Chapter 84
Laccase Catalysis:
A Green Approach in Bioactive Compound Synthesis

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ABSTRACT

The search for cost-effective and environmental benign practices for the production of bioactive compounds has gained considerable attention since last decade, due to increasing demand of eco-friendly processes. Many industries have started adopting routes for the development of green chemistry by employing enzymatic approaches to overcome the limitations of physico-chemical methods and environmental concerns. Laccase is one such enzyme which has gained considerable attention in recent years as a biocatalyst in organic synthesis. Laccases possess versatile biochemical properties and the reactions catalyzed by laccase require only molecular oxygen with concomitant release of water as a byproduct. They have been widely used for reactions such as dimerization, polymerization, coupling, and grafting reactions and for antibiotic modifications. This chapter summarizes the advances that have been made in developing technologies based on laccase mediated reactions in the field of medicine, agriculture, food, and pharmaceuticals.

INTRODUCTION

The development of bioprocesses for producing bioactive compounds has received superior attention in recent years due to their enormous applications of these compounds in food, pharmaceutical and chemical industries. The bioactive compounds are present in small quantities in plants and food products (Kris-Etherton, Hecker, Bonanome, Coval, Binkoski, Hilpert, … & Etherton, 2002), sponges (Müller, Grebenjuk, Le Pennec, Schröder, Brümmer, Hentschel, ... & Breter, 2004), bacteria and fungi (Debbab, Aly, Lin, & Proksch, 2010). They are supposed to be beneficial and nutritionally rich, thus making

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them a key functional component in nutraceuticals. The market value of these compounds is likely to increase by 7.03% over a period of 5 years (2013-2018). Commonly observed bioactive compounds are mainly secondary metabolites which include antibiotics, phenolic compounds, food grade pigments, growth factors, mycotoxins and alkaloids (Hölker, Höfer, & Lenz, 2004). In last few years, bioactive compounds and their method of synthesis have been intensively studied for the benefits they provide to human health such as anti-oxidant, anti-allergic, anti-inflammatory and anti-mutagenic properties (Ham, Kim, Moon, Chung, Cui, Han, ... & Choe, 2009; Parvathy, Negi, & Srinivas, 2009), decrease in frequency of degenerative diseases like diabetes and cancer (Kim, Shin, & Jang, 2009; Martins, Aguilar, Garza-Rodriguez, Mussatto, & Teixeira, 2011), and reduction in threat of cardiovascular diseases (Jiménez, Serrano, Tabernero, Arranz, Díaz-Rubio, García-Diz, ...& Saura-Calixto, 2008). Apart from their use in pharmaceutical sector, they are also being employed in food industry for functional food (nutraceuticals) production, in chemical industries, agrochemicals, geo-medicine, cosmetics and nano-bioscience (Guaadaoui, Benaicha, Elmajdoub, Bellaoui, & Hamal, 2014).

There are several methods that are being employed for the production and recovery of bioactive compounds some of which include, use of microwave and ultrasound assisted techniques, fermentation techniques, solid liquid extraction in heat-reflux systems using organic solvents, use of supercritical fluids and, high pressure practices (Markom, Hasan, Daud, Singh, & Jahim, 2007; Martins, Aguilar, Garza-Rodriguez, Mussatto, & Teixeira, 2010). However, these physico-chemical processes are low yielding, energy demanding and often lead to generation of excessive amounts of waste showing adverse effect on the environment (Kudanga, Nyanhongo, Guebitz, & Burton, 2017). The 12 Principles of Green Chemistry framed by Anastas and Warner (1998) guides the chemists in scheming safer and environmentally benign chemical compounds and processes. Many of these principles are based on the elimination and reduction of waste generation. The standard metrics such as E-factor are being used for assessing the waste generation, it measures kilogram of waste produced per kilogram of product formed, thereby highlighting the inefficiencies of any process (Sheldon, 1992). It is reported that the amount of waste generated per kilogram of any fine chemical or pharmaceutical product synthesis was 5-100 times higher than the desired product (Li & Trost, 2008). To overcome the waste generation associated with any process environmental concerns have created an awareness in encouraging the use of green methods in pharmaceutical industries (Constable, Dunn, Hayler, Humphrey, Leazer Jr, Linderman, ... & Zaks, 2007; Kudanga, Nyanhongo, Guebitz, & Burton, 2017), leading to the development of newer, eco-friendly and cost effective practices for bioactive compound synthesis.

In chemical processes, catalysis is an important foundational pillar of green chemistry (Anastas & Warner, 2001). The use of catalysts in chemical transformations significantly reduces the amount of chemicals required and also the amount of waste generated during a process, thus fulfilling both environmental and economic objectives (Cannatelli & Ragauskas, 2017). Biocatalysts, or enzymes, are gaining a notable attention in organic synthesis, as they are very active in aqueous solvents at room temperature, non-toxic, and biodegradable. They can be easily obtained from the biological systems and involve less process steps during a reaction. Unlike classical chemical catalysts, enzymes are typically highly selective, a quality which is important for the synthesis of therapeutically valuable compounds (Maugh, 1984). Thus, nowadays research has been focused on the use of microorganisms, isolated enzymes and other natural resources for the generation of fuels, valuable materials, and chemicals.