supply, agricultural biotechnology has received special attention. High-yielding and hardy transgenic crops such as corn, rice, soybeans, tomatoes and wheat have been produced, and new biotechnological techniques have been effective in increasing milk and cattle production. The application of biotechnology in the 21st century is so great that it will have a profound impact on the economy, health, environment, education, agriculture, industry, nutrition, and other aspects of human life. For this reason, some thinkers in the world have called the 21st century the century of biotechnology [12].

3. Applications of Biotechnology

The applications of biotechnology are so wide that they affect almost all aspects of human life. It is predicted that in the near future, a word bio or biotech will be added to most of the common science and technology branches, which indicates the effect of this science on those disciplines [4,13].

The use of biotechnology has expanded in various sectors such as industry, agriculture, environment and medicine. In fact, biotechnology can be used not only in fields related to living organisms, but also in all activities that use living organisms or biological compounds to improve the quality of a product [14].

A number of terms have been coined to identify branches of biotechnology:

- Green biotechnology: This technology is used in agricultural processes.
- Red biotechnology: This technology is used in medical applications.
- Blue biotechnology: This is a term used to describe the aquatic and marine applications of biotechnology.
- White biotechnology: This technology is used in industrial processes [11].

In the following, various applications of biotechnology in the production of products are presented [14].

3.1. Medical biotechnology

Medical biotechnology involves the use of living cells and other cellular compounds to improve human health. Basically, biotechnology is used to find treatments to treat or prevent disease. This science includes the use of research tools to find different or effective ways to maintain human health, identify pathogens and understand the biology of human cells [15]. The following are some examples of important achievements of biotechnology in the medical sciences, which have created or will bring about great changes in various areas of human life [16].

3.1.1. Genetic diagnosis and gene therapy

Many scholars refer to the present century as the century of genetic engineering and molecular biotechnology. Genetic engineering with many applications as one of the most prominent signs of progress in the present age and one of the tools and branches of biotechnology, tries not to limit the realm of life to the current boundaries but expand these boundaries with new methods to solve human problems.

The process of identifying suspected genetic defects before starting treatment and using genetic testing is called genetic diagnosis. Depending on the inherited patterns of a pathogenic gene, family members are advised to have genetic testing. Treatment plans are based on the findings of genetic tests that determine the type of disease. If the disease is caused by inherited gene mutations, other relatives are also advised to undergo genetic testing and periodic screening. According to many scientists, the birth of gene therapy in the early 1990s was a major and revolutionary event that created a new perspective in the field of molecular medicine; Because for the first time in the history of life sciences, the application of very sensitive and new methods and techniques to transfer healthy genes into the cells of the body and the correction and treatment of mutated and defective genes, a new window to serious, fundamental and causal struggle is open to many diseases. Gene therapy is the transfer of genetic material into the cells for therapeutic purposes in a variety of ways, i.e. physical, chemical, and biological.

The discovery of many important pathogenic genes in the near future, the use of diverse and unprecedented methods of genetic screening and very accurate predictions about the fate of the fetus in terms of genetic diseases before and after birth, are other capabilities of genetic engineering and gene therapy. Researchers have overcome many of the limitations of gene therapy through extensive research. Significant progress has also been made in the highly specific targeting of cells and the transfer of naked genes or DNA into them (as drugs)

[17,18]. Although gene therapy is currently a costly method that requires advanced and specialized techniques, it will soon be used for a wide range of diseases. There is also growing and promising evidence that the use of molecular medicine techniques will reduce treatment costs hundreds of times over in the not-too-distant future, compared to the current situation. The International Human Genome Project (IHGP) is one of the most important and massive biology research projects of the present age, which, by deciphering the human genome, has opened countless nodes and conquered many peaks. This project, which is the result of new advances and information of researchers in the field of genetic engineering, will bring about profound and unexpected developments in the medical sciences in the near future. The International Human Genome Project can be considered a turning point in the history of life sciences, especially genetic engineering and molecular biotechnology [19].

3.1.2. Identification of molecular mechanisms of cancer genesis

Today, through the use of genetic engineering and molecular biotechnology, the question of how cancer develops is no longer one of the unknown scientific mysteries. Over the past two decades, researchers have made stunning advances in identifying the molecular causes and stages of cancer using molecular methods and the achievements of the human genome decoding scheme. These advances will lead to revolutionary approaches to cancer treatment in the near future. Although no one is yet able to predict the exact time of the complete defeat of cancer, the outlook is very promising. In this regard, extensive efforts to treat cancer using gene therapy methods, e.g. such as the transfer of cancer-inhibiting genes into cells, are increasingly taking place. Inhibition of genes that are overgrown (such as activated oncogenes) and replacement of a defective or deleted gene are some of the strategies in this treatment. Recently, US researchers have developed a "smart" virus that could multiply inside cancer cells and kill all malignant cells in the body, but not harm healthy cells. The results of this new method have been successful in model mice and have been able to kill about 60% of cancer cells. Relying on the processes and capabilities of molecular biotechnology, a number of pharmaceutical companies around the world are working on the design of drugs and therapeutic agents with the aim of stopping the proliferative machine of cancer [20]. Undoubtedly, these studies, which in the near future will lead to useful results in the treatment of a number of human cancers, would not have been possible without the application of the principles and techniques of genetic engineering and biotechnology [21].

