Frontiers in Environmental Research
ISSN: 2960-026X
DOI: 10.61784/fer240115

APPLICATION OF BIOTECHNOLOGY IN GREEN CHEMISTRY RESEARCH

Jo Lubell
Temple University, Philadelphia, PA 19122, USA.

Abstract: The research orientation in the field of green chemistry still follows 12 principles: replacing toxic substances with green substances at nodes such as raw materials, reaction reagents, catalysts, synthesis routes and products. Another obvious research trend is to closely combine or utilize biotechnology for the synthesis of chemical products, and the key to the application of biosynthesis is to find suitable biocatalysts.
Keywords: Green chemistry; Biotechnology; Biocatalyst

1 RESEARCH TRENDS IN GREEN CHEMISTRY

The term "green chemistry" first appeared in the "Pollution Prevention Action" Act passed in the United States in 1990. The core concept of green chemistry is to use chemical principles to reduce and eliminate environmental pollution from industrial production from the source; all atoms of the reactants are transformed is the desired final product, so "green chemistry" is also called environmentally sound chemistry, environmentally friendly chemistry, and clean chemistry [1]. The United States established the "President's Green Chemistry Challenge Award" (PGCC Award) in 1995. This was the first policy in the world that a government of a country introduced to reward green chemistry, aiming to promote pollution prevention and industrial ecological balance. my country launched the "Environmentally Friendly Petrochemical Catalytic Chemistry and Chemical Reaction Project" in 1997, which marked the beginning of my country's green chemistry research and development, and regarded basic research projects in green chemistry as one of the important directions of support.

Green chemistry involves organic synthesis, catalysis, biochemistry, analytical chemistry and other disciplines. Its research is mainly carried out around the greening of chemical reactions, raw materials, catalysts, solvents and products. On the one hand, it follows the principles of green design [2-3] , That is to make full use of resources and energy, use non-toxic and harmless raw materials, and carry out reactions under non-toxic and harmless conditions to reduce the discharge of waste to the environment; on the other hand, follow the principles of atomic economy [4] to achieve "zero emissions"; producing environmentally friendly products.

Anastas and Warner proposed the "12 principles of green chemistry" in 1998 [5-6]. These principles are now used as standards for developing and evaluating whether a synthetic route, a production process, or a compound is green. Green chemistry has brought revolutionary changes to the traditional chemical industry in terms of principles and methods, and also posed huge challenges. The idealized principles of green chemistry are in line with the characteristics of biological science and technology. Judging from the research results of green chemistry in recent years, chemists are increasingly relying on biological science and biotechnology to obtain the products they need.

2 CLOSE INTEGRATION OF GREEN CHEMISTRY AND BIOTECHNOLOGY

The 2010 US Presidential Green Chemistry Award further confirmed the close relationship between green chemistry and biotechnology. In this year's awards, Chinese-American professor Liao Junzhi of the University of California, Los Angeles, won the highest personal honor academic award for his research result "CO2 recycling in biosynthesis". In this study, genetically modified engineering bacteria can be used to synthesize long-chain alcohols from glucose or directly using CO2, breaking through the limitation that wild microorganisms cannot synthesize alcohol molecules with more than 2 carbons, and improving the energy value of alcohols as fuel additives. Once this technology is commercialized, it can replace a quarter of petroleum fuels every year and reduce 500 million tons (about 8.3%) of carbon waste gas for the earth.

South San Francisco-based biotech company LS9 won the Small Business Award for its production of renewable fossil fuels and microbial-based chemicals. The company developed technology that uses a series of genetically modified microorganisms to convert plant sugars into various alkanes and alkenes. , fatty alcohols, fatty esters and other products; Merck and CDX won the Green Reaction Condition Award for their development of a new transaminase production process for type 2 diabetes drugs [7].

