Black jurema bark powder as new alternative material for treatment of water containing two toxic dyes

Emprego do pó da casca de jurema preta como uma nova alternativa para o tratamento de água contendo dois corantes tóxicos

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ABSTRACT
Black jurema bark powder (BJBP) (*Mimosa hostilis* Benth) was studied for the removal of textile dyes Methylene Blue (MB) and Indigo Blue (IB) in water. The chemical and physical analysis of BJBP showed a heterogeneous surface with chemical groups capable to interact with MB and IB. The experiments were optimized for use of 1g of BJBP and stirring time of 3 minutes for IB, and 0.5g of BJBP and stirring time of 2 minutes for MB. The maximum adsorptive capacities for IB (115.21 mg/g) and MB (3.50 mg/g), obtained through the Langmuir Mathematical Model, were favorable for the use of BJBP as an adsorbent in water containing both dyes. The results obtained in this work suggest BJBP as a new alternative for the removal of IB and MB in aqueous medium. Besides, this work stimulates new studies to evaluate the BJBP adsorption capacity for other chemical pollutants.

Keywords: black jurema bark powder, water, adsorption, dyes

RESUMO
O pó de casca de jurema preta (BJBP) (*Mimosa hostilis* Benth) foi estudado para a remoção dos corantes têxteis Azul de Metileno (MB) e Índigo Blue (IB) em água. As análises fisicoquímicas do BJBP revelaram um material detentor de superfície heterogênea e de grupos químicos capazes de interagir com MB e IB. Os resultados mostraram que a melhor porcentagem de adsorção de IB ocorreu com o emprego 1g de BJBP e tempo de agitação de 3 minutos. Já em relação à MB, isto se deu com o emprego de 0,5g de BJBP e tempo de agitação de 2 minutos. As capacidades máximas adsortivas (CMAs) para IB (115,21 mg / g) e MB (3,50 mg / g), obtidas através do Modelo Matemático de Langmuir, revelaram que BJBP é capaz de remover esses dois corantes a partir da água. Aliadas a outros parâmetros fisicoquímicos, as CMAs justificam a necessidade de estudos mais avançados que possam sugerir, com segurança, o BJBP como uma nova alternativa para remoção de IB, MB e outros poluentes presentes em água.

Palavras-chave: água, corantes, jurema, adsorção

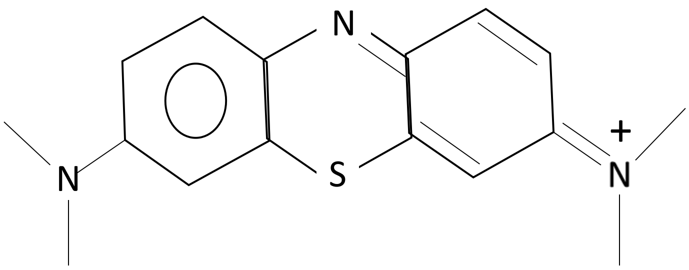
1 INTRODUCTION

Considering the industrial expansion and populational development, environmental problems became increasingly constant and excessive, making the soil, water and air negatively influenced by the quantity of waste generated (Naidu et al., 2021). Within this context, the amount of effluent generation by textile industries stands out, which, in case it is not remedied, can cause serious problems regarding environmental contamination (Han et al., 2016), negatively affecting the absorption of light by photosynthesizing organisms, and increasing the possibility of contamination of water treatment plants (Guaratini and Zanoni, 2000). Besides, the contact with dyes can generate several health problems to humans, such as dermatitis (Hatch and Maibach, 1995), respiratory problems (Ozkurt et al., 2012) and cancer (Singh and Chadha, 2016). Among the dyes used by industry and other different sectors, methylene blue (MB) stands out (Figure 1), a dark green colored compound that, when dissolved in an aqueous medium, produces a color dark blue. This compound can be used as a bactericide (Li et al., 2016), and drug for malaria, encephalopathy, and vasoplegic syndrome. In neonates MB dye provoke respiratory depression, pulmonary edema, phototoxicity, and severe hemolytic anemia. In Adults, MB can cause dizziness, delirium, and headaches (Bistas and Sanghavi, 2021). Another dye also widely used is the indigo blue (IB) (Figure 1). The IB is one of the oldest known dyes to mankind, being used in the dyeing of cellulosic fabrics, such as the cotton used in the production of jeans (Meksi et al., 2007). The IB dye its chemical derivatives can represent a problem for natural water source and public health (Ribeiro et al., 2021). Taking into consideration the generated problems by the dyes, technologies that can remove it from water are extremely important. Several of those techniques have been studied, such as biodegradation (Manimekalai and Swaminathan, 2000), photodegradation (Giraldo and Restrepo, 2004), ozone treatment (Kunz et al., 1999) and the adsorption process (Carneiro et al., 2019; Ribeiro et al., 2019). The latter method being the focus of this work. Adsorption is a phenomenon of adhesion of molecules from a fluid (the adsorbed or adsorbate) to a solid surface (the adsorbent) (Foo and Hameed, 2010). The use of activated carbon (AC) as an adsorptive agent is one of the best-known methods for removing dyes from aqueous medium (Santana et al., 2018), however, its cost is what restricts its use, resulting in the search for natural adsorbents that have the same efficacy but are also financially viable (Gupta, 2009). Several studies suggest the natural adsorbents for the treatment of effluents polluted by drugs (Ribeiro et al., 2016), metals (Pereira and Arruda, 2003), and dyes (Kubra et al., 2021). Adsorption processes, using natural adsorbents, provide satisfactory results when used for the removal of different type of dyes (Brito et al., 2010).

