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Green biotechnology for sustainable pharmaceutical products

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Abstract

Technically speaking, biofuels and biobased bulk chemicals are low-hanging fruits, but higher-value and more complicated compounds are thought to have a greater economic and ecological impact from biotechnology. Different priorities have sprung from the "buzzword" biotechnology, frequently without taking long-term socioeconomic implications into account. Nevertheless, biotechnology presents extremely promising answers to a number of our issues through waste recycling, smart products, and benign synthesis. Biotechnology has enormous commercial potential—an incredible $1000 billion, or roughly an order of magnitude more than it does now! However, in order not to disappoint investors and taxpayers, we need to further develop our tools, especially for producing complex molecules for various applications.[1]

Active Pharmaceutical Ingredients (APIs) and excipients are the essential elements of pharmaceutical formulations, and the pharmaceutical industry is highly dependent on raw materials for medication development. Conventional approaches to generating pharmaceutical raw materials are frequently beset by inefficiencies, environmental issues, and difficulties in creating complex compounds.

Keywords: Microbial fermentation; Biotransformation; Plant-based pharmaceuticals; Biocatalysis; Green chemistry

1. Introduction

Most people agree that white or industrial biotechnology has excellent perspectives. It offers one of the biggest, if not the biggest, commercial prospects in biotechnology going forward. Industrial biotechnology is experiencing a rebirth due to new technological and methodological advancements, shifting ecological and economic conditions, current policies, and political commitments. Developing green and sustainable technologies for the conversion of waste biomass into biofuels, commercial chemicals, and new bio-based materials like bioplastics is one of the major issues in chemistry and biology, motivated by the urgent need to mitigate climate change.According to Anastas and Warner's twelve principles of green chemistry, the design of ecologically friendly products and processes is known as "benign by design." In a nutshell, green chemistry avoids the use of hazardous and/or toxic solvents and reagents in the production and use of chemical products, effectively uses (ideally renewable) raw resources, and gets rid of waste. It consists of three fundamental components. [2]

First, reducing waste by making effective use of raw materials. Second, avoiding the use of hazardous and/or poisonous compounds, such as solvents, in order to avoid health, safety, and environmental problems.

Third, substituting non-renewable fossil feedstocks like coal, natural gas, or crude oil with renewable biomass. Unlike end-of-pipe waste cleanup, green chemistry focuses on primary pollution prevention. It's interesting to note that there

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is no economic component to the idea of "green chemistry." In contrast, sustainable development comprises the so-called three pillers of sustainability: people, planet and profit, that is social, environmental and economic elements. It is described as satisfying current wants without sacrificing the ability of future generations to satisfy their own needs, and it recognizes the necessity of sustainable industrial and societal growth.

1.1. How green (sustainable) can the industry become?

Green chemistry is an idea and tenet that promotes the creation of products and manufacturing techniques with the least amount of environmental damage. Instead of only getting rid of pollution, the green chemistry idea and principles aim to prevent it and use less resources. Anastas and Warner developed the 12 principles of green chemistry.[3] are compiled in 1998. For one straightforward reason, synthetic and process organic chemists have long adhered to these principles, either consciously or unconsciously: they also make a lot of sense economically. It is evident from these twelve principles that biotechnology should be able to contribute significantly more to green chemistry than is now the case. The potential contribution of biotechnology is discussed also under synonymously used terms, such as third-wave biotechnology, suschem , greenchem , or white biotechnology. The common denominator is sustainability, which always includes three dimensions: ecological sustainability, economic sustainability, and social sustainability .[4]

1.2. Biocatalysis

Utilizing the catalytic potential of enzymes, biocatalysis offers a complex and effective way to convert basic materials into particular medicinal components. These extremely selective biological catalysts are essential for improving the sustainability and efficiency of several steps in the pharmaceutical production process.

1.3. Illustrations of Biocatalysis in Pharmaceuticals

Statins: Enzymatic processes are employed in the production of statins, a class of medications utilized for reducing cholesterol levels .

Antibiotics: Certain biocatalytic pathways contribute to the production and semisynthesis of various antibiotics .

Pegfilgrastim: This granulocyte colony-stimulating factor, utilized to boost white blood cell counts following chemotherapy, is synthesized using biocatalysis .[5]

Using a plant extract containing a hydroxynitrile lyase, Rosenthaler created (R)-mandelonitrile from benzaldehyde and hydrogen cyanide more than a century ago, paving the way for a whole new area of study: biocatalysis. Over the course of the following century, this field of study underwent three different waves of rapid development, moving from the use of crude extract to purified enzymes and finally to recombinant enzyme systems. The screening of biocatalysts had evolved from natural source extraction to gene mining with bioinformatic methods. Finally, sequence—structure—function analysis benefited from the developments in structural biology.

