catalysts

MDPI

Editorial

Editorial Catalysts: Special Issue on Novel Enzyme and Whole-Cell Biocatalysts

Anwar Sunna [1,*] and Richard Daniellou [2,*]

[1] Department of Molecular Sciences, Macquarie University, Sydney, NSW 2109, Australia
[2] ICOA UMR CNRS 7311, University of Orleans, rue de Chartres, BP 6759, CEDEX 2, 45067 Orléans, France
* Correspondence: anwar.sunna@mq.edu.au (A.S.); richard.daniellou@univ-orleans.fr (R.D.)

Received: 16 September 2020; Accepted: 17 September 2020; Published: 20 September 2020

check for updates

Keywords: chemo-enzymatic synthesis; glycosyl transferases; protein engineering; carbohydrates; biocatalysis; synthetic biology; industrial enzymes; thermostable enzymes; glycoside hydrolases; cell-free biocatalysis; natural and non-natural multi-enzyme pathways; bio-based chemicals

Global trends emphasizing the reduction of organic waste, carbon capture and landfill avoidance are driving the demand for greener products with improved properties. Recent advances in synthetic biology, molecular biology, computational tools and metabolic engineering have promoted the discovery of new enzymes and the rational design of whole-cell biocatalysts. Accordingly, with increased demand for sustainable and environmentally-friendly biomanufacturing, the field of enzyme technology and biocatalysis (multi-enzymes and whole-cells) has become a primary focus for the synthesis of bio-based chemicals and high-value compounds.

In this Special Issue, we would like to highlight these current advances in the field of biocatalysis, with special emphasis on novel enzymes and whole-cell biocatalysts for applications in industry, health, or cosmetics.

Over the past decades, biodiesel has attracted great interest as a sustainable alternative for fossil fuels. Two research papers focused on this important challenge. The enzymatic production of biodiesel from waste cooking oil that could contribute to resolve the problems of energy demand and environment pollution. Yang et al. [1] report on the activation of *Burkholderia cepacia* lipase by surface imprinting and its immobilization in magnetic cross-linked enzyme aggregates, thus exhibiting a significant increase in biodiesel yield and tolerance to methanol. Shafiq et al. [2] describe the use of response surface methodology to optimize the reaction parameters of bioproduction of biodiesel from waste chicken fat oil and demonstrated that optimal yield can be obtained in their conditions using immobilized *Aspergillus terreus* lipase on Fe_3O_4 nanoparticles with a methanol-to-oil ratio of 6:1 at 42 °C for 36 h.

However, bioproduction is certainly not limited to solving energy and environmental troubles and there is also a challenging area in the field of biomass valorization, as depicted by an excellent review from Martinez et al. [3]. The authors outlined the challenges and opportunities in the discovery of original keratinases for value-added peptide production. Indeed, keratins represent millions of tons of protein wastes and their enzymatic hydrolysates can generate valuable industrial applications. To do so, the search for original, innovative and robust biocatalysts is a key step, and extremophile sources are a good starting point. Therefore, a large part of this special issue has been devoted to this immense field of research. First, Kopp et al. [4] identify and characterize the first archaeal mannonate dehydratase from *Thermoplasma acidophilum* and demonstrate it to have an original physiological role in this extremophile. Then, Burkhardt et al. [5] show interest in two endo-β-1,3-glucanases from the thermophilic bacterium *Fervidobacterium* sp. These two enzymes proved to be highly specific to laminarin and tolerant to high temperature, and are good candidates for application in biomass

conversion. In addition, Tahir et al. [6] clone and overexpress a novel hormone-sensitive lipase-like esterase from *Glaciozyma antartica*. Unlike other known enzymes, this protein demonstrates higher activity towards medium-chain ester substrates, rather than shorter chain esters, and increased stability at 60 °C, as well as alkaline pH conditions. In addition, asymmetric catalysis is evoked by the article of Aregger et al. [7], in which the authors report the characterization of the novel ene reductase Ppo-Er1 from *Paenibacillus polymyxa*. This biocatalyst exhibits enantioselective activity towards a large panel of substrates, a large range of temperature and co-solvents, making it a promising tool for industrial bioconversions. Finally, an excellent review from Shah et al. [8] presents the cofactor F420 both (i) as an alternative to nicotinamide cofactors implicated in asymmetric reduction of enoates, imines and ketones, and (ii) as an underexplored resource for asymmetric redox biocatalysis at the industrial level.

