INDOX — Result In Brief

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Going back to nature for greener production

The EU-funded INDOX project has made an important contribution to Green Chemistry by exploring enzyme technology and biocatalytic processes for manufacturing production.

The chemical industry has long recognised that it could look to nature in the form of living cells for industrial production that is more environmentally friendly. An important sector of industrial chemistry that relies on oxidation/reduction processes and oxidative enzymes (oxidoreductases) is of special interest to carry out synthetic transformations.

However, the chemical industry has not yet embraced enzymatic oxidation reactions due to the lack of biocatalysts with the required selectivity, availability and compatibility with rigorous process conditions. INDOX has provided relevant industrial oxidative enzyme scenarios to demonstrate the efficacy of optimised biocatalysts on targeted reactions. It also outlined the scalability, sustainability and cost-efficiency of the processes, versus the traditional chemical conversion processes.

Developing proof-of-concept scenarios

INDOX explored oxidoreductases for their application in target reactions of interest to the chemical industry. Project coordinator Prof. Angel T. Martínez explains, ‘the choice of oxidation reactions as a focus area is important, as some oxidations can be very difficult to manage even with modern synthesis tools. Enzymes may not only offer a more sustainable route to produce industrial chemicals, but might even be able to offer more cost-effective and selective routes for their manufacture.’

The project selected the most promising enzyme candidates from the groups of heme-peroxidases/peroxygenases, flavo-oxidases and copper-oxidoreductases from fungal genomes, and then used protein engineering tools, assisted by computational analyses, to improve their catalytic properties and/or increase their robustness. Additionally, several approaches were followed to optimise the reaction conditions and reactor configurations (including immobilisation technologies and new enzyme cascade reactions).

Martínez cites the 100 % conversion of biomass-derived 5-hydroxymethylfurfural into 2,5- furandicarboxylic acid (FDCA) in a smart cascade reaction combining two oxidative enzymes, as an example of how this approach was successful. ‘FDCA has been identified as one of 12 ‘platform chemicals’ (together with succinic and other organic acids, 3-hydroxybutyrolactone, glycerol derivatives, sorbitol and xylitol) and can be utilised as a sustainable alternative for production of a range of high volume polymers, e.g. polyester and polyamides. The current chemical technology for FDCA production has low selectivity, leading to undesirable by-products that decrease the yield of polymer production, a problem that could be overcome using our
One of the novel approaches of INDOX was that the oxidative enzymes it worked with were fungal oxidoreductases, which unlike other enzyme types investigated for this purpose, are relatively new to the scientific community. Martínez comments, ‘this has led to some bottlenecks in trying to showcase their efficacy in relevant industrial applications for the manufacture of bulk chemicals and large volume specialty chemicals, which has been the main objective of the INDOX project.’

Towards greener chemistry

INDOX has created a collection of new oxidative biocatalysts that have been lab-tested, providing a proof of concept for several target reactions such as oxyfunctionalisation of aliphatic and aromatic compounds, coupling of phenols and other aromatics to produce polymers and dyes, decolorisation of dyes and oxidative modification of lignin.

Getting complex molecules for specialty chemicals through the identification and engineering of specific enzymes is a near impossible task for chemical synthesis. When this ability is combined with an improvement in production efficiency (e.g. by modifying low cost raw materials in low-temperature, energy efficient and selective processes) using enzymes becomes a key ‘green chemistry’ ingredient, boosting efforts to increase the sustainability of production processes.

Work has continued beyond INDOX. Funding now comes from the Bio-based Industries Joint Undertaking initiative, a public-private partnership between the EU and the Bio-based Industries Consortium operating under Horizon 2020.

**Subjects**

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