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Methylene blue biosorption from aqueous solutions by yellow passion fruit waste

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Abstract

The yellow passion fruit (*Passiflora edulis* Sims. f. *flavicarpa* Degener) (YPFW) a powdered solid waste, was tested as biosorbent for the removal of a cationic dye, methylene blue (MB), from aqueous solutions. Adsorption of MB onto this low-cost natural adsorbent was studied by batch adsorption at 25 °C. The effects of shaking time, biosorbent dosage and pH on adsorption capacity were studied. In alkaline pH region the adsorption of MB was favorable. The contact time required to obtain the maximum adsorption was 48 h at 25 °C. Four kinetic models were tested, being the adsorption kinetics better fitted to pseudo-first order and ion exchange kinetic models. The ion exchange and pseudo-first order constant rates were 0.05594 and 0.05455 h^{-1}, respectively. The equilibrium data were fitted to Langmuir, Freundlich, Sips and Redlich–Peterson isotherm models. Taking into account the analysis of the normal distribution of the residuals (difference of $q_{measured} - q_{model}$), the data were best fitted to Sips isotherm model. The maximum amount of MB adsorbed on YPFW biosorbent was 44.70 mg g^{-1}.

Keywords: Biosorbent; Low-cost adsorbent; Yellow passion-fruit waste; Methylene blue; Aqueous solution; Batch adsorption; Isotherm models

1. Introduction

The removal of color from aquatic systems caused by presence of synthetic dyes is extremely important from the environmental viewpoint because most of these dyes are toxic, mutagenic and carcinogenic [1]. The release of colored waters into the ecosystem is a source of aesthetic pollution, also causing perturbation to aquatic life [2]. Several methods have been developed to remove synthetic dyes from waters and wastewaters in order to decrease their impact on the environment. The processes developed consist in decolorizing by photocatalytic oxidation, microbiological or enzymatic decomposition and adsorption on inorganic or organic matrices [3]. The most commonly used adsorbent to remove dyes from waters and wastewaters is activated carbon [4], but due to the relatively high operating costs, such as regeneration of the used adsorbent had limited application on a larger scale [5]. Thus, the use of an inexpensive adsorbent to remove dyes from waters and wastewaters, which does not require previous pre-treatment, has been object of study [5].

Non-conventional adsorbents, including natural materials such as waste from agro-industrial activities, have been used successfully, used as alternative low-cost adsorbents for the removal of several dyes from aqueous solution [6–11]. For example, several studies on the removal of methylene blue using various kinds of these non-conventional materials have been reported, such as: the adsorption on, chromium waste sludge [11], fibrous clay minerals [12], natural sepiolite [13], marine green alga [14], de-oiled-soya and bottom ash [15], fly ash [16], on Indian rosewood sawdust [17], on several agricultural wastes such as cotton hulls, coconut tree sawdust, sago waste, maize cobs and banana piths [18], cassava peel [19]; rice husk [20] and maize waste [21].

In a previous study [22], we reported of statistical design of experiments to optimize the best conditions for dye, methylene blue, removal from aqueous solution using yellow passion fruit waste (YPFW – *Passiflora edulis* Sims. f. *flavicarpa Degener*). This previous work was a base for optimizing the batch adsorption conditions carried out in this work, where basically all

