Yeast residues activated carbon: nanomodification with magnetite for adsorption of pesticides

J. L. Ramos[1], J. O. F. Monteiro[1], G. Labuto[2], E. N. V. M. Carrilho[1,3]

[1]Laboratory of Polymeric Materials and Biosorbents, Federal University of São Carlos, Araras, São Paulo, 13600-970, Brazil.
[2]Department of Chemistry, Federal University of São Paulo, Diadema, São Paulo, 09913-030, Brazil.
[3]Department of Nature Sciences, Mathematics and Education, Federal University of São Carlos, Araras, São Paulo, 13600-970, Brazil.
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Presenting author email: elma.carrilho@gmail.com

Introduction

Pesticides are chemical compounds widely used to control pests and plant diseases. The use of pesticides in commercial agriculture has led to an increase in agricultural productivity. Pesticides are indispensable in modern agricultural practices, however, even in low concentrations, due to their high toxicity, carcinogenic nature and high persistence in ecosystems, they are considered a great threat to the environment and health, classified as emerging pollutants, presenting low biodegradability, which hinders its elimination in wastewater treatment plants and leads to its frequent presence in treated effluents (Cengiz et al., 2006; Sanz-Santos et al., 2021). With this, adsorption arises, which has the advantages of high efficiency, low cost, availability, controllability and is being expanded as an efficient alternative to conventional methods of removing pollutants (Mohammadi et al., 2021). Due to its large surface area and high adsorption capacity, activated carbon is one of the most effective adsorbents that can be produced from abundant, low-cost products precursors, whose nanomodification allows to obtain nanoscale biomass particles in order to improve sorption properties (Özsin et al., 2019; Mamani et al., 2013). This work aims to evaluate the potential of a biosorbent produced with residues from the sugar and alcohol industry, yeasts, nanomodified with magnetite (Fe_3O_4) for its use in the removal of the thiamethoxam pesticide from contaminated waters.

Methods

Preparation of magnetite nanoparticles (NP) and yeast activated carbon magnetic nanocomposite (YAC-NP): To synthesize magnetite nanoparticles (NP), the coprecipitation method was used (Panneerselvam et al., 2011). For this, solutions of Fe (II) and Fe (III) salts were diluted in 1 mol/L HCl and agitated constantly. Then, NH_4OH 0.7 mol/L was added by dripping, while the temperature was increased to 80 ºC for 30 min. Afterwards, yeast activated carbon (YAC) was added to the solution for its nanomodification with ferromagnetic particles, thus forming yeast activated carbon magnetic nanocomposite (YAC-NP) with paramagnetic properties.

Sortion pH: This test proceeded with the mixture of 10 mL of 10 mg/L Thiamethoxam (TMX) solutions (previously adjusted with HCl or NaOH 0.1 mol/L to pH values 2, 3, 4, 5, 6, and 7) and 10 mg of YAC-NP. The mixtures were kept under constant agitation at 185 rpm for 10 minutes and the supernatants were collected and analyzed by Ultraviolet–visible (UV–vis) Spectroscopy (Genesys, 10S, Thermo Fisher Scientific, USA), at a previously chosen wavelength. The tests were performed in duplicate.

Kinetic studies: To perform the kinetic studies for TMX, 10 mg of YAC-NP were mixed with solutions containing 10 mg/L of TMX, in pH previously defined, under constant agitation (185 rpm), at intervals of 5, 10, 20, 30, 40 and 60 minutes. After different contact times between adsorbents-adsorbate, the supernatants were collected and analyzed to determine non-adsorbed TMX in each time studied, by UV-Vis Spectroscopy. Kinetic models of pseudo-first and pseudo-second order reactions were applied to the data. The tests were performed in duplicate.

Results and discussion

In Figure 1, it is possible to observe that the results for the sorption of TMX by YAC-NP was favorable for all pH values tested, in which values close to the percentage of pesticide removal were obtained, with removal efficiency of TMX between 42% to 52%. Thus, with the similar adsorption of TMX in the tested pH values, thinking in industrial applications, it was chosen to use the pH value of the solution without changes (pH = 5.6) to facilitate studies and possible future applications on a large scale.

With regard to kinetic studies, it is possible to verify that the percentage of removal of the pesticide by the adsorbent was fast at the beginning, indicating a sorption efficiency already in the first 5 minutes, in which equilibrium was reached after 30 minutes of contact, where there was removal about 58% of the pesticide (Figure 2A). The quick removal of the adsorbate and the equilibrium reach in a short period of time indicate that the adsorbent is efficient. In addition, it is possible to view the experimental data and adjustments to the kinetic models of pseudo-first and pseudo-second order (Figure 2B).

