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Enzymes - important players in green chemistry

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Abstract

Green chemistry has become a worldwide approach that leads to sustainable growth through application and development of its principles. A lot of work has to be put into designing new processes comprising of materials which do not emit pollutants to the atmosphere. Inventing new safer methods and finding less harmful products can be challenging. Enzymes are a great hope of scientists in the field of green chemistry. Enzymes as catalysts require mild conditions therefore it is a great way of saving resources such as energy or water. Processes with the use of enzymes have become more feasible by being more cost effective and eco friendly. Taking into account the benefits of green chemistry, enzyme biocatalysis has quickly replaced traditional chemical processes in several fields, and this substitution is going to reach even more areas because of new emerging technologies in enzyme engineering.

Keywords: green chemistry, enzymes, green enzymes, catalysts, catalysis

Introduction

A particular interest in green chemistry has emerged in the recent past. In 1990 when the staff of EPA Office of Pollution Prevention and Toxics created a new idea and a phrase “green chemistry” which was elaborated in twelve principles (Fig. 1) [1,2,3]. Ten years later the Institute of Green Chemistry turned into the American Chemical Society, worldwide known as the biggest scientific community for chemists. The interest in green chemistry quickly brought results as significant as two won Nobel Prizes in 2001 and 2005 [1].

The purpose of green chemistry is the reduction of hazardous emissions and high amounts of chemicals causing environmental pollution. Moreover, green chemistry supporters seek the control of the atom economy. Green Chemistry can be described as a responsible use of substances and processes, which tend to decrease or completely eliminate the release of hazardous chemicals, having negative influence on conditions of both fauna and flora [7]. Additionally, green chemistry refers to innovative development of new efficient processes and safer products. Nowadays engineers and scientists working with green chemistry, make an attempt to introduce this new approach to our lives (Fig. 2) [2]

Fig. 1. Twelve principles of green chemistry [1].

Enzymes in green chemistry.

Green chemistry became a worldwide approach, which leads to sustainable growth through application and development of its principles. A lot of work has to be put into designing new processes comprising of materials that do not emit pollutants to the atmosphere. Inventing new safer methods and finding less harmful products can be challenging [2]. Increased oil prices are the reason for seeking alternatives, which are both cheaper and greener sources of energy like biomasses. Additionally, the pressure from the public to prioritize green technologies is rising. People become more aware of the environment and a wish of replacing chemical processes with eco-friendly biocatalytic reactions can be observed [5,6,9].

Enzymes are a great hope of scientists in the field of green chemistry. They are biological catalysts that are present in all living organisms. Enzymes as catalysts require mild conditions, therefore it is a great way of saving resources such as energy or water. Processes with the use of enzymes become more financially feasible just by being more cost effective and eco friendly [2].

Enzymes become more and more present in all aspects of society. They are exploited in detergent, paper and textile production as well as in healthcare, pharmaceutical and food processing industries. They can be used for synthesis in non-aqueous media [2]. It has been observed that application of enzymes or even entire cells in production of various kinds of biological and chemical contents generally provides shorter time of processes, less reaction steps and limited amount of waste [5]. Taking into account the benefits of green chemistry, it is obvious, that enzyme biocatalysis quickly replace traditional chemical processes in several fields. This substitution is going to reach even more areas, because of emerging new technologies in enzyme engineering [4].

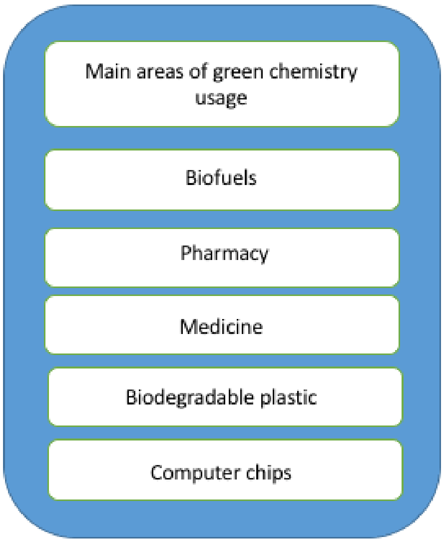

Fig. 2. Areas of green chemistry usage [1].

