Chemical Engineering Journal 214 (2013) 8–16

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Application of chitosan films for the removal of food dyes from aqueous solutions by adsorption

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HIGHLIGHTS

- The adsorption of food dyes onto chitosan films was studied.
- The Redlich–Peterson model was the best to fit the equilibrium data.
- The maximum adsorption capacity was 194.6 mg g^{-1}.
- The adsorption process was spontaneous, favorable and exothermic.
- Chitosan films were easily separated from the liquid phase after the adsorption.

ARTICLE INFO

Article history:
Received 16 September 2012
Received in revised form 20 October 2012
Accepted 22 October 2012
Available online 30 October 2012

Keywords:
Acid red 18
Adsorption
Chitosan films
FD&C blue no. 2
Phase separation

ABSTRACT

Chitosan films were applied to remove acid red 18 and FD&C blue no. 2 dyes from aqueous solutions. The films were prepared by casting technique and characterized. Batch adsorption equilibrium experiments were carried out at different temperatures (298–328 K). Freundlich, Langmuir and Redlich–Peterson models were fitted to the experimental data. The thermodynamic parameters (ΔG^0, ΔH^0 and ΔS^0) were also estimated. Kinetic study was realized using pseudo-first order, pseudo-second order and Elovich models. The possible films–dyes interactions were investigated by Fourier transform infrared spectroscopy, differential scanning calorimetry and color parameters. The maximum experimental adsorption capacities were 194.6 mg g^{-1} and 154.8 mg g^{-1} for the acid red 18 and FD&C blue no. 2, respectively, obtained at 298 K. It was found that the Redlich–Peterson isotherm model presented satisfactory fit with the experimental data ($R^2 > 0.98$ and ARE < 9.00%). The adsorption process was spontaneous, favorable, exothermic, and occurred by electrostatic interactions. The Elovich model was the more appropriate to represent the adsorption kinetic data ($R^2 > 0.95$ and ARE < 5.00%). The chitosan films maintained its structure and were easily separated from the liquid phase after the adsorption process.

1. Introduction

Dyes are extensively used in food industries to improve the sensorial aspects of its products [1]. Due to losses in the process, a considerable amount of these food dyes are present in the industrial effluents [2]. Dyes are visible to human eye and therefore, a highly objectionable type of pollutant on aesthetic grounds. They also interfere with the transmission of light and upset the biological metabolism processes which cause the destruction of aquatic communities present in ecosystem [3]. Therefore, the dye-containing effluents from the food industries should be carefully treated before discharge. Several techniques have been used to treat dye-containing effluents [3–7]. Among these, adsorption with chitosan is considered an alternative eco-friendly technology in relation to the existing costly water treatment technologies due to low initial cost, ease of operation, insensitivity to toxic substances, and complete removal of dyes from dilute solutions [7–10].

Chitosan is a polysaccharide composed by polymers of glucosamine and N-acetyl glucosamine [7]. Due to the advantages, coupled with its biocompatibility and biodegradability, chitosan has been successfully used by several researchers as an adsorbent for the capture of dissolved dyes from aqueous solutions [7–16]. However, it is very difficult to remove the dyes adsorbed by chitosan from aqueous phase after the adsorption process [7]. An alternative to solve this problem is the development of chitosan based materials, which can facilitate the phase separation after adsorption [17].

Among the chitosan based materials (nanoparticles, gel beads, membranes, films, sponge, fibers or hollow fibers) [17], chitosan films are an attractive way to removal pollutants from aqueous solutions, mainly due its good mechanical properties [18–21]. Recently, chitosan films were applied for the removal of lead [18,19],

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http://dx.doi.org/10.1016/j.cej.2012.10.027