Besides revealing their original activities, many processes also can be improved so to increase industrial applications of enzymes. One elegant and powerful example relies in the machine learning approach described by Nagaraja et al. [9] for the efficient selection of enzyme concentration and its application for flux optimization. Pham et al. [10] demonstrate the immobilization of β-galactosidase on the *Lactobacillus* cell surface using LysM, the common peptidoglycan-binding motif, thus facilitating many uses of the biocatalyst and showing its potential for applications in the synthesis of prebiotic galacto-oligosaccharides.

Understanding the intrinsic mechanism of the enzyme also can help in improvement of the biocatalyst. Bracco et al. [11] demonstrated one decisive criterion to differentiate between esterase and lipase, with the latter being the only one active in dry organic solvents. Substrates also can give important clues on the mechanism, as demonstrated by Guillotin and co-workers [12] when using glycosyl thioimidates with biologically-relevant glycoside hydrolases. Fine tuning of amino acids is another level of improvement. Liu et al. [13] show the role of V88L substitution in increasing the enzyme activity and decreasing the protein stability in the New Dehli metallo-β-lactamase-1 family. Mutagenesis of enzymes is a further powerful tool as shown by Schwardmann et al. [14]. The authors studied the well-defined outer ring of the substrate groove of a non-specific nuclease from *Pseudomonas syringae* and defined it as a potential target for modulation of the enzymatic performance. Perugino et al. [15] demonstrated that random mutagenesis and biological selection allowed the identification of residues that are critical in determining thermal activity, stability and substrate recognition of a β-glycosidase from the thermoacidophile *Saccharolobus solfataricus*. Cyclodextrin transferase's product specificity was changed finally by Sonnendecker et al. [16] by semi-rational mutagenesis, obtaining larger cyclodextrin's rings of up to 12 units.

Whole-cell biocatalysed reactions are also discussed broadly. First, the impact of low-level organic solvents on engineered *Escherichia coli* strains was studied in a model reaction of multi-enzyme whole-cell biocatalysts by Yang and co-workers [17]. Secondly, Milessi-Esteves et al. [18] described the production of ethanol from xylo-oligomers by native *Saccharomyces cerevisiae*. The authors investigate a new concept of biocatalysts to overcome the ease of the contamination of the bioreactor by bacteria that metabolize xylose. In addition, Cang et al. [19] showed that the extremely radiation resistant *Deinococcus wulumquiensis* R12 was a new and robust biocatalyst for selective oxidation of 5-hydroxymethylfurfural to 5-hydroxymethyl-2-furancaroxylic acid. In the final contribution, Noshahri et al. [20] examined the Iranian soil to locate robust microorganisms with ω-transaminase activities.