Some studies have already been performed using natural adsorbents, as in the case of the use of Brazil nut husk for the removal of methylene blue and indigo carmine dyes (Brito et al., 2010), in the use of sugar-cane bagasse for the treatment of water containing congo red (Raymundo et al., 2010), in the use of vermicompost for congo red and indigo blue dyes removal (Ribeiro et al., 2021), in the use of *Ziziphus Joazeiro* pell for indigo blue adsorption (Ribeiro et al., 2019), and others (Gupta, 2009). Within this scenario would be black jurema bark powder (BJBP) a new alternative for dyes effluents treatment? *Mimosa hostilis* Benth, popularly known as black jurema, is a typical plant from the caatinga, found mainly in northeastern Brazil and very known in Latin American countries. Some parts of the jurema, such as the leaf and the bark, have been popularly used for the treatment of burns or allergies (Camargo-Ricalde, 2000). Studies have shown its various uses, such as anti-inflammatory, antioxidant and antibacterial activities and other therapeutic purposes (Souza et al., 2008; Costa et al., 2009). However, no reports of its use as a natural adsorbent were found until the realization of this study. Therefore, the objective of this work was to evaluate BJBP as a new natural adsorbent for the removal of MB and IB dyes (Figure 1) present in aqueous solutions (Figure 2). For this, the following steps were necessary: a) evaluation of the physicochemical properties of the BJPB's surface using scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR), b) study on the influence of adsorbent's mass, stirring, and contact time between BJPB and the dyes, c) influence of the dyes concentration in the adsorptive process and, finally, d) application of the appropriate mathematical model to obtain the BJPB's maximum adsorptive capacity (MAC) for the MB and IB and others important physicochemical parameters. These experiments were necessary for the validation of BJPB as a new probable and efficient alternative for the treatment of water containing MB and IB.

Figure 1. Chemical structures of MB (A) and IB (B).

(A)



(B)

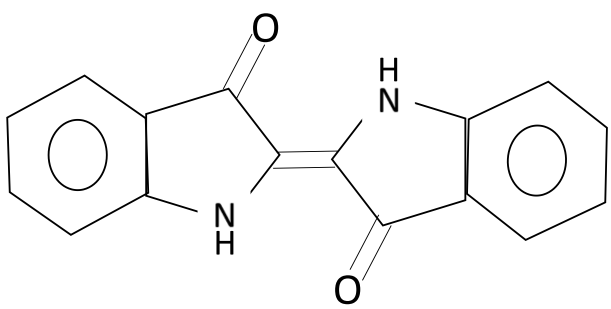


Figure 2. Aqueous solutions of 15 mg/L MB (A) and 800 mg/L IB (B)

(A) **(B)**

2 MATERIAL AND METHODS

2.1. MATERIALS

The dye's solutions were prepared in water with pH around 7.0, values for colour around 4 mg PT-Co/L (Hazem Unity), total dissolved solids (160 mg/L), and turbidity 2.17 NTU (Nephelometric Turbidity Unity) in accordance with the requirements of the National Council for the Environment (Conama, 2004). The IB and MB dyes were purchased from Tupy Industry (Sao Paulo-SP, Brazil) and Neon Chemical Industry (Suzano-SP, Brazil) respectively. For physical chemistry analysis were utilized a sputter coater (Shimadzu, IC-50 Ion Coater model, Japan), a scanning electron microscope (Shimadzu, SSX 550 model, Japan), and infrared spectrophotometer (Cary 630 model, Agilent Technologies, Santa Clara, California, USA). For drying the adsorbent, a laboratory oven was used (Quimis Q-317 B model, Brazil). The pH of aqueous solution dyes was monitored around 7.0 utilizing a pH meter from PHTEK, Labitec, Londrina-PR, Brazil. The BJBP's particles size (< 0.425 mm) was obtained using particles size sieves from Granutest Cequimica, Fortaleza-CE, Brazil. For absorbance's dyes analysis a UV/Vis spectrophotometer (Even, IL-562 model, Brazil) was used. For data processing, a graphical/statistical program Origin version 6.1 was utilized (Origin Lab Corporation, Northampton, MA 01060, United States). For mass measurements and aqueous solutions agitation was necessary an analytical balance (Shimadzu AY 220 model, Japan), and magnetic stirrer (Warmnest, 78HW-1 model, Canada) respectively. To separate the adsorbent from the solution was necessary the microcentrifuge EVLAB EV026 Model

(Londrina, PR, Brazil). This last step was used to replace common filtration because the filter paper adsorbs the MB dye.