2.1 Biomass Raw Materials

Biomass refers to various organisms produced through photosynthesis using the atmosphere, water, land. It is a renewable resource on the earth. Because biomass is mainly composed of three elements: C, H, and O, biomass is used as raw material. Synthetic chemical products or used to replace mineral resources can greatly reduce the pressure on resources and the environment. In the research on the conversion of biomass into fuels, some industrial wastes are mainly used to synthesize valuable fuels.

Xing et al. [8] used hemicellulose waste liquid, a by-product of the wood processing industry, to synthesize long-chain (C12 ~ C13) alkanes through four steps of acid catalysis, aldol condensation, hydrogenation and deoxygenation, which can be widely used as jet fuel. Fuel for aircraft and diesel engines. Hemicellulose waste liquid mainly contains xylose oligomers, glucose, gum aldose, lactic acid, acetic acid and formic acid. Its theoretical conversion yield is 76%, and C12 ~ C13 accounts for 91% of the synthetic products. At the same time, this process helps eliminate industrial waste.

γ-valerolactone (GVL) is a platform molecule of biomass. Alonso et al. [9] converted the non-terminal olefins derived from γ-valerolactone into olefins suitable for use in Liquid fuel for transportation. On the synthetic route, researchers have introduced biotechnology to eliminate industrial waste while avoiding secondary waste pollution. For example, Steinbusch et al. [10] used mixed culture fermentation technology to biosynthesize low-carbon biomass acetic acid (organic waste) Converted into caproate and octanoate, the latter are precursors for further synthesis of biodiesel and products for the chemical industry.

Lignocellulose is an abundant raw material for the preparation of fuels and chemicals. Hick et al. [11] introduced the method of solid-solid catalysis or mechanical catalysis. By mechanical grinding and adding catalysts, they solved the problem that solid cellulose reactants are not easily catalyzed. After Through one-step catalysis, 84% of cellulose is converted into water-soluble substances, reducing waste generation and increasing the stability of raw materials.

Improper disposal of waste biomass can also lead to environmental pollution or become a source of disease. Zhang Zhijian et al. [12] used liquefaction technology to produce biomass from waste biomass including polysaccharides, lignin, proteins, oils and other biomacromolecules. Oil not only solves the problem of organic matter pollution, but also develops a new idea for biomass energy utilization.

2.2 Biosynthetic Reactions

The process of using microbial fermentation to combine fructose and ethanol in series reported by Shih et al. [13] embodies the principle of atom economy. In this process, Bacillus subtilis (B. subilis) first uses sucrose to ferment and completely converts sucrose into fructan; the fermentation liquid is collected, ultrafiltrated to obtain a fructan solution, and further fermented to obtain ethanol, and finally to produce Two valuable environmentally friendly products-fructan and ethanol. The amount of alcohol required to recover fructan is only 1/4 of the traditional preparation method, so this process is an environmentally friendly green process. As mentioned before, Steinbusch et al. [10] used mixed microbial culture fermentation technology to convert low-carbon biomass acetic acid (organic waste) into caproate and octanoate through biosynthesis in one step.

3 CONTINUE TO REPLACE TRADITIONAL TOXIC SUBSTANCES WITH “GREEN” SUBSTANCES

Green chemistry requires the use of non-toxic and harmless raw materials, catalysts and solvents as much as possible in the chemical reaction process. The "President's Green Chemistry Challenge Award" has also specially established an award for changing the synthesis route and changing the solvent/reaction conditions. In the latest green chemistry research reports, it can be seen that researchers still use biological, degradable, environmentally friendly raw materials and reagents to synthesize products under mild conditions, and minimize the generation of waste and reduce reaction steps. and subsequent product recycling procedures. In some studies, catalysts are recycled to protect the environment and reduce production costs.

3.1 Green Solvent

Harjani et al. [14] reported that the use of biodegradable ionic liquids, such as 3-butoxycarbonyl-1-methylpyridine bistrifluoromethanesulfonimide salt, was catalyzed by palladium to carry out effective Sonagashira coupling reaction (alkyne synthesis). reaction), the reaction is carried out at room temperature using ultrasound, avoiding the use of copper salts and large amounts of phosphine, which are toxic reagents that easily cause pollution. The immobilized palladium catalyst can be recycled and reused, and its catalytic activity remains unchanged.