3.1.3. Cloning

Another very important topic in the field of genetic engineering and molecular biotechnology, which is closely related to the medical sciences and is likely to be the source of great developments in this field in the future, is the issue of cloning or asexual proliferation of cells; during which, by replicating from the adult cell of an organism, similar copies of the original organism are made. It is worth noting that the first human success in cloning an adult mammal (Dolly the sheep) was in 1996 by Ian Wilmot and his colleagues at the Russell Institute (Edinburgh, Scotland) by transferring the nucleus of a somatic cell into the cytoplasm of an oocyte whose nucleus had been removed was obtained (Figure 3) [3].

Figure 3: The first mammal produced by cloning [3].

3.2. Agricultural biotechnology

There are many constraints that severely affect global agricultural production and productivity. These factors include increasing rate of population growth, loss of natural resources, climate change and pests, which among them, biological limitations or known pests cause the loss of 25-50% or the entire plant production [22]. Scientific and research advances in the field of biotechnology in developed and developing countries indicate that in recent years, much attention has been paid, especially to the field of plant biotechnology. Increasing the tendency to use biotechnology to create food security for the growing population will be a good way to overcome poverty and hunger in the coming years. Since the Green Revolution and classical plant breeding methods alone cannot provide food security and overcome common problems in agriculture, the use of plant biotechnology to overcome production problems and barriers such as biological and non-biological stresses can be useful [23].

Agricultural biotechnology focuses on the production of genetically modified crops in order to increase crop yield or create beneficial properties in crops. For example, genetically modified plants can continue to grow in areas where there are stressors such as drought, specific climatic conditions, and the presence of pests, with the resistance and beneficial properties they have acquired during genetic modification; whereas in the past, without the use of genetic engineering techniques, the use of chemical pesticides was required to repel pests and make plants resistant to adverse environmental conditions; in this case, in addition to environmental hazards and soil and water pollution, these toxins remain stable in the plant. An example of the production of pest-resistant crops is a gene that is transmitted to crops by the bacterium Bacillus thuringiensis. The reason for using the bacterial gene is that the bacterium produces a toxic protein called Bt which is very effective against pests such as the European corn borer. Bt protein is a useful trait that scientists want to create in plants, so they identified the gene for Bt protein in bacteria and transferred it to the corn plant. In such a situation, corn can produce protein toxin naturally and by eliminating the cost of treating crops with pesticides, the production cost is reduced (Figure 4) [24].

In some cases, to produce plants with beneficial properties, scientists must find the desired trait in other plants, identify the gene that produced the trait and, through genetic engineering, insert it into the genome or cells of the plant. In this case, by transcribing the input gene in the plant cells, proteins to produce the desired trait are produced and the plant can have higher yields and resistance than before [25,26]. In a review study, the use of DNA and protein-based diagnostic methods in agricultural biotechnology was investigated [27].

Figure 4: Comparison of corn with Bt protein and natural corn that suffers from perforating pest [24].

3.3. Industrial biotechnology

Industrial applications of biotechnology range from the production of cellular structures to the production of biological elements for innumerable uses. In recent years, molecular biotechnology has found a unique place in various industries. Today, in some mines of the world, extraction and recycling of valuable minerals such as gold, silver, copper and uranium is done with the help of microorganisms and by bioleaching [28]. Industrial production of many organic acids such as citric, acetic and lactic acids, as well as the production of oils with special fatty acid compounds that have high value in the food industry and detergents, are other areas of biotechnology presence in industry. Production of biodegradable plastics, production of renewable energy using biomass, design and production of nanostructures such as biotransistors, biochips and protein polymers using protein engineering methods, production of fermented beverages, production of high performance detergents, production of personal healthcare with biological characteristics, preparation of breads using yeasts and biological enzymes, production of resistant fibers for military use (such as production of bulletproof vests from spider webs), and bio-assisted environmental cleanup are another new and valuable fields of biotechnology in industry and the environment [29,30]. For example, the laccase enzyme can be used in bioremediation to destroy plastic waste containing olefin units. This enzyme is also used in the food, the pulp and paper, and the textile industries [31-34]. Table 1 lists some of the enzymes and their industrial uses.