In conclusion, this Special Issue showcases a large panel of techniques and tools in biocatalysis, so as to transform biomass into valuable energy and other bioproducts.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Yang, H.; Zhang, W. Surfactant imprinting hyperactivated immobilized lipase as efficient biocatalyst for biodiesel production from waste cooking oil. *Catalysts* **2019**, *9*, 914. [CrossRef]
2. Shafiq, F.; Mumtaz, M.W.; Mukhtar, H.; Touqeer, T.; Raza, S.A.; Rashid, U.; Nehdi, I.A.; Choong, T.S.Y. Response surface methodology approach for optimized biodiesel production from waste chicken fat oil. *Catalysts* **2020**, *10*, 633. [CrossRef]
3. De Oliveira Martinez, J.P.; Cai, G.; Nachtschatt, M.; Navone, L.; Zhang, Z.; Robins, K.; Speight, R. Challenges and opportunities in identifying and characterising keratinases for value-added peptide production. *Catalysts* **2020**, *10*, 184. [CrossRef]
4. Kopp, D.; Willows, R.; Sunna, A. Characterisation of the first archaeal mannonate dehydratase from *Thermoplasma acidophilum* and its potential role in the catabolism of D-Mannose. *Catalysts* **2019**, *9*, 234. [CrossRef]
5. Burkhardt, C.; Schäfers, C.; Claren, J.; Schirrmacher, G.; Antranikian, G. Comparative analysis and biochemical characterization of two endo-β-1,3-glucanases from the thermophilic bacterium *Fervidobacterium* sp. *Catalysts* **2019**, *9*, 830. [CrossRef]
6. Tahir, H.M.; Raja Abd Rahman, R.N.Z.; Leow, A.T.C.; Ali, M.S.M. Expression, characterisation and homology modelling of a novel hormone-sensitive lipase (HSL)-like esterase from *Glaciozyma antarctica*. *Catalysts* **2020**, *10*, 58. [CrossRef]
7. Aregger, D.; Peters, C.; Buller, R.M. Characterization of the novel ene reductase Ppo-Er1 from *Paenibacillus polymyxa*. *Catalysts* **2020**, *10*, 254. [CrossRef]
8. Shah, M.V.; Antoney, J.; Kang, S.W.; Warden, A.C.; Hartley, C.J.; Nazem-Bokaee, H.; Jackson, C.J.; Scott, C. Cofactor F_{420}-dependent enzymes: An under-explored resource for asymmetric redox biocatalysis. *Catalysts* **2019**, *9*, 868. [CrossRef]
9. Nagaraja, A.A.; Charton, P.; Cadet, X.F.; Fontaine, N.; Delsaut, M.; Wiltschi, B.; Voit, A.; Offmann, B.; Damour, C.; Grondin-Perez, B.; et al. A machine learning approach for efficient selection of enzyme concentrations and its application for flux optimization. *Catalysts* **2020**, *10*, 291. [CrossRef]
10. Pham, M.L.; Tran, A.M.; Kittibunchakul, S.; Nguyen, T.T.; Mathiesen, G.; Nguyen, T.H. Immobilization of β-galactosidases on the *Lactobacillus* cell surface using the peptidoglycan-binding motif LysM. *Catalysts* **2019**, *9*, 443. [CrossRef] [PubMed]
11. Bracco, P.; van Midden, N.; Arango, E.; Torrelo, G.; Ferrario, V.; Gardossi, L.; Hanefeld, U. *Bacillus subtilis* lipase A—Lipase or esterase? *Catalysts* **2020**, *10*, 308. [CrossRef]
12. Guillotin, L.; Assaf, Z.; Pistorio, S.G.; Lafite, P.; Demchenko, A.V.; Daniellou, R. Hydrolysis of glycosyl thioimidates by glycoside hydrolase requires remote activation for efficient activity. *Catalysts* **2019**, *9*, 826. [CrossRef]
13. Liu, Z.; Piccirilli, A.; Liu, D.; Li, W.; Wang, Y.; Shen, J. Deciphering the role of V88L substitution in NDM-24 metallo-β-lactamase. *Catalysts* **2019**, *9*, 744. [CrossRef]
14. Schwardmann, L.S.; Schmitz, S.; Nölle, V.; Elleuche, S. Decoding essential amino acid residues in the substrate groove of a non-specific nuclease from *Pseudomonas syringae*. *Catalysts* **2019**, *9*, 941. [CrossRef]
15. Perugino, G.; Strazzulli, A.; Mazzone, M.; Rossi, M.; Moracci, M. Effects of random mutagenesis and in vivo selection on the specificity and stability of a thermozyme. *Catalysts* **2019**, *9*, 440. [CrossRef]
16. Sonnendecker, C.; Zimmermann, W. Change of the product specificity of a cyclodextrin glucanotransferase by semi-rational mutagenesis to synthesize large-ring cyclodextrins. *Catalysts* **2019**, *9*, 242. [CrossRef]
17. Yang, Y.; Liu, M.Z.; Cao, Y.S.; Li, C.K.; Wang, W. Low-level organic solvents improve multienzyme whole-cell catalytic synthesis of myricetin-7-*O*-glucuronide. *Catalysts* **2019**, *9*, 970. [CrossRef]
18. Milessi-Esteves, T.S.; Corradini, F.A.S.; Kopp, W.; Zangirolami, T.C.; Tardioli, P.W.; Giordano, R.C.; Giordano, R.L.C. An innovative biocatalyst for continuous 2G ethanol production from xylo-oligomers by *Saccharomyces cerevisiae* through simultaneous hydrolysis, isomerization, and fermentation (SHIF). *Catalysts* **2019**, *9*, 225. [CrossRef]

19. Cang, R.; Shen, L.Q.; Yang, G.; Zhang, Z.D.; Huang, H.; Zhang, Z.G. Highly selective oxidation of 5-hydroxymethylfurfural to 5-hydroxymethyl-2-furancarboxylic acid by a robust whole-cell biocatalyst. *Catalysts* **2019**, *9*, 526. [CrossRef]
20. Noshahri, N.G.; Fooladi, J.; Syldatk, C.; Engel, U.; Heravi, M.M.; Mehrjerdi, M.Z.; Rudat, J. Screening and comparative characterization of microorganisms from iranian soil samples showing ω-transaminase activity toward a plethora of substrates. *Catalysts* **2019**, *9*, 874. [CrossRef]