In the enzymatic carbon coupling reaction of aldehydes (C-C bond formation), Shanmuganathan et al. [15] used 2-methyltetrahydrofuran (2-MTHF) as a cosolvent to replace dimethyl sulfoxide (DMSO) and methyl Tert-butyl ether (MTBE) serves as a co-solvent or organic phase medium. 2-Methyltetrahydrofuran can be derived from biological matrix raw materials such as levulinic acid, and can undergo non-biological degradation in the air. It is environmentally friendly and can eliminate the pollution problems caused by difficult separation or degradation of DMSO and MTBE.

In the study of Kulkarni et al. [16] , the non-volatile hydrophobic environmentally friendly solvent polypropylene glycol was used to extract limonene from orange peels. After organic pervaporation, the solvent-free product can be recovered with high yield. Tan et al. [17] studied an environmentally friendly solvent system. In solvent-free or in glycerol, styrene, vinylferrocene and 2-phenylindole can be easily substituted with 1,3-disubstituted-5-Pyrazolone reacts with formaldehyde without any catalyst. Not only does it reduce waste generation, but it also simplifies the synthesis steps.

3.2 Green Catalyst

Sun et al.[18] used sodium acetate (CH3 COONa) as a catalyst for the first time to catalyze the methoxycarbonylation reaction of 1,6-hexanediamine (HDA) and dimethyl carbonate (DMC) at 348 K for 6 h. The yield of 1,6-hexamethylenedicarbamate methyl ester is as high as 99%. The reaction of sodium hydroxide and methylacetic acid can be used to recover sodium acetate as a catalyst.

Bonamore et al. [19] used (S)-desmethylhigenate synthase (NCS) to synthesize stereoselective S-higenate from cheap tyrosine and dopamine substrates through a two-step reaction in a system. Base, the yield of purified enantiomeric product reaches 93%. The source of (S)-desmethylhigenamine synthetase is to express the enzyme gene in E. coli to synthesize the target protease through genetic recombination technology, and this enzyme can be recycled and reused.

Hahn et al. [20] first studied the cyclization reaction catalyzed by biocatalyst laccase. Under mild and environmentally friendly reaction conditions, cycloheptene, cyclooctene, and diazaspiro can be synthesized without high temperature and high pressure. Cyclohexene, phenazine. Laccase is a biological enzyme synthesized, isolated and purified from white rot fungi.

3.3 Environmentally Friendly Products

Another important aspect of green chemistry is the design, production and use of environmentally friendly products that will not cause harm to human health and the ecological environment after their processing, application and disappearance of functions. The Designing Safer Chemicals Award is an award for this type of green chemical products. The 2010 President's Green Chemistry Challenge Award Design Award was awarded to Clark Company, which engages in environmental products and services. The company developed Spinosad, a spinosad The slow-release technology allows Spinosad, a green insecticide, to be stably present in water and used to control the growth of mosquito larvae. Since the application of this technology reduces the number of spinosad injections each season, the pressure on the environment is further reduced [6].

3.4 Green Synthetic Pathways

Research by Yu et al. [21] found that in the reaction of using biosynthetic lipase Novozym 435 to transesterify soybean oil and methanol to synthesize fatty acid methyl esters, compared with traditional heating conditions, microwave radiation can enhance enzyme activity. and increase the reaction rate. The yield reached 94% in 12 h under microwave irradiation, while heating required 24 h to reach the same yield. Cukalovic et al. [22] studied a simple method to convert 5-hydroxymethylfurfural (HMF) into 5-alkyl (arylaminomethyl)-2-furanmethanol. This reaction does not require a catalyst and is carried out under mild conditions. , the product yield is very high and requires only minor purification.