Enzyme	industry	application
Lipases	Food	Increases the taste of cheese [35]
Lipozyme *TL IM*	Food	Transparency of vegetable oil [36]
Amylase	Food/Biofuel	A group of enzymes that break down starch into glucose monomers [37]
Amidase	Chemical	A group of enzymes used to produce pure non-protein amino acids [38]
Laccases	Pulp and paper	Improving the quality of production paper [39]
Cellulase	Biofuel	A group of enzymes that break down cellulose into glucose monomers [40]

Table 1: Some enzymes and their industrial applications.

Another important application of biotechnology is wastewater treatment [41]. Indeed, biological methods play an important role in the removal of contaminants, including emerging methods, integrated biotreatment processes, and biosensors [42-44]. A review article on waste gas treatment biotechnology was written by Burgess et al. In this article, the progress made in the field of odor control was studied [45]. Biotechnology techniques can also be used to increase oil recovery and desulfurization of crude oil [46,47]. Bachmann et al. conducted a review study on biotechnology in the petroleum industry [48].

3.4. Marine biotechnology

Marine biotechnology is a growing field of technology that uses organisms such as fish, algae, or bacteria directly and indirectly. In fact, marine biotechnology is a type of biotechnology that explores and exploits aquatic organisms to produce new products. One of the most important benefits of marine biotechnology can be the production of new and improved products; provide new techniques for tracking, assessing, storing, protecting and managing marine ecosystems as well as sustainable and safe fisheries and aquaculture. Also, marine animals and plants are the source of unique compounds that have industrial potential in areas such as the production of pharmaceuticals, cosmetics, food additives, molecular probes, enzymes, special chemicals and chemicals used in agriculture [49,50]. In the book of "Handbook of Marine Macroalgae: Biotechnology and Applied Phycology" the properties of seaweed materials, source species, types, production and applications have been expressed [51]. Freitas and colleagues reviewed advances in marine biotechnology to produce new functional foods containing marine ingredients [52]. Furthermore, marine sources such as algae can be a potential and reliable biomass source and produce a plethora of biofuels including biodiesel, biogas, biomethane, biobutanol, bioethanol, syngas, bio-oil, etc. A basic summary of the production of biofuels from marine algae sources through biotechnological advances is provided in a book written by Hossain et al [53].

4. Biotechnology and Chemical Engineering

This section describes several terms related to biotechnology in relation to engineering sciences, especially chemical engineering.

a. Bioengineering

A general term includes measures taken by medical and agricultural systems specialists in the fields of chemical engineering, electronics, mechanics, industry, and the environment. Biological engineering is a term similar to bioengineering [54].

b. Bioprocess engineering

Bioprocess engineering is the application of engineering rules to the design, development, and analysis of processes in which biocatalysts are used. These processes may lead to the formation of desirable compounds or the removal of undesirable substances. Engineering sciences, especially chemical engineering, are essential for the successful exploitation of bioprocesses [55,56].

c. Chemical bioengineering

Biochemical engineering is the application of chemical engineering to perform that group of chemical processes in which biological catalysts are used. Biochemical engineering is often divided into two subgroups: bioreaction engineering and bioseparation engineering [57].

d. Biomedical engineering

Although biomedical engineering is considered as a separate branch of biochemical engineering, the boundary between the two is not completely clear. The field of biomedical engineering is animal cell culture and cell surface receptors [58].

4.1. Bioseparation

Biochemical products always need to be separated and purified after production. Biochemical separation processes are often much more difficult and costly than their production process. Based on experience, the following four steps can be considered for most separations [59]:

a. Removing insoluble components

Filtration, centrifugation and cell disintegration are the main units of this section. In this step, a little concentration is done and as a result, there is a slight improvement in the quality of the products [60].

b. Separation of products

At this stage, significant concentration takes place and as a result, a relative improvement in product quality is achieved. Adsorption and solvent extraction are among the operations used in this section [61].

c. Purification

The techniques used in this step have a high selectivity towards the products and remove impurities with similar physical and chemical properties. Chromatography, electrophoresis, precipitation and ultrafiltration are good examples of these processes [62].

d. Finishing

The polishing step is the final separation step that involves processes such as crystallization and drying [63,64].

4.2. Biological reaction

In the process of bioreaction, feed or substrate is consumed and by the activity of a microorganism or catalytic components of organisms (such as enzymes) reaction products are produced. Substrates needed for cell survival include carbon sources such as sugar and oil, nitrogen sources such as ammonia and amino acids, and electron receptors such as O_2. In addition, bioactive products can include a variety of organic compounds, biomass and CO_2. To achieve the optimal reaction rate, it is necessary to know the mechanism and manner of mass transfer in the processes of transfer of substrate to the surface of the enzyme or cell and transfer of products from the surface of the enzyme or organism to the reaction medium. Bioreactor and biocatalytic engineering is a prerequisite for a biological reaction process [65,66].

