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Silica-based monoliths functionalized with peroxidase as bifunctional tools for industrial and environmental applications

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PURPOSE OF THE ABSTRACT
The high concentration of wastes in urban areas and the modern recycling policies have allowed the collection of bio-organic matter in well-confined spaces, favouring the possible utilization of urban biowastes as source of energy and materials.
The lignin-like fraction obtained after the composting process of urban biowastes contains a lot of organic substances similar to humic acids. In particular, from the humid fraction of urban wastes a mixture of soluble bio-based substances (BBS) can be isolated [1].
These substances are constituted by long aliphatic carbon chains, partially substituted by aromatic rings and containing several functional groups. The potential use of BBS deriving from food waste as a cost-effective source of bio-based products was also reported [2]. A non-exhausted list of potential fields of application for BBS includes: textile industry, detergency, agriculture, polluted soil washing, wastewater treatment and material science.
The possibility to develop environmental friend alternative to existing materials induced us to study the employ of BBS in different kinds of systems useful in removal of water pollutants. In particular, we reported the preparation and characterization of stable and effective biocatalysts obtained by covalent bonding of Soybean peroxidase on silica monoliths prepared from commercial siliceous powders by using BBS as binding agent [3-4]. This way it is possible to combine the environmentally friend reuse of waste to prepare technological tools with the efficiency and the affordability of reusable enzymes.
In this work we explored the efficiency of these systems in the removal of water pollutants and show as it is possible to obtain promising results taking advantage of the co-operative effect of the adsorbing properties of the material and the enzymatic catalysis. Moreover, the immobilization on monoliths give to Soybean peroxidase an unusual resistance to the thermic denaturation permitting its use in a wider set of experimental conditions.
Several monoliths were synthesized (figure 1) with a previously reported procedure [2] by mixing BBS and two silica powders with different hydrophilicity (Sipernat320 and Aerosil300 by Evonik) in different percentage. The samples were initially characterized by nitrogen adsorption in order to determine surface area and porosity. Then their breaking load was measured in order to assess their mechanical resistance in case of practical applications. Furthermore their adsorption properties were studied by adsorption microcalorimetry and UV-visible spectroscopy. The results show as the adsorption properties depend both from the relative amount of the two silicas and the different surface properties induced by the presence of BBS. In fact, the adsorption properties of the monoliths are stronger than those of the silica powders alone.
Some monoliths, chosen on the basis of their adsorption properties, were functionalized with Soybean peroxidase by means of the aminopropyltriethoxysilane/glutaraldehyde method [3,4]. The catalytic properties of these biocatalysts were successively tested with different substrates and in the depuration of two real wastewaters supplied by a textile fabric. The results show as the enzymatic action contributes to the decolourization of the test solutions and, in the presence of a mixture of coloured waste, the total bleaching is guaranteed by the join action of surface adsorption and enzymatic degradation (figure 2).

Finally, the thermal denaturation of a biocatalyst was studied and the results compared with the modification in the protein conformation observed by FTIR spectroscopy. Surprisingly, even after heating at 150°C, immobilized Soybean peroxidase maintain its secondary structure unchanged and retains a part of its initial activity.

FIGURES

FIGURE 1

Silica-based monoliths

Image of monoliths synthesized by BBS and silica powder. The scale is in centimeters.

FIGURE 2

Bleaching of a real waste

Progressive decolourization of a textile fabric waste treated with functionalized monoliths.

KEYWORDS

monolith | peroxidase | wastewater | adsorption

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