The engineering of biocatalysts now involves guided evolution of enzymes to adapt to reaction circumstances and substrate molecular structures, rather than altering reaction parameters to fit enzymatic features. The development and integration of multidisciplinary technologies and theories that span the majority of scientific disciplines, including chemistry, biology, pharmaceutics, food, physics, mathematics, computer science, automation, and engineering, benefited all of these technological revolutions. Additionally, the in-depth study of single-step enzymatic reactions, including enzymatic properties, reaction mechanisms, and protein engineering, flourished.[6]

1.4. Plant based pharmaceuticals

Plants are utilized to create a variety of pharmacological preparations and serve as a significant source of medications. In addition, they are good excipients and pharmacological aids.

2. Economic and Environmental Advantages

2.1. Financial advantages

Beautification increases store appeal, attracts customers, and lessens shopper stress. Businesses are looking for innovative ways to successfully retain their clientele in the current economic environment. Few companies are aware that adding landscaping to a storefront can have a big impact on how customers view the establishment.

In addition to welcoming consumers inside, aesthetically beautiful landscaping raises their opinion of the caliber of goods and services that the store provides. Customers are prepared to spend more money, travel farther, and spend more time at a store they believe to be of excellent quality. Adding flowers or bushes to a business's front can increase sales and expand the clientele. Ornamental plants are also a great method to rejuvenate a dormant business, attract new clients, and enhance the store's atmosphere. rates of occupancy.

In order to increase the occupancy rate of apartments and other commercial buildings, landscape amenities are a useful tool. There is a strong association between attractive landscaping and high building occupancy rates because people like aesthetically pleasing spaces and are significantly more likely to choose to live and work in buildings with appealing landscapes. As a result, investing in landscaping becomes more financially viable as the quantity of renters and the money they generate far outweigh the expense of putting in decorative plants.[7]

In general, properties near parks, botanical gardens, and other urban green spaces are far more valuable than those that are not. As a result, they indirectly raise the amount of money the municipality receives from its property tax base. fewer repairs to the streets. Along paved residential roads, planting trees lowers ground temperatures and extends the life of the asphalt. Asphalt tends to deteriorate more quickly when exposed to high temperatures from the sun, necessitating more frequent maintenance that can be expensive and inconvenient for locals.

The temperature of a building's outside walls can be considerably lowered by planting trees and other decorative plants around it, which also lowers the related energy costs for heating and cooling. As a result, the building will use less energy for heating and cooling, which will lessen the building's negative environmental effects on the neighborhood. Therefore, planting trees around a building or business has a major financial benefit in addition to being a beneficial step towards lowering energy use. Minimize damage from heat and cold Minimize damage from heat and cold.[8]

This can make living in the city uncomfortable and hot, especially for those who prefer to use pedestrian pathways. Urban heat islands can be mitigated by incorporating urban green spaces into a city's landscape.

Neighborhood noise levels can be lowered with the use of trees and urban green areas, which benefits both human and animal populations. Urban noise pollutants can induce physiological stress, animals may change their activity patterns due to noise and light pollution, and mesopredator release may result from the disappearance of top predators. Noise pollution—sound waves that locals find irritating and abrasive—is absorbed by landscaped landscapes. Noise pollution can be considerably decreased by putting in natural landscaping. This raises the standard of living for all people in.[9]

3. Case studies in green biotechnology

3.1. How Should Ideas Be Handled in the Commercialization Environment?

When a start-up innovation develops a truly novel "idea" in technology, they must make a difficult strategic decision about how to market the product. On the one hand, creating a value chain from the ground up enables the innovator to directly compete with more established competitors in the product market. Alternatively, the innovation can be directly integrated into an existing value chain through strategic cooperation with more established players, whether through licensing, an alliance or partnership, or even outright acquisition. However, this eliminates the possibility of using innovation to displace the established value chain. Commercialization strategy is thus one of the most crucial decisions a firm makes in terms of its ability to profit from technologies developed within the firm.

The relative cost and profitability of creating a new value chain as opposed to expanding upon an existing value chain, as well as the possibility that the knowledge underlying the innovation can be controlled even after the established firm learns about the new technology, are two aspects of the commercialization environment that are critical to the choice of commercialization strategy for the majority of start-up innovators. These elements work together to shape the best commercialization plan by determining the potential for advantage under a cooperative or competitive strategy.[10]

3.2. Advantages of Using Biotechnology

Decreased reliance on natural resources The difficulties in obtaining raw materials from natural reservoirs can be effectively addressed by biotechnology. Traditional procedures for rare or endangered species frequently require taking components from plants or animals that are in danger of going extinct, which raises questions about sustainability and ethics. By producing identical molecules in controlled settings, biotechnology provides an alternate strategy. Furthermore, geographical limitations cause some natural resources to be scarce. By creating the needed molecules without regard to these restrictions, bioprocesses provide an answer. Moreover, the quality and potency of natural

sources sometimes vary, resulting in inconsistent medication output. In the past, obtaining Artemisinin was dependent on rare Artemisia annua plants. But thanks to biotechnology, it can now be produced with genetically modified yeast, guaranteeing a steady and sustainable supply of this vital drug.[11]

Similar to this, large-scale spider harvesting presents ethical issues for the production of synthetic spider silk, which is known for its remarkable strength and elasticity. By creating spider silk proteins in genetically altered species, biotechnology offers a workable option. creation of innovative medications The development of novel medications has made biotechnology an essential tool.