4.3. Some applications of biotechnology in chemical engineering

4.3.1. Application of biological processes in gas sweetening

So far, a variety of biological processes for sour gas sweetening containing the acidic compounds of H_2S and CO_2 have been identified, although a limited number of these methods are used on an industrial scale. Biological processes take place at ambient temperature and pressure, and thus energy consumption is minimized. The relatively high costs of providing chemicals, catalysts, and waste disposal related to conventional physicochemical processes have been eliminated in biological processes.

Conventional physicochemical technologies for the removal of sulfur compounds from sour gas at capacities of less than 100 Million Standard Cubic Feet Per Day (MSCFD) for the amine process and 5 MSCFD for the reduction oxidation process are not economically viable. Therefore, the gas refining industry is looking for new, biocompatible and simple technology that can be used for small volumes of gas produced. Common biological processes are of two types [67]:

- Indirect biological treatment processes

In the indirect method, the sulfur species is first converted to sulfur by the catalyst, and then the catalyst is recycled by bacteria and microorganisms (such as microorganisms such as thiobacillus ferroxidan) using air. In this case, the process, in addition to being safer, requires less energy and, as a result, the process is more economical.

- Direct biological treatment processes

In these processes, Thiobacillus bacteria oxidize sulfur species as a source of energy. The oxidation reaction takes place in the presence of the following compounds:

Final electron receiver such as NO_3^-;

Source of carbon such as carbon dioxide in gas streams or HCO_3^- present in the culture medium;

NH_4^+ as a source of reduced nitrogen [68].

4.3.2. Biological treatment of soil

One of the main problems facing the industrial world today is the pollution of soils, sediments and surface and groundwater. The most common contaminants are chlorinated solvents, hydrocarbons, polychlorinated biphenyls, and metals. Biological treatment is the use of microorganisms to reduce or detoxify contaminants. Bioremediation technology is basically based on biodegradation. Bacteria, fungi and plants are usually involved in reducing or eliminating toxic contaminants [69,70]. Biological treatment processes try to accelerate the deformation or natural decomposition of chemical compounds by providing the nutrients needed by bacteria and other limiting factors. This method is common in the case of hydrocarbon pollutions [71,72]. The basis of the biological treatment process is the use of petroleum hydrocarbons as a source of carbon and energy [69].

4.3.3. Biological treatment of water

Bacteria that use these substances as an energy source are used to remove organic matter from the water. This can be done aerobically or anaerobically:

- Aerobic purification

"Aerobic" is a process in which there is oxygen. In this method, the water to be treated is sent to an aeration tank where the organic matter in it is oxidized to carbon dioxide, nitrate and phosphate by aerobic bacteria [73].

Dissolved Organic Matter+O_2 → New Biomass+CO_2+HNO_3+H_3PO_4

- Anaerobic treatment and production of biogas

Anaerobic conversion of organic compounds to biogas is a multi-step process in which different groups of bacteria are involved in reducing the substrate:

Hydrolytic Acidogens bacteria convert polymers into short-chain fatty acids.

Syntrophic Acetogens convert fatty acids to acetate and H_2.

Mathanogens bacteria convert acetate and H_2 to CH_4 and CO_2 (biogas) [74, 75].

4.3.4. Microbial corrosion

Microbial corrosion is a form of galvanic corrosion in which galvanic cells are formed based on differences in oxygen concentration. For example, consider the sediment created in cold water pipes. Sediment may contain corrosive products and various particles and mineral shells, etc.

These materials are often adhered to the metal surface by microbiological sludge. Cold water does not come into direct contact with the metal parts under the scale, but must penetrate the scale. Oxygen dissolved in water under sediment is completely consumed by metal reactions with sediment. The non-precipitated metal comes in direct contact with water and acts as a cathode because the cathode is where oxygen is reduced. On the other hand, the surface of the metal under the deposit where the oxygen concentration is low or zero becomes anode, because the anode is where iron is oxidized and dissolved. Thus, the formation of corrosion cavities begins. Corrosion products such as iron oxide also increase the amount of scale and increase the rate of corrosion. Such corrosion cells form wherever there is stagnation or poor water flow in the system [76]. If the system is microbially active, biological substances called bilayers are formed. Biomass is an interconnected set of microbial cells that encapsulate in extracellular polymer molds and act as adhesives, adhering the scale to the metal surface. In this way, anaerobic bacteria can grow under favorable conditions for sediment production.