4 ATOMIC ECONOMY IS REFLECTED EVERYWHERE

One of the core contents of green chemistry is the use of "atom economy" reactions, and the concept of "atom economy" of reactions was first proposed by Professor Trost of Stanford University in the United States [4]. Generally, economics alone are used to measure whether a process is feasible. Traditionally, he clearly pointed out the application of a new standard to evaluate chemical processes, namely the concepts of selectivity and atom economy. The latter considers how many atoms of raw materials enter the product during the chemical reaction. This standard not only requires saving as much as possible those raw material resources that are generally non-renewable, but also requires minimizing waste emissions.

In some of the above research reports, it can be seen that while researchers are selecting green raw materials and reagents, they are also exploring the best synthesis routes and mild conditions to increase yields. For example, Shih et al. [13] reported the results of a series combination of microbial fermentations. In the process of polysaccharides and ethanol, sucrose is completely utilized, which best explains the principle of atom economy.

5 CONCLUSION AND OUTLOOK

(1) Biotechnology will become the dominant technology for the synthesis of chemical products. It has the advantages of high efficiency, low cost, high selectivity, and less secondary pollution than traditional physical and chemical methods. It is of great significance to both scientific research and environmental economy. From the perspective of environmental benefits, biocatalysts synthesized using modern biotechnology, compared with traditional industrial catalysts, can not only be recycled and reused, but are biodegradable and reduce environmental pollution. At the same time, the reactions catalyzed by biocatalysts are generally It is carried out under mild environmentally friendly conditions, which greatly reduces the energy consumption of high temperature and high pressure conditions required for industrial catalysts. From the perspective of economic benefits, biomass raw materials such as wood, crop straws and some non-food plants are cheaper and easier to obtain than crude oil resources. According to a study by the U.S. Environmental Protection Agency (EPA), the chemical industry has greatly reduced expenditures caused by adverse impacts on the environment and society due to the introduction of the concept of green chemistry. According to statistics, the chemical industry can save US$6.56 billion in cost expenditures by 2020 [23].

(2) The application of biotechnology or routes for the synthesis of chemical products requires more complex processes and control technologies than chemical synthesis, involving the selection of excellent bacterial strains, the synthesis of biocatalysts, the optimization of reactors and the regulation of reaction conditions, and then to the separation and

purification of products. Generally speaking, the efficiency of biosynthesis is much lower than that of chemical synthesis methods. How to improve its production efficiency is a key issue. Therefore, it is necessary to find the most suitable biological enzyme catalyst or biosynthetic system for different products. This can be achieved by conducting induced mutation breeding from existing biological enzymes or biological strains, using genetic engineering technology or synthetic biology methods to construct new engineering enzymes or engineering bacteria.

(3) In addition, the complex biosynthetic reaction system results in a complex mixture of product systems, so the downstream separation and purification process has also become a key technology that affects the yield of biosynthetic products. In addition to traditional separation methods such as distillation, extraction, and fractionation, the application of membrane fixation technology, ion technology, and supercritical technology provides new ideas and methods for product separation. However, these technologies require high value-added equipment to support and achieve Industrialization also needs to consider production cost factors.

The 21st century is the era of biotechnology. The penetration of biotechnology into the field of chemical engineering will definitely bring a new change to the future chemical industry.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Chen Jianxin, Wang Jingkang. Green chemistry and chemical industry and the development of harmonious society. Modernization Engineering, 2007, 27(12): 1-6.

[2] Gong Changsheng. Green chemistry-the only way for the sustainable development of my country's chemical industry. Modern Chemicals, 2002, 22(1): 8-14.

[3] Ye Xiangqun. Green design and green chemical design. Environmental Pollution and Prevention, 2002, 24(3): 190-192.

[4] Trot BM, Atom Economy. A challenge organic synthesis. Angew Chem Int Ed Engl, 1995, 34(3): 259-281.

[5] Min Enze, Fu Jun. Progress of green chemistry. Chemical Bulletin, 1999, (1): 10-15.

[6] 2010 Presidential Green Chemistry Challenge Awards. http://www.epa.gov/gcc/.