High-throughput Drug Screening: Biotechnology speeds up the discovery process by enabling the quick screening of large libraries of possible drug candidates using automated techniques and genetically modified cells. Development of Gene Therapies: Biotechnology enables the creation of potentially curative gene therapies for illnesses that were previously incurable by directly addressing the genetic causes of disorders.[12]

3.3. Remarkable Examples of Novel Drugs Developed Through Biotechnology:

Drugs: These drugs offer a novel approach to cancer treatment by using the body's immune system to fight cancer.

Genetically Engineered Enzymes: In patients with genetic problems, these enzymes can replace damaged ones, potentially curing diseases like cystic fibrosis that were previously incapacitating.13]

3.4. Disadvantages and Challenges

3.4.1. High initial investment

Despite the unquestionable promise of biomanufacturing to produce pharmaceutical raw materials, a significant barrier to entry is the costly initial expenditure.

Infrastructure and facility construction: Building a biomanufacturing facility that maintains sterility and conforms to strict regulations can be very expensive. Technology and equipment: Specialized equipment like fermentation apparatus, bioreactors, purification systems, and quality control instruments are often needed for bio-manufacturing operations.[14]

3.4.2. Research and development

Extensive research and development efforts are frequently required to design and optimize bio-manufacturing methods customized for particular pharmaceutical raw materials, which further increases the initial expenditure.

3.4.3. Regulatory factors

Compared to medications made traditionally, biotechnologically generated drugs—including those made through biomanufacturing—are subject to strict regulations and drawn-out approval procedures. [15]

Unlike conventional medications, biologics are complicated and innovative because they frequently contain molecules made by living things, which calls for a thorough assessment of their safety and effectiveness. Concerns about genetically modified organisms and biohazards may need to be addressed in order for regulatory authorities to ensure the safety of both the production process and the finished product . Furthermore, regulatory frameworks must change as biotechnology advances quickly in order to handle new issues and maintain continuing safety requirements.[16]

3.4.4. Safety issues

The use of potentially hazardous ingredients and living organisms, particularly genetically modified ones, in bio-manufacturing raises questions about worker and environmental safety. [17,18]

A major risk is the unintentional introduction of genetically engineered organisms, which could have unforeseen ecological repercussions and disturb natural ecosystems.

Additionally, handling pathogens or hazardous materials is a part of bio-manufacturing operations, which puts workers at risk for exposure or infection. Furthermore, in order to reduce the environmental impact of the waste streams generated during biomanufacturing, certain treatment and disposal techniques are required.[19,20]

4. Conclusions

The sustainability of an impact-intensive industry must be ensured due to the sharp rise in pharmaceutical use. Only a small percentage of pharmaceutical goods are examined in the current sustainability assessments, and individual evaluations are required because to the stark variations in environmental effects. In order to comprehend the industry's current state of sustainability and to compare the safety of various technologies in a comprehensive manner, it will be essential to include all effect categories. Refactoring (semi)synthetic production pathways biologically has the potential to optimize the sector in terms of various dimensions of social, environmental, and economic sustainability. Pharmaceuticals with large market volumes, high current environmental impact, and relative bio-refactoring viability can be the focus of bio-refactoring activities to effectively lead the industry's sustainable transition.

4.1. Embracing Biotechnology for a Sustainable Pharmaceutical Future

In conclusion, a new era of innovation and sustainability in healthcare is heralded by the increasing significance of biotechnology in the manufacturing of pharmaceutical raw materials. Even though they are fundamental, traditional approaches are becoming more and more limited in terms of their effectiveness, environmental impact, and ability to change to meet changing healthcare demands. Biotechnology provides a revolutionary answer to these problems by utilizing the power of living things and genetic engineering.

In conclusion, the growing importance of biotechnology in the production of pharmaceutical raw materials heralds a new era of innovation and sustainability in healthcare. Traditional methods are becoming increasingly constrained in terms of their efficacy, environmental impact, and adaptability to evolving healthcare needs, notwithstanding their essential nature. By harnessing the power of living organisms and genetic engineering, biotechnology offers a revolutionary solution to these issues.

Biotechnology makes it possible to produce pharmaceutical raw materials with previously unheard-of accuracy and purity in an efficient and scalable manner using methods like cell culture technology, microbial fermentation, biocatalysis, and recombinant DNA technology. Biotechnology opens the door to a more sustainable pharmaceutical sector by lowering dependency on finite natural resources and providing alternatives to methods that affect the environment.

Additionally, biotechnology drives the development of new medications that provide hope for diseases that were previously incurable, such as gene treatments for genetic abnormalities and immunotherapy for cancer. The possibility of customized treatments based on unique genetic profiles is becoming more realistic with developments in gene editing, synthetic biology, and personalized medicine, offering more efficient and individualized healthcare solutions.

To fully achieve the potential of biotechnology in pharmaceutical manufacture, however, issues like expensive initial investment, safety concerns, and regulatory issues must be resolved. To overcome these obstacles and guarantee the responsible and safe development of biotechnological applications in healthcare, cooperation between researchers, industry stakeholders, and regulatory agencies is essential world.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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