Many types of anaerobic bacteria produce organic acids themselves as part of metabolic processes. These bacteria are called acid-producing bacteria. Under the influence of acid production process, the pH of the water in the sediment decreases and as a result, the corrosion rate of the cavities under the sediment increases. Anaerobic bacteria obtain the oxygen they need by reducing oxygenated compounds and ions in the water. For example, sulfate-reducing bacteria, known as SRBs, reduce sulfate ions. Reduction of sulfate ions by SRB is a complex process that produces a variety of sulfate-containing compounds. The final product that causes corrosion is sulfide. Sulfide reacts with hydrogen ions in water to form the corrosive acid H2S [77]. The prevention operation of microbial corrosion can be chemical, biochemical or biological, which includes washing, adding oxidizing and non-oxidizing microbiocides and cultivating SRB-killing bacteria, etc. [78,79].

4.3.5. Fermentation

Fermentation is derived from the Latin word fervere, meaning boiling, because yeast produces CO2 gas by anaerobic fermentation of sugars by culturing on fruit and sprouted seeds, which is emitted from the extract and is similar to fermentation [80]. According to biochemists, fermentation is an exothermic process that results from the metabolism of sugars, and the organic matter in it acts as an electron donor or electron acceptor. According to the industrial microbiologist, the concept of fermentation is more general and refers to any process that is performed to produce biological products using microorganisms on an industrial scale [81-83]. The five groups of fermented products are:

- Biomass

Such as bread yeast and protozoan protein [84].

- Enzymes

The most important sources for enzymes are microbial, plant and animal sources. Microbial sources have an advantage due to their high production efficiency and simplicity. Enzymes with animal sources can be produced in microbes and stimulants and inhibitors can be used [85].

- Metabolites

These products are obtained from the biological activity of microorganisms, which are divided into two categories:

- Primary metabolites

These metabolites which are produced in the growth stage and are essential for cell growth, include amino acids, proteins, nucleotides, lipids and carbohydrates, ethanol, citric acid, glutamic acid, lysine, polysaccharide, vitamins, and phenylalanine, etc.

- Secondary metabolites

These metabolites are not produced in the growth phase, but in the dormancy phase. They are important in their antimicrobial properties, enzyme inhibitors and growth promoters. Types of antibiotics fall into this category [86].

- Recombinant products

The genes of higher organisms can be transferred to host microorganisms such as Escherichia coli, and products such as insulin, interferon, albumin, coagulation factor eight, skin growth factor, calf chymosin, and bovine somatostatin can be produced [87].

- Products from biotransmission

Microbial cells can be used to convert a compound to another due to its high catalytic power at low temperatures and pressures. Biomodifications are: dehydrogenation, oxidation, isomerization, amination, deamination, etc. Products in this category include the production of vinegar from alcohol, fructose syrups, steroids, etc. [88,89].

4.3.6. Biofuels

Biofuel production is one of the largest applications of biotechnology in the field of energy production. Given the concerns about declining global oil resources and the environmental impact associated with them, finding an alternative environmentally friendly fuel source can prevent a leading energy crisis. Biotechnology, with advances such as the use of corn to produce combustible fuels for car engines, makes it possible to use clean alternatives to fossil fuels. These fuels are environmentally friendly because they do not produce greenhouse gases [90].

5. Conclusions and Outlook

Biotechnology is a broad technology that has been introduced in various industrial fields using basic sciences and engineering and the role of chemical engineering in it is very significant. Certainly, the applications of this technology in various industries such as medicine, pharmaceuticals, agriculture, environment, oil and gas, etc. are much wider than can be included in this brief. In developing countries, despite the significant expansion of scientific and research activities in academic departments and research centers, unfortunately, we have not yet witnessed a broad and comprehensive change in industrial sector that reflects the approach of the country's industry to this advanced technology. Meanwhile, according to a market forecast report, biopharmacy segment dominated the overall biotechnology market demand, accounting for more than 50% market share in 2018 [91].

Increasing usage of bio-recombinant proteins in several vaccines used to treat chronic and infectious diseases is anticipated to foster the biopharmacy market growth. Growing incidence of chronic ailments such as diabetes and cancer worldwide will primarily upsurge the market demand for biotechnology products over the forecast timeframe. Thus, increasing prevalence of such chronic diseases, owing to various factors including lifestyle changes, stress and unhealthy dietary patterns, will drive the demand for effective drugs and vaccines, thus boosting the industry progress over the forecast period. Moreover, wide-ranging applications of biotechnology, improving healthcare access in remote areas, unmet medical needs in certain geographies and growing R&D investment in the field are some of the other factors that will spur the market revenue. Furthermore, rising demand for bio-based agricultural products and growing adoption of biotechnology practices in clinical research will accelerate the market expansion. However, risks associated with genetic information may hinder industry growth to certain extent in the coming years. Also, widespread applications of tissue engineering and regeneration technology in the field of life science, forensic science and clinical research are expected to foster market growth.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest Disclosures

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The research council at Iran University of Science and Technology (IUST) is highly appreciated for its financial support during this research.