[7] Liu Changhong, Wu Shuxin, Cao Wenhua. Review of the 2010 U.S. President's Green Chemistry Challenge Award Project. Modern Chemicals, 2010, 30(7): 86-89.

[8] Rong Xing, Ayyagari V Subrahmanyam, Hakan Olcay. Produc-tion of jet and diesel fuel range alkanes from waste hemicellulose-derived aqueous solutions. Green Chem, 2010, 12: 1933- 1946.

[9] David Martin Alonso, Jesse Q Bond, Juan Carlos Serrano-Ruiz. Production of liquid hydrocarbon transportation fuels by oligome-rization of biomass-derived C9 alkenes. Green Chem, 2010, 6: 992-999.

[10] Kirsten J J Steinbusch, Hubertus V M Hamelers, Caroline M Plugge. Biological formation of caproate and caprylate from acetate: Fuel and chemical production from low grade biomass Energy Environ. Sci, 2011, 4:216-224.

[11] Sandra M Hick, Carolin Griebel, David T Restrepo. Mechano-catalysis for biomass-derived chemicals and fuels. Green Chem, 2010, 3:468-474.

[12] Zhang Zhijian, Li Hongyi, Zhu Jun. Research progress on bio-oil production from waste biomass liquefaction. Environmental Pollution and Prevention, 2014, 25(3): 87-93.

[13] Ing-Lung Shih, Li-Dar Chen, Tsaur-Chin Wang. Tandem pro-duction of levan and ethanol by microbial fermentation. Green Chem, 2010, (7): 1242-1247.

[14] Jitendra R Harjani, Theodore J Abraham, Alwyn T Gomez. So-nogashira coupling reactions in biodegradable ionic liquids derived from nicotinic acid. Green Chem, 2010, (4): 650-655.

[15] Saravanakumar Shanmuganathan, Dessy Natalia, Anne vanden Wittenboer. Enzyme-catalyzed C-C bond formation using 2-methyltetrahydrofuran (2-MTHF) as (co) solvent: Efficient and bio-based alternative to DMSO and MTBE. Green Chem, 2010, (12): 2240-2245.

[16] Prashant S Kulkarni, Carla Brazinha, Carlos A M Afonso. Se-lective extraction of natural products with benign solvents and re-covery by organophilicpervaporation: Fractionation of D-limonene from orange peels. Green Chem, 2010, (11): 1990 -1994.

[17] Jia-Neng Tan, Minghao Li, Yanlong Gu. Multicomponent reactions of 1, 3-disubstituted 5-pyrazolones and formaldehyde in environ-mentally benign solvent systems and their variations with more fun-damental substrates. Green Chem, 2010, (5): 908-914.

[18] Da-Lei Sun, Shun-Ji Xie, Jian-Ru Deng. CH3 COONa as an ef-fective catalyst for methoxycarbonylation of 1, 6-hexanediamine by dimethyl carbonate to dimethylhexane-1, 6-dicarbamate. Green Chem, 2010, (3):483-490.

[19] Alessandra Bonamore, Irene Rovardi, Francesco Gasparrini. An enzymatic, stereoselective synthesis of (S)-norcoclaurine. Green Chem, 2010, (9): 1623 -1627.

[20] Veronika Hahn, Timo Davids, Michael Lalk. Enzymaticcycliza-tions using laccases: Multiple bond formation between dihydroxy-benzoic acid derivatives and aromatic amines. Green Chem, 2010, (5): 879-887.

[21] Dahai Yu, Li Tian, Dongxiao Ma. Microwave-assisted fatty acid methyl ester production from soybean oil by Novozym 435. Green Chem, 2010, (5): 844-850.

[22] Ana Cukalovic, Christian V Stevens. Production of biobased HMF derivatives by reductive amination. Green Chem, 2010, (7): 1201 -1206.
[23] Green Chemicals will save industry $ 65. 5 billion by 2020. http://www2.epa.gov/green-chemistry.