Green enzymes

Nowadays, great development of new enzymatical methods can be observed, due to the nature of enzymes, their strong selectivity and potent efficiency during catalysis. Biocatalysis is particularly profitable for pharmaceutical industries, since all reactions are being catalysed under mild conditions, not consuming a lot energy and producing relatively small amounts of greenhouse gasses. No use of heavy or toxic metals is a significant benefit over transition metal catalysts. What more, enzyme-catalysed reactions may be conducted in water, instead of organic solvents and in general they generate less waste products than reactions catalysed by chemocatalysts [2,7]. For worldwide biocatalysts commercialization, reusability is an important factor, hence immobilized enzymes with improved efficiency and increased reproducibility are exploited [12]. Most of commercially relevant enzymes are biodegradable and may be reused.

Moreover, enzyme-catalysed reactions are supreme in the synthesis of chiral compounds, because of their high efficiency and regio- and stereospecifity. There are cases, in which they take part in composite transformations and allow diminution of the number of stages required for synthesis of complex particles containing few chiral centres [2].

There are many methods used to produce enantiomerically pure compounds, but the application of lipases as biocatalysts is exceptionally beneficial in regard of milder reaction conditions, decreased energy consumption and reduced production costs. [8]. Lipases may mediate biotransformations such as esterification, transesterification and aminolysis [2].

Immobilized lipase B from *Candida Antarctica* are tested for generating biodegradable substances derived from renewable sources. A bio surfactant called N-alkanoyl-N- methylglucamide, is produced in a solvent-free process. A final yield of 99 % is obtained, with the use of molar ratio engineering of substrates and additional step with hydrolysis of the prior reports. Another bio product is trimethylolpropane-oleate, which is obtained by the use of lipase B in the reaction of esterification and it reached great yield, higher product quality and is more eco-friendly than the process using heterogenous chemical catalyst. [11]. Lipases may be used to obtain enantiomerically pure drugs, alcohols, amides. Nitrile aminohydrolases e.g. mediate catalysing the hydrolysis of nitriles to carboxylic acids and ammonia. Acylases catalyse the reactions of semisynthesis of new penicillin [13, 14, 2].

There has been a growing interest in laccases, belonging to the group of oxidoreductases, catalysing the monoelectronic oxidation of substrates using molecular oxygen. Laccases are substantially ‘eco-friendly’ enzymes, because they use air and produce water as the only by-product. They have been used in wide range of branches, from the textile to the pulp and paper industry, through the applications in food industry and bioremediation processes [11].

Esterases have also been investigated as a clean alternative for the reaction of synthesis of chiral compound, S-clopidogrel. Actual production of that enantiomer engage the use of L-camphorsulfonic acid as a resolving agent and organic solvents. Esterases show several advantages as biocatalysts for organic synthesis. Moreover, that enzyme is easily expressed in E. coli and presents high stability [11]. There are more examples of enzymes commonly used in green chemistry, such as chloroperoxidase mediating the oxidation of S-alkylcysteine derivatives to obtain sulfoxides or subtilisin, which is an endoprotease working enantioselectively to hydrolyse N-acylaminoacid esters to (S)-amino acids [2].

Conclusion

From 1990 green chemistry developed from just a conception to a conscious approach for environmental protection. Application of green chemistry methods may reduce the waste of materials, preserve atom economy and avert the use of dangerous chemicals. The request for production and use of enzymes is increasing every day, hence the demand for industrial biocatalysts is also growing. The triumph of green chemistry may depend on the way of educating and instructing young chemists. It is extremely relevant to make new generations familiar with all faces of green technology so the main purpose would be the environment preservation [2].

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