2.2 METHODS

2.2.1. Preparation of BJBP

To clean up the BJBP, 300 mg of this natural adsorbent was washed sometimes in distilled water, containing pH around 7.0. The washes were realized until obtain minimal absorbance values at 573 and 665 nm (maximal absorbance of IB and MB respectively) for wash water. These minimal absorbance values indicating reduction in the chemical interferents concentrations from BJBP, which absorb light between 573 and 665 nm. The adsorbent material was filtered and dried at 60°C for 48 hours until obtain invariable values of mass. This adsorbent was sieved to obtain particles with sizes smaller than 0.425 mm. After sieving, the BLBP looks like a very fine powder (Figure 3). The powder was stored in a transparent plastic bag (Figure 4) and kept in a desiccator.

Figure 3. BJBP after drying and sieving.

Figure 4. Transparent plastic bag for BJBP storage.

2.2.2. Physicochemical characterization of BJBP through SEM and FTIR

At this stage, the surface morphology of the BJBP was evaluated. The sample prepared in step 2.2.1 was covered with a thin layer of gold, through a sputter coater and later analyzed in a scanning electron microscope (SEM). A 10 kV electron beam was used in this analysis, which made it possible to obtain microphotographs of BJBP surface's physical structure. For the next stage, it was evaluated, through infrared spectroscopy (FTIR), the presence of chemical groups in the BJBP capable of interacting with the pollutants and retaining them. To confirm it, the crushed material was placed in a laboratory oven to dry (60 ºC for 24 hours) and storage in a desiccator to remove any remaining moisture for another 24 hours. Posteriorly, the samples were placed in an attenuated total reflectance accessory (ATR-manual press) in order to be compacted for the FTIR analysis. The experiment was carried out between wavelengths of 650 to 4000 cm^{-1} (16 scans) and pressure of 0.5 tons. The resolution was 4.0 cm^{-1} and the interval 1.0 cm^{-1}. These experiments were realized as described in other studies (Ribeiro[A] et al., 2016; Ribeiro[B] et al., 2016; Ribeiro et al., 2021).

2.2.3. Influence of mass and stirring and contact time in the adsorption percentage dyes by BJBP

This experimental step was performed to select the BJBP's mass and stirring and contact time that provide the highest percentage adsorption dyes. For this, 25.00 mL of aqueous solutions of IB (1,000 mg/L) or MB (25 mg/L) were prepared in water with pH around 7.0, temperature around 298.15 K, values for colour around 4 mg PT-Co/L (Hazem Unity), 160 mg/L of total dissolved solids, and turbidity around 2.17 NTU (Nephelometric Turbidity Unity). Different masses (0.25, 0.5, 0.75, 1.0, 1.5, 1.75, 2.0,and 3.0 g) of adsorbent were added in these aqueous dye solutions. These solutions were stirred at 800 rpm at different contact times (0.5, 1.0, 2.0, 3.0, 4.0, 6.0, 8.0, 9.0, and 10.0 minutes). After the stirring and contact time, 2.0 mL of each solution was centrifuged at 13,000 rpm for 3 minutes. The supernatant was removed, and its absorbance was determined in an UV/Vis spectrophotometer at 573 and 665 nm for IB and MB respectively. To calculate the concentration of dyes in the supernatant (*Cds*) were utilized the equations of the straight line of the standard curves (Figure 5) of both dyes. To calculate the percentage of adsorbed dyes (*%Ad*) by BJBP, were utilized the equations 1 and 2 respectively:

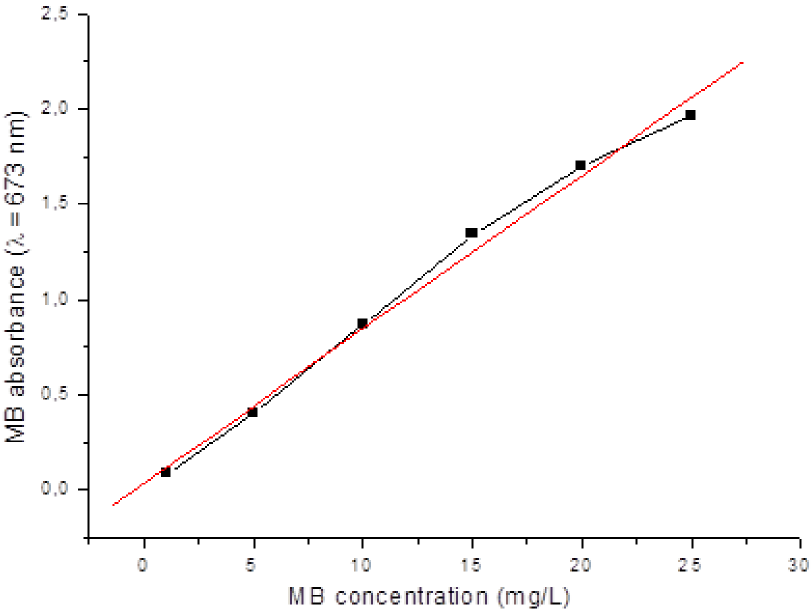
$$Cad = Idc - Cds \quad (1)$$

$$Ci \text{ ---------- } 100\,\% \quad (2)$$

$$Cad \text{ --------- } \%Ad$$

In which *Cad* represents the dye concentration adsorbed by BJBP adsorbent, *Idc* represents initial dye concentration before BJBP mass addiction and stirring and contact time, *Cds* represents the concentration of dyes in the supernatant after centrifugation, and *%Ad* represents the percentage of adsorbed dyes by BJBP. These experiments were performed in triplicates and using analytical blanks for each BJBP mass and stirring and contact time. The analytical aqueous solutions blanks consisted of 25.00 mL of water with pH around 7.0, values for colour around 4 mg PT-Co/L (Hazem Unity), total dissolved solids (160 mg/L), and turbidity 2.17 NTU (Nephelometric Turbidity Unity) in the presence of BJBP’s masses and stirring and contact times mentioned above.