References

1. Bhatia S, Goli D. History, scope and development of biotechnology. Introd to Pharm Biotechnol (2018): 1-61.
2. Shuler M L, Kargi F. Bioprocess Engineering. 2th ed. Basic Concepts (2002).
3. Thieman WJ. Introduction to biotechnology. 4th ed. Pearson Education India (2009).
4. Gupta V. An introduction to biotechnology. In: Gupta V, Sengupta M, Prakash J, Tripathy B C, editors. Basic and Applied Aspects of Biotechnology, Springer (2017): 1-21.
5. Gupta V, Sengupta M, Prakash J, et al. Basic and Applied Aspects of Biotechnology. 1th ed. Springer (2017).
6. Verma AS, Agrahari S, Rastogi S, et al. Biotechnology in the realm of history. J Pharm Bioallied Sci 3 (2011): 321.
7. Ruyters G, Betzel C, Grimm D. Biotechnology, Cell Biology and Microgravity. In: Ruyters G, Betzel C, Grimm D. editors. Biotechnology in Space, Springer (2017): 1-10.
8. Bhatia S, Goli D. Introduction to Pharmaceutical Biotechnology. IOP science (2018).
9. Mosier NS, Ladisch MR. Modern Biotechnology. Wiley (2009).
10. Raju P. World history of modern biotechnology

and its applications. Biotechnol an Indian J 12 (2016): 107.

11. Fiechter A. History of modern biotechnology. Springer (2000).
12. Cantor CR. Biotechnology in the 21st century. Trends Biotechnol 18 (2000): 6-7.
13. Ratledge C, Kristiansen B. Basic biotechnology. Cambridge University Press (2001).
14. Demain AL. Reviews: The business of biotechnology. Ind Biotechnol 3 (2007): 269-283.
15. Pham PV. Medical biotechnology: techniques and applications. In: Debmalya B, Vasco A. editors. Omics Technologies and Bio-Engineering. Elsevier (2018): 449-469.
16. Sasson A. Medical biotechnology: Achievements, prospects and perceptions. United Nations University Press (2005).
17. Lian J, Wang Y, Luo Y, et al. Development and Application of Novel Genome Engineering Tools in Microbial Biotechnology. Front Bioeng Biotechnol 8 (2020): 1415.
18. Yang D, Hartman MR, Derrien TL, et al. DNA materials: bridging nanotechnology and biotechnology. Acc Chem Res 47 (2014): 1902-1911.
19. Zand M, Narasu M. A review article Biotechnology Applications in Medicine. Intl Res J Appl Basic Sci 4 (2013): 2557-2563.
20. Silva AC, Moreira JN, Lobo JMS, et al. Current Applications of Pharmaceutical Biotechnology. Springer (2020).
21. Imran A, Qamar HY, Qurban ALI, et al. Role of molecular biology in cancer treatment: A review article. Iran J Public Health 46 (2017): 1475.
22. Alemu M. Trend of Biotechnology Applications in Pest Management: A Review. Int J Appl Sci Biotechnol 8 (2020): 108-131.
23. Khan FF, Ahmad K, Ahmed A, et al. Applications Of Biotechnology In Agriculture-Review Article. World J Biol Biotechnol 2 (2017): 139-142.
24. Narva KE, Storer NP, Meade T. Discovery and Development of insect-resistant crops using genes from Bacillus thuringiensis. Adv. In Insect Phys 47 (2014): 177-247.
25. Hartley S, Gillund F, Hove LV, et al. Essential features of responsible governance of agricultural biotechnology. PLoS Biol 14 (2016): 1002453.
26. Zahry NR, Besley JC. Genetic engineering, genetic modification, or agricultural biotechnology: does the term matter?. J Risk Res 22 (2019): 16-31.
27. Alarcon CM, Shan G, Layton DT, et al. Application of DNA-and protein-based detection methods in agricultural biotechnology. J Agric Food Chem 67 (2018): 1019-1028.
28. Dunbar WS. Biotechnology and the mine of tomorrow. Trends Biotechnol 35 (2017): 79-89.
29. Primer S. The Application of Biotechnology to Industrial Sustainability–A Primer. Organ. Econ. Co-Operation Dev (2001).
30. Tang WL, Zhao H. Industrial biotechnology: tools and applications. Biotechnol J Healthc Nutr Technol 4 (2009): 1725-1739.
31. Senthivelan T, Kanagaraj J, Panda RC. Recent trends in fungal laccase for various industrial applications: an eco-friendly approach-a review. Biotechnol Bioprocess Eng 21 (2016): 19-38.
32. Bilal M, Rasheed T, Nabeel F, et al. Hazardous contaminants in the environment and their laccase-assisted degradation–a review. J Environ Manage 234 (2019): 253-264.
33. Patel N, Shahane S, Majumdar R, et al. Mode of action, properties, production, and application of laccase: a review. Recent Pat Biotechnol 13

(2019): 19-32.