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Nomenclature

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a_{RP}	the Redlich–Peterson constants $(mg\,l^{-1})^{-\beta}$
A^+	is the adsorbate
$[A^+]$	the molar concentration of the ions A^+
B	is the adsorbent matrix
C^+	is the ion released to the aqueous solution after exchange process
$[C^+]$	the molar concentration of the ions C^+
Co	the initial dye concentration put in contact with the adsorbent $(mg\,l^{-1})$
Ce	the dye concentration at the equilibrium $(mg\,l^{-1})$
dq	differential of q
F	is the fraction attained of equilibrium at time t, obtained by ratio between the amount adsorbed $(mg\,g^{-1})$ at time t and at infinite time $(F = q_t/q\infty)$
h_o	the initial sorption rate (h_o, expressed in $mg\,g^{-1}\,h^{-1}$)
k_1 and k_2	are the forward and reverse specific rate constants (h^{-1})
k_f	pseudo-first order rate constant (h^{-1}).
k_s	is the pseudo-second order rate constant $(g\,mg^{-1}\,h^{-1})$.
K_F	the Freundlich constant related with adsorption capacity $[mg\,g^{-1}\,(mg\,l^{-1})^{-1/n}]$
K_L	the Langmuir affinity constant $(l\,mg^{-1})$
K_{RP}	Redlich–Peterson constants $(l\,g^{-1})$
K_S	the Sips constant related with affinity constant $(mg\,l^{-1})^{-1/n}$
m	the mass of adsorbent (g)
n	dimensionless exponents of Freundlich and Sips equations
n_{AB} and n_{BC}	the moles of A^+ and C^+ adsorbed on the adsorbent. $E = n_{AB} + n_{BC}$
q	amount adsorbed of adsorbate by the adsorbent $(mg\,g^{-1})$
q_e	is the adsorption capacity in the equilibrium $(mg\,g^{-1})$
q_t	is the amount of adsorbate adsorbed at time t $(mg\,g^{-1})$
Q_{max}	the maximum adsorption capacity of the adsorbent $(mg\,g^{-1})$
S	the ion exchange constant rate (h^{-1})
t	time of contact (h)
V	the volume of dye put in contact with the adsorbent (l)

Greek letters

α	the initial adsorption rate $(mg\,g^{-1}\,h^{-1})$ of Elovich equation
β	Elovich constant related to the extent of surface coverage and the activation energy involved in chemisorption $(g\,mg^{-1})$
β	The Redlich–Peterson exponent (dimensionless)

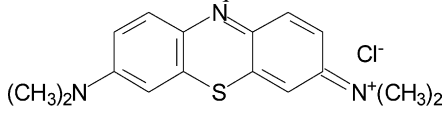
the parameters optimized using statistical tools were in agreement with the parameters optimized using univariate analysis, as already reported for several adsorption systems [23–26], however the kinetics and equilibrium studies were not shown in the previous study. The yellow passion fruit is cultivated on a large scale in Brazil and it has an agronomic importance because the fruits are widely used *in nature* or in a processed form as concentrated juice [27,28]. The by-products resulting from juice processing represent major disposal problem for industry and the environment. Thus, its reutilization is of great interest.

In this work, we are continuing our studies, exploring the potential use of yellow passion-fruit waste (YPFW) as a biosorbent to remove methylene blue (MB) dye from aqueous solutions. The important parameters such pH, kinetics and equilibrium isotherm studies were carried out to complement the usability of YPFW as an alternative and low-cost adsorbent.

2. Experimental procedure and methods

2.1. Solutions and reagents

The cationic dye, methylene blue (MB) (CI 52030, $C_{16}H_{18}N_3SCl$) was obtained from Sigma Chemical Co., USA, with analytical grade that was used without further purification. The stock solution was prepared by dissolving accurately weighted dye in distilled water to the concentration of $1000\,mg\,l^{-1}$. The working solutions were obtained by diluting the dye stock solution to the required concentrations.



Structural formula of methylene blue.

In order to adjust the pH solutions, $0.10\,mol\,l^{-1}$ sodium hydroxide or hydrochloric acid solutions were used, using a pH-meter Digimed Model DM 20 for the measurements.

2.2. Preparation and characterization of biosorbent

Yellow passion-fruit were purchased at local marked. The waste peel was removed and the colleted biosorbent was extensively washed with water, dried under sunlight for 48 h. Afterwards, the yellow passion peel was crushed in a knife-mill. The resulting material was sieved, and the portion with particle diameter lower than 250 μm, was subsequently washed with doubly distilled water for 10 min, and then dried in an oven at 60 °C for 24 h. Powdered material was preserved in the desiccator and used in the adsorption studies.

Yellow passion-fruit waste (YPFW) was characterized by FTIR using a Shimadzu FTIR, model 8300 (Kyoto, Japan). The spectra were obtained with a resolution of $4\,cm^{-1}$, with 100 cumulative scans.

The specific surface area of biosorbent was determined by the Brunauer, Emmett and Teller (BET) multipoint technique,