Figure 5. Example of the standard curves of MB to calculate the *Cds* value. R = 0.9958. For each experiment a standard curve was obtained.



2.2.4. Influence of IB and MB concentration in the adsorptive process and application of Langmuir Mathematical Model for obtain of the maximal adsorption capacity and others physicochemical parameters.

MB and IB aqueous solutions (25 mL) were prepared in water with pH around 7.0 with temperature around 298.15 K, values for colour around 4 mg PT-Co/L (Hazem Unity), 160 mg/L of total dissolved solids, and turbidity around 2.17 NTU (Nephelometric Turbidity Unity). The adsorbent masses and the stirring and contact times were optimized in item 2.2.3. The BJBP's masses for IB and MB were 1.0 and 0.5 g respectively. The solutions containing IB concentration between 200 and 4,000 mg/L and MB between 25 and 400 mg/L were stirred at 800 rpm for 3 and 2 minutes for IB and MB respectively. After the stirring and contact time, 2.0 mL of each solution were centrifuged at 13,000 rpm for 3 minutes for both dyes. The supernatant was removed, and its absorbance was determined in an UV/Vis spectrophotometer at 573 and 665 nm for IB and MB respectively. The same conditions were established for blank of each dye. For this, the analytical aqueous solutions blanks consisted of 25.00 mL of water with pH around 7.0, values for colour around 4 mg PT-Co/L (Hazem Unity), total dissolved solids (160 mg/L), and turbidity 2.17 NTU (Nephelometric Turbidity Unity) in the presence of 1.0 or 0.5 g of BJBP’s and 3 or 2 minutes of stirring and contact times optimized in 2.2.3

item. From results obtained in the experiments of concentration dyes variation was possible to obtain the maximum adsorption capacity (MAC), the variation of Gibbs free energy (ΔG), the Langmuir constant (K_L), and the dimensionless constant (R_L). In addition, through results obtained for these parameters was possibly to know the adsorption mechanism between BJBP and dyes, as well as the efficiency of BJBP as natural adsorbent.

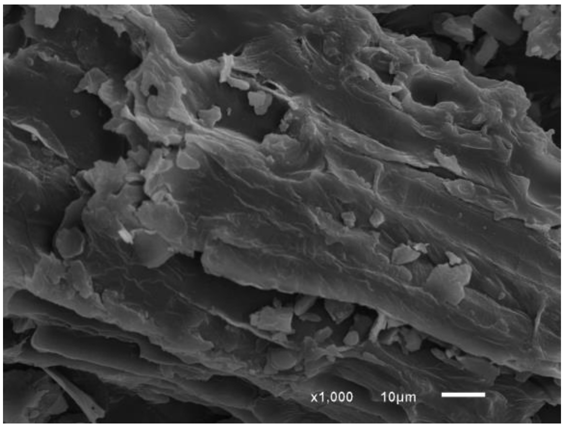
3 RESULTS AND DISCUSSION

3.1. PHYSICOCHEMICAL CHARACTERIZATION OF BJBP THROUGH SEM AND FTIR

The images obtained in this work through scanning electron microscopy (SEM) (Figure 6) are like other results available in the scientific literature (Pereira & Arruda, 2003; Pereira et al., 2009; Brito et al., 2010; Ribeiro[A] et al., 2016; Ribeiro[B] et al., 2016; Ribeiro et al., 2019; Ribeiro et al., 2021). Generally, the natural adsorbent's surface has many irregularities and concavities that increase the contact surface. These characteristics contribute for more favorable physical interactions between adsorbent and chemical pollutants in aqueous medium (Pereira et al., 2009; Ribeiro et al., 2021). However, not only physical interaction is responsible for adsorption between pollutants and adsorbent material. Chemical interactions can be occurred between functional groups of adsorbent and pollutants (Chaari et al., 2015). Therefore, we performed FTIR analysis to identify the presence of functional chemical groups in the BJBP. The chemical composition of all parts of the plant is complex. Studies have revealed the presence of chalcones, steroids, terpenoids such as triterpenoid saponins, phenoxychromones, alkaloids, and others (Souza et al., 2008). However, all chemical classes mentioned are secondary when compared to the presence of biomacromolecules such as cellulose, hemicellulose, lignin, and proteins. These macromolecules have several functional groups capable of interacting with chemical pollutants (Ribeiro et al., 2019). The massive presence of these macromolecules increases the signal intensities of some know functional groups that composite many natural adsorbents (Ribeiro[A] et al., 2016; Ribeiro[A] et al., 2018; Ribeiro et al., 2019; Ribeiro et al., 2021). The FTIR spectrum profile of BJBP (Figure 7) presented several similar bands obtained from the *Glycyrrhiza glabra* L. root powder, other material absorbent previously studied for textile dyes removal (Ribeiro[A] et al., 2018). The BJBP's spectrum revealed the broad band at 3250 cm^{-1} from O-H stretching. This band probably is present on compounds with axial deformation due to intermolecular hydrogen bonds. We also identified the C-H stretching from methyl group at 2918 cm^{-1} and probably C=O (carbonyl) at 1605 cm^{-1}. The bands at 1507 cm^{-1} and 1448 cm^{-1} were attributed to C = C ring stretching probably due to aromatic compounds present in the BJBP. The presence of C-O group was also detected at approximately 1023 cm^{-1}, probably due to axial deformation present in C-O-C system (Wong, 2015; Favaro et al., 2018). The asymmetric C-O-C stretch was identified at 1155 cm^{-1}. These chemical groups cited can be capable to interact with the IB and MB dye molecules acting as a absorbent material.