34. Mate DM, Alcalde M. Laccase: a multi-purpose biocatalyst at the forefront ofbiotechnology. Microb Biotechnol 10 (2017): 1457-1467.
35. Houde A, Kademi A, Leblanc D. Lipases and their industrial applications. Appl Biochem Biotechnol 18 (2004): 155-170.
36. Compton DL, Laszlo JA, Eller FJ, et al. Purification of 1, 2-diacylglycerols from vegetable oils: Comparison of molecular distillation and liquid CO2 extraction. Ind Crops Prod 28 (2008): 113-121.
37. Van Der Maarel MJEC, Van der Veen B, Uitdehaag JCM , et al. Properties and applications of starch-converting enzymes of the α-amylase family. J Biotechnol 94 (2002): 137-155.
38. Martínez-Rodríguez S, Torres JM, Sánchez P, et al. Overview on Multienzymatic Cascades for the Production of Non-canonical α-Amino Acids. Front Bioeng Biotechnol 8 (2020): 887.
39. Shiroya AJ. Recent advances of laccase enzyme in industrial biotechnology: areview. Pharma News (2021).
40. Sun Y, Cheng J. Hydrolysis of lignocellulosic materials for ethanol production: a review. Bioresour Technol 83 (2002): 1-11.
41. Sadatshojaei E, Mowla D, Wood DA. Review of progress in microalgal biotechnology applied to wastewater treatment. Sustain Green Chem Process Their Allied Appl (2020): 539-557.
42. Yi H, Li M, Huo X, et al. Recent development of advanced biotechnology for wastewater treatment. Crit Rev Biotechnol 40 (2020): 99-118.
43. Okafor N, Okeke BC. Modern industrial microbiology and biotechnology. CRC Press (2017).
44. Surkatti R, El-Naas MH, Van Loosdrecht M, et al. Biotechnology for Gas-to-Liquid (GTL) Wastewater Treatment: A Review. Water 12 (2020): 2126.
45. Burgess JE, Parsons SA, Stuetz RM. Developments in odour control and waste gas treatment biotechnology: a review. Biotechnol Adv 19 (2001): 35-63.
46. Chen GQ. New challenges and opportunities for industrial biotechnology. Microb Cell Fact 11 (2012): 1-3.
47. Prajapat G, Rellegadla S, Jain S, et al. Application of Biotechnology in Oil and Gas Industries. In: Singh A, Srivastava Sh, Rathore D, Pant D. editors. Environmental Microbiology and Biotechnology, Springer (2021): 113-133.
48. Bachmann RT, Johnson AC, Edyvean RGJ. Biotechnology in the petroleum industry: an overview. Int Biodeterior Biodegradation 86 (2014): 225-237.
49. Kim SK. Springer Handbook of marine biotechnology. Springer (2015).
50. Trincone A. Enzymatic processes in marine biotechnology. Mar Drugs 15 (2017): 93.
51. Kim SK. Handbook of marine microalgae: Biotechnology advances. Academic Press (2015).
52. Freitas AC, Rodrigues D, Rocha-Santos TAP, et al. Marine biotechnology advances towards applications in new functional foods. Biotechnol Adv 30 (2012): 1506-1515.
53. Hossain J, Jahan R. Biofuel: Marine Biotechnology Securing Alternative Sources of Renewable Energy. In: Raju N, Cruzatty L C G, Chakraborty S. editors. Advances in the Domain of Environmental Biotechnology, Springer (2021): 161-194.
54. Kumar A, Srivastava A, Galaev IY, et al. Smart polymers: physical forms and bioengineering