It is possible to observe that for the retention of TMX by YAC-NP, the material revealed that the pseudo-second order equation provided the best adjustments, which is suitable for represent the studied sorption phenomenon. This result reveals that the control of the speed mechanism is chemical adsorption. The pseudo-second order model is based on the adsorption capacity of the solid phase. The best adjust to this model indicates that the chemisorption has significant contribution to this process (Ho, 2006).

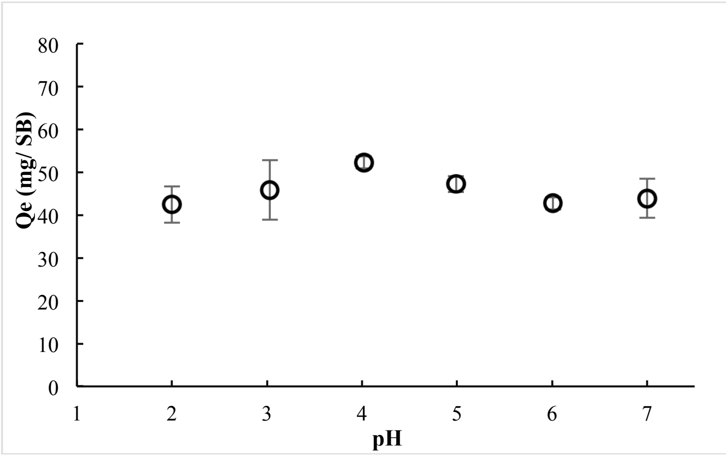

Figure 1. Effect of pH on the sorption of TMX. 10 mg of yeast activated carbon magnetic nanocomposite (YAC-NP) was mixed with 10 mL of 10 mg/L TMX solution. n = 2.

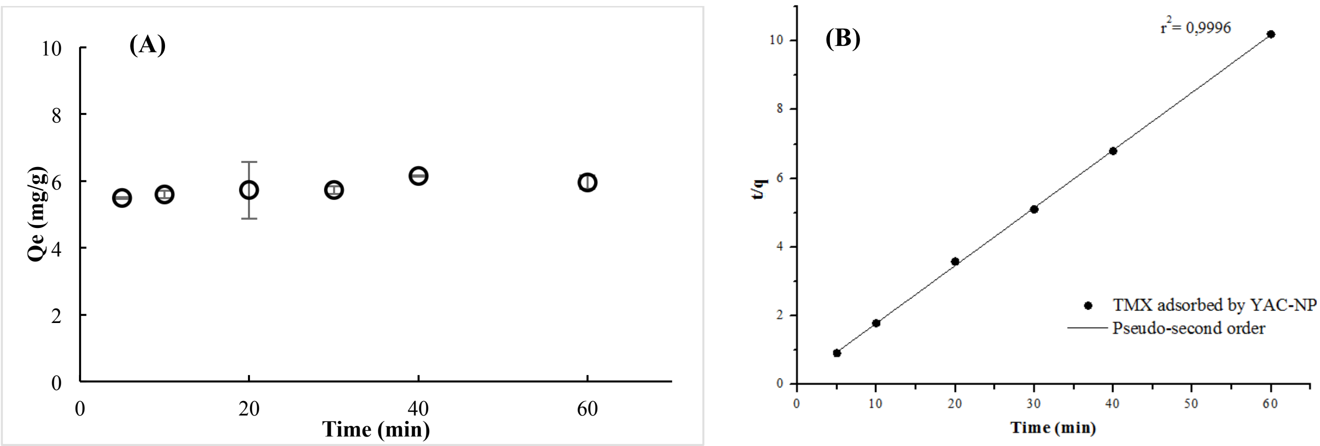

Figure 2. (A) TMX kinetics studies by YAC-NP, using 10 mg of the biosorbent with 10 mL of 10 mg/L TMX solution. **(B)** Experimental data and fittings to the pseudo-second order kinetic model. n = 2.

Conclusion

The results showed that the synthesized nanocomposite is an efficient and low-cost material that has characteristics suitable for the rapid removal of contaminants in an aqueous medium, and can easily be removed from the medium by a magnet. Thus, YAC-NP is a promising biosorbent for adsorption of the pesticide thiamethoxam and, therefore, its efficiency for the removal of some other anionic pesticides and herbicides can be investigated.

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