Figure 6. SEM images of BJBP's surface x1,000 (A) and x5,000 (B) with scale of 10 and 5 μm respectively.

(A)



(B)

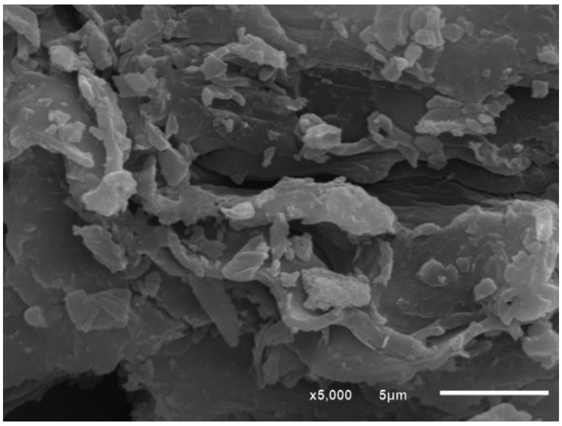
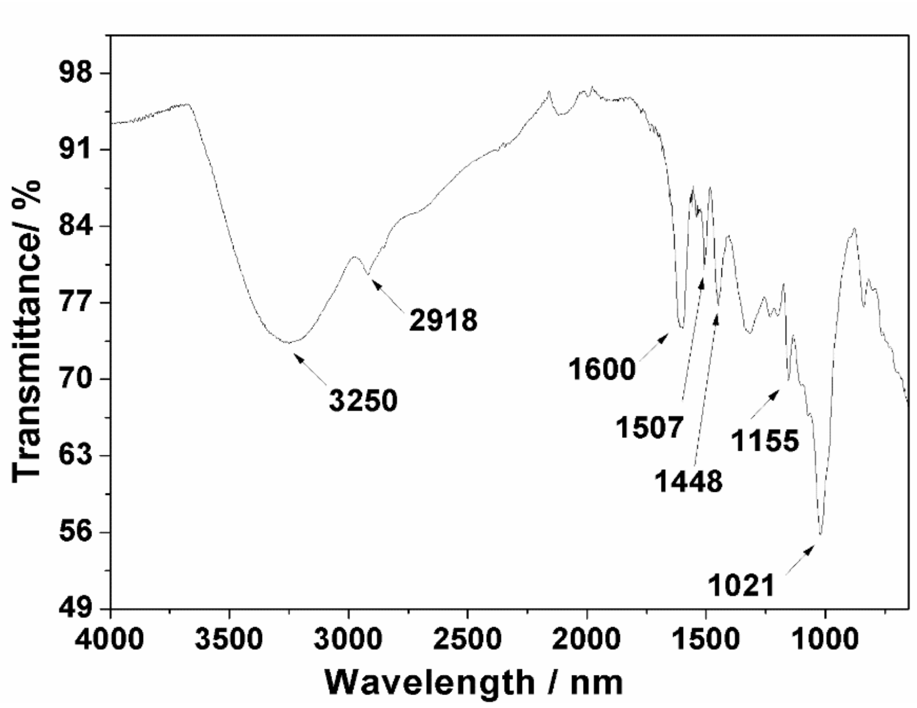