applications. Prog Polym Sci 32 (2007): 1205-1237.
55. Barragán-Ocaña A, Silva-Borjas P, Olmos-Peña S, et al. Biotechnology and bioprocesses: Their contribution to sustainability. Processes 8 (2020): 436.
56. Koutinas M, Kiparissides A, Pistikopoulos EN, et al. Bioprocess systems engineering: transferring traditional process engineering principles to industrial biotechnology. Comput Struct Biotechnol J 3 (2012): e201210022.
57. Najafpour G. Biochemical engineering and biotechnology. 2th ed. Elsevier (2015).
58. Enderle J. Introduction to biomedical engineering. Academic press (2012).
59. Asenjo JA.Separation processes in biotechnology. CRC Press (2020).
60. Leung WWF. Centrifugal separations in biotechnology. Butterworth-Heinemann (2020).
61. Igwe J, Abia AA. A bioseparation process for removing heavy metals from waste water using biosorbents. African J Biotechnol 5 (2006): 1167-1179.
62. Harrison RG, Todd P, Rudge SR, et al. Bioseparations science and engineering. Oxford University Press, USA (2015).
63. Lightfoot EN, Moscariello JS. Bioseparations. Biotechnol Bioeng 87 (2004): 259-273.
64. Aires-Barros MR, Azevedo AM. Fundamentals of Biological Separation Processes. In: Pandey A, Teixeira J A C. editors. Current Developments in Biotechnology and Bioengineering. Elsevier (2017): 187-237.
65. Webb C, Atkinson B. The role of chemical engineering in biotechnology. Chem Eng J 50 (1992): 9-16.
66. Dunn IJ, Heinzle E, Ingham J, Prenosil JE. Biological reaction engineering. Wiley (2003).
67. Amirfakhri J, Vosoughi M, Soltanieh M. New method for natural gas sweetening by combination of biological method and seaboard process. Nashrieh Shimi Va Mohandesi Shimi Iran 25 (2006): 26-33.
68. Syed M, Soreanu G, Falletta P, et al. Removal of hydrogen sulfide from gas streams using biological processes a review. Can Biosyst Eng 48 (2006): 2.1-2.14.
69. Jain PK, Bajpai V. Biotechnology of bioremediation-a review. Int J Env Sci 3 (2012): 535-549.
70. Gu JD. On Environmental Biotechnology of Bioremediation. Appl Environ Biotechnol 5 (2021): 3-8.
71. Gong X, Huang D, Liu Y, et al. Remediation of contaminated soils by biotechnology with nanomaterials: bio-behavior, applications, and perspectives. Crit Rev Biotechnol 38 (2018): 455-468.
72. Agathos S, Reineke W. Biotechnology for the Environment: Soil Remediation. Springer Science & Business Media (2002).
73. Rittmann BE. Aerobic biological treatment. Water treatment processes. Environ Sci Technol 21 (1987): 128-136.
74. Anukam A, Mohammadi A, Naqvi M, et al. A review of the chemistry of anaerobic digestion: Methods of accelerating and optimizing process efficiency. Processes 7 (2019): 504.
75. Hendricks D. Fundamentals of water treatment unit processes: physical, chemical, and biological. Crc Press (2010).
76. Loto CA. Microbiological corrosion: mechanism, control and impact-a review. Int J Adv Manuf Technol 92 (2017): 4241-4252.

77. Yang F, Shi B, Bai Y, et al. Effect of sulfate on the transformation of corrosion scale composition and bacterial community in cast iron water distribution pipes. Water Res 59 (2014): 46-57.
78. Loto CA. Microbiological corrosion: mechanism, control and impact-a review. Int J Adv Manuf Technol 92 (2017): 4241-4252.
79. Kakooei S, Ismail MC, Ariwahjoedi B. Mechanisms of microbiologically influenced corrosion: a review. World Appl Sci J 17 (2012): 524.
80. El-Mansi EMT, Nielsen J, Mousdale D, et al. Fermentation microbiology and biotechnology. CRC press (2018).
81. Stanbury PF, Whitaker A, Hall SJ. Principles of fermentation technology. Elsevier (2013).
82. Bamforth SW, Cook DJ. Food, fermentation, and micro-organisms. Wiley (2019).
83. Paulová L, Patáková P, Brányik T. Advanced fermentation processes. Eng Asp Food Biotechnol (2013): 89-105.
84. Ali A, Shehzad A, Khan MR, et al. Yeast, its types and role in fermentation during bread making process-A. Pakistan J Food Sci 22 (2012): 171-179.
85. Gänzle MG. Enzymatic and bacterial conversions during sourdough fermentation. Food Microbiol 37 (2014): 2-10.
86. Verbeke KA, Boobis AR, Chiodini A, et al. Towards microbial fermentation metabolites as markers for health benefits of prebiotics. Nutr Res Rev 28 (2015): 42-66.
87. Adrio JL, Demain AL. Recombinant organisms for production of industrial products. Bioeng Bugs 1 (2010): 116-131.
88. Berenjian A. Essentials in Fermentation Technology. Springer (2019).
89. Gutiérrez-Correa M, Villena GK. Characteristics and techniques of fermentation systems. Compr Food Ferment Biotechnol (2010): 183-227.
90. Kilbane JJ. Future applications of biotechnology to the energy industry. Front Microbiol 7 (2016): 86.
91. Ugalmugle S, Swain R. Biotechnology Market Size By Application (Biopharmacy, Bioservices, Bioagriculture, Bioindustries, Bioinformatics), By Technology (Fermentation, Tissue Engineering and Regeneration, PCR Technology, Nanobiotechnology, Chromatography, DNA Sequencing, Cell Based Assay), Industry Analysis Report, Regional Outlook, Application Potential. Competitive Market Share & Forecast (2019) 2019-2025.