Figure 7. IR of BJBP obtained by FTIR spectroscopy

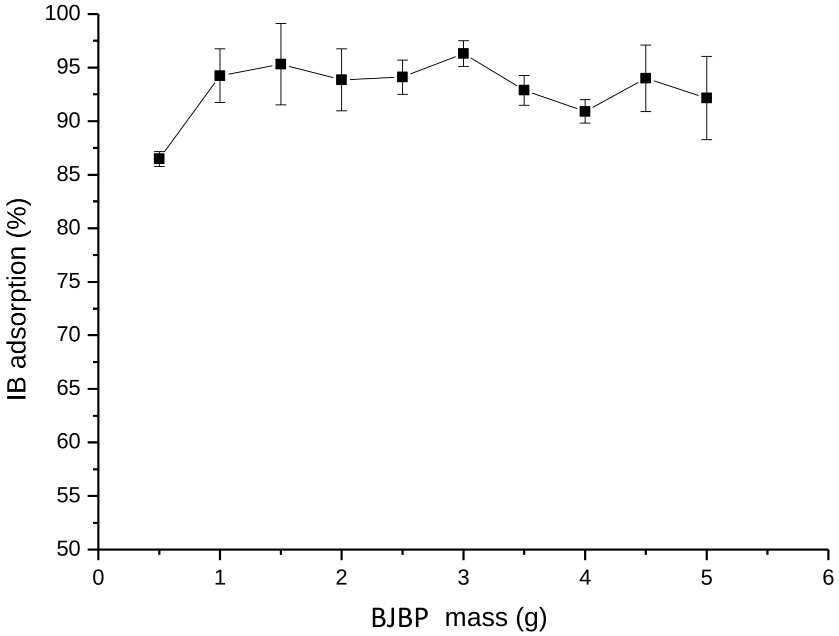


3.2. INFLUENCE OF MASS AND STIRRING AND CONTACT TIME IN THE ADSORPTION PERCENTAGE DYES BY BJBP

It's necessary to obtain the mass of adsorbent for the maximal dye adsorption. Besides it's also necessary the determination of the stirring and contact time between adsorbent and dyes, which occur the major adsorption. The optimization of these parameters it's very important for obtain the maximum adsorption capacity and other physical chemistry parameters that can describe the characteristics of adsorption between BJBP and both dyes. Considering the means and standard deviations was determined that the better BJBP's masses for IB and MB adsorption were around 1.0 and 0.5 g respectively (Figure 8). The two graphs reveal that increases in amount of BJBP's mass provoke increase in adsorption percentage of both dyes until an equilibrium conditions. Similar kinds of graphics of mass influence on adsorption process were observed by other authors that studied the adsorption of chemical pollutants by natural adsorbents (Pereira et al., 2009; Ribeiro[A] et al., 2016; Ribeiro et al., 2019). The increase of adsorbent mass provoke increase in the adsorptive sites that interact with dyes until interaction equilibrium establishment. It's more evident in the interaction between BJBP and MB than the interaction between this natural adsorbent and IB. (Figure 8). Regarding the percentage of adsorption due to the stirring and contact time between the adsorbent and both dyes, the results can be seen in Figure 9. In both experiments was determined the equilibrium time for physical, chemical, or both kinds of reactions between BJBP and both dyes. The determined times were 3.0 and 2.0 minutes for IB and MB respectively. Many times, this kind of experiment provide similar graphics as obtained in this work (Pereira et al., 2009; Sircar et al., 2011; Yang et al., 2016; Ribeiro[B] et al., 2018). However, sometimes, the equilibrium is not obtained why can occur increase and decrease of adsorption percentage along reaction. This event represents adsorption and desorption of adsorbate by adsorbent. This kind of event was observed, for example in the adsorption of congo red by sugarcane bagasse (Raymundo et al., 2010) and indigo blue and congo red adsorption by vermicompost (Ribeiro et al., 2021).

Figure 8. Influence of BJBP's mass on adsorption of IB (A) and MB (B).

(A)



(B)

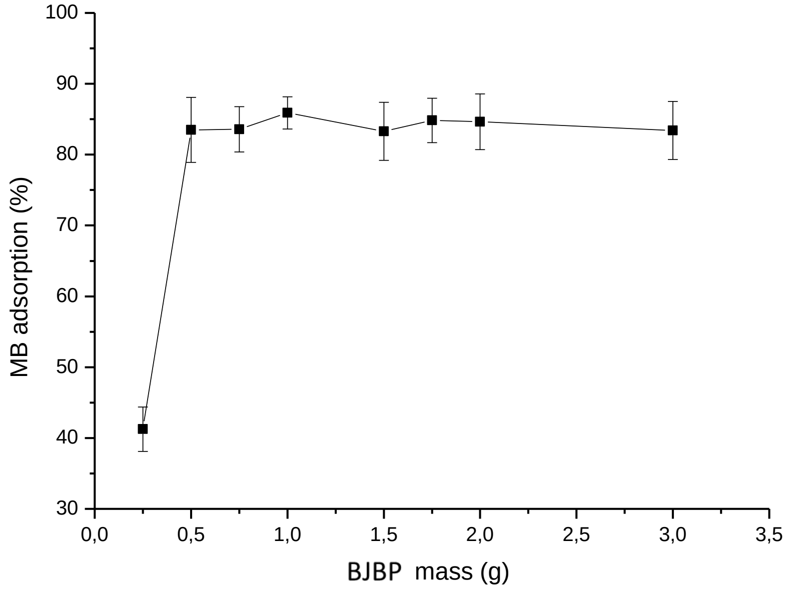
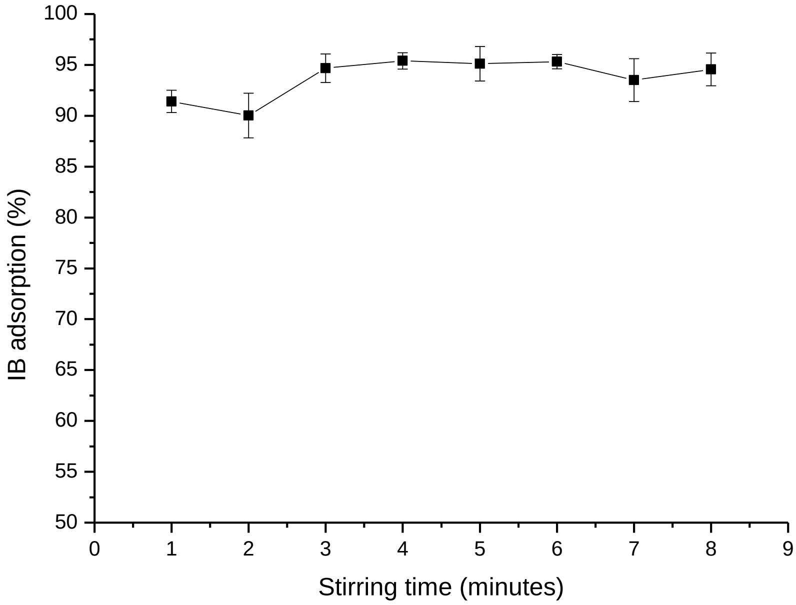
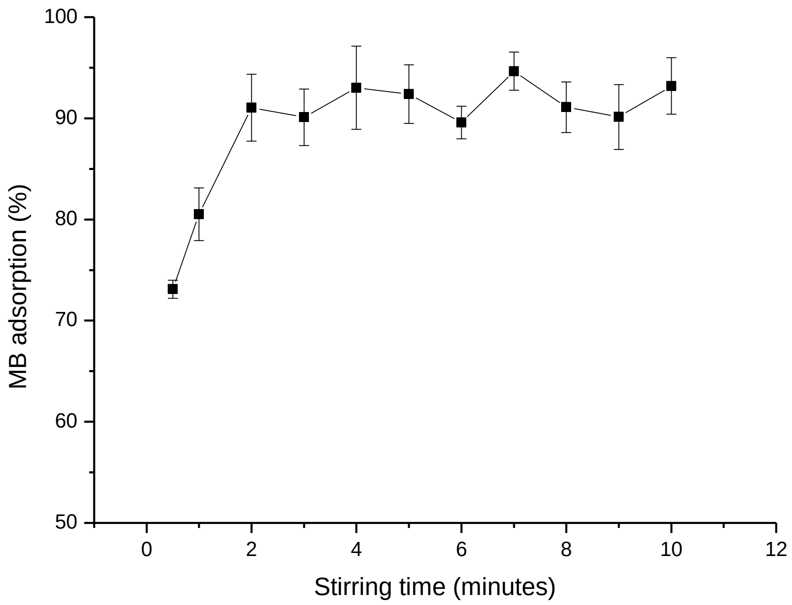


Figure 9. Influence of stirring and contact time on adsorption of IB (A) and MB (B) by BJBP

(A)



(B)

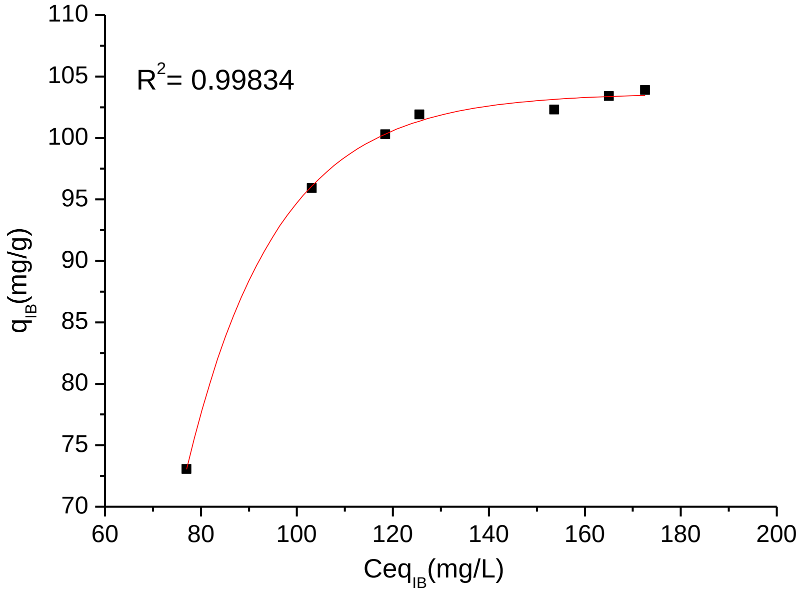


3.3. INFLUENCE OF IB AND MB CONCENTRATION IN THE ADSORPTIVE PROCESS AND APPLICATION OF LANGMUIR MATHEMATICAL MODEL FOR OBTAIN OF THE MAXIMAL ADSORPTION CAPACITY AND OTHERS PHYSICOCHEMICAL PARAMETERS

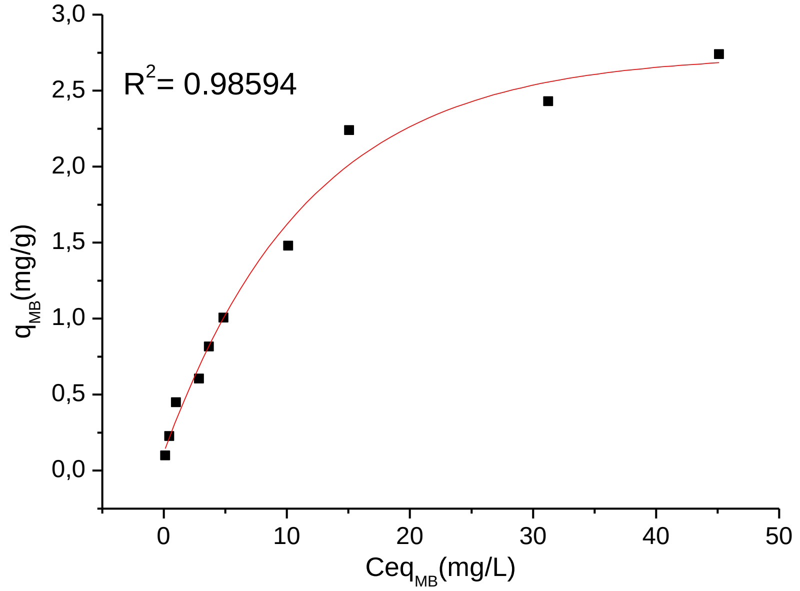
The Langmuir's Mathematical Model (Langmuir, 1916) allowed obtaining the main parameters that determined the BJBP's efficiency to adsorb MB and IB. Before the calculus of these parameters, the results obtained from the dyes concentration variation allowed to obtain two no linearized graphics to IB and MB respectively (Figure 10).

Figure 10. No linearized isotherms for adsorption of IB (A) and MB (B) respectively by BJBP adsorbent.

(A)



(B)



The graphics from Figure 10 can be described by equation 3:

$$q_D = K_{LD} . MAC_D . Ceq_D . (1 + K_{LD} . Ceq_D) \quad (3)$$

In this equation, D represents IB or MB, q_D represents the amount (mg/g) of dye retained in determined adsorbent mass optimized previously (Figure 8), MAC_D represents the maximum adsorption capacity (mg/g) of BJBP for IB or MB, Ceq_D represents the equilibrium concentration of dyes no adsorbed by BJBP (mg/L), and finally K_{LD} represents the Langmuir constant (L/mg), which is related to the adsorption energy (Ribeiro et al., 2021). In the Figure 10, the R square values obtained for IB (0.99834), and MB (0.98594) demonstrate the occurrence of favorable adsorption process between BJBP and both dyes (Bayramoglu et al., 2009). Furthermore, these adsorption isotherms are like the L model (Giles et al., 1960). In this model the amount of adsorbent adsorption sites diminishes with the pollutant mass increase (Giles et al., 1960). The linearization of previously isotherms (Figure 10) made it possible to obtain two linearized isotherms for IB and MB (Figure 11) that can be described by following equation 4:

$$Ceq_D / q_D = (K_{LD} . MAC)^{-1} + (MAC)^{-1} . Ceq_D \quad (4)$$

Where Ceq_D / q_D against Ceq_D of IB resulted in:

$$Ceq_{IB} / q_{IB} = (K_{LIB} . MAC_{IB})^{-1} + (MAC_{IB})^{-1}. Ceq_{IB} \quad (4)$$

$$Ceq_{IB} / q_{IB} = 0.1595 + 0.00868.Ceq_{IB} \text{ with } R^2 = 0.99756 \quad (4A)$$

To determine the MAC_{IB} value for IB adsorption by BJBP was necessary the use of angular coefficient (AC) value (0.00868) trough of following equation:

$$MAC_{IB} = 1/AC \quad (5)$$

$$MAC_{IB} = 1/0.00868 = 115.21 \text{ mg/g}$$

This value is very significant in comparison to others present in the literature (Ribeiro et al., 2021).

For the determination of K_{LIB} value was utilized the equation 6 containing linear coefficient (LC) value (0.1595) and MAC_{IB} value (115.21 mg/g):

$$K_{LIB} = 1 / (LC \,.\, MAC_{IB}) \quad (6)$$

$$K_{LIB} = 1 / (0.1595 \,.\, 115.25)$$

$$K_{LIB} = 0.0544 \text{ L / mg}$$

The value of K_{LIB} allowed the obtain of the $\Delta G_{1IB/BJBP}$ value trough equation 7,

$$\Delta G_{IB/BJBP} = - RTlnK_{LIB} \quad (7)$$

Where ΔG is the variations of Gibbs free energy related R is the universal gas constant (8.314472 J/mol . K), T is related as the temperature in Kelvin (298.15 K), and K_{LIB} is a constant for the adsorption or binding energy (L/mol). For use of equation 7 it's necessary to convert the units of K_{LIB} in L/mol, wich IB's molecular weight is 262.26 g/mol. Therefore, the value of $\Delta G_{IB/BJBP}$ for interaction between IB and BJBP was – 23.71 KJ/mol. This value demonstrates that the interaction between IB and BJBP is a spontaneous process (Atkins et al., 2018). Additionally, it is possible to obtain the value of another parameter known as a dimensionless constant (R_L). R_L is a parameter that allow to know if the adsorption process is favorable or unfavorable. The values between 0 and 1 indicates favorable adsorptions, while $R_L > 1$ is related with unfavorable adsorptives process (Esmaeili & Beni 2014). Therefore, the equation 8 allow the obtain of R_L value between BJBP and IB,

$$R_L = 1/[1 + (K_{LIB} \,.\, C_{0IB})] \quad (8)$$

where R_L is dimensionless constant, K_{LIB} represents the Langmuir constant (L/mg), which is related to the adsorption energy between BJBP and IB, and C_0 is the initial IB concentration (200 mg/L) used for to obtain adsorption isotherm. The value obtained for

R_L (0.084) demonstrates that the adsorptive process between IB and BJBP is very favorable (Esmaeili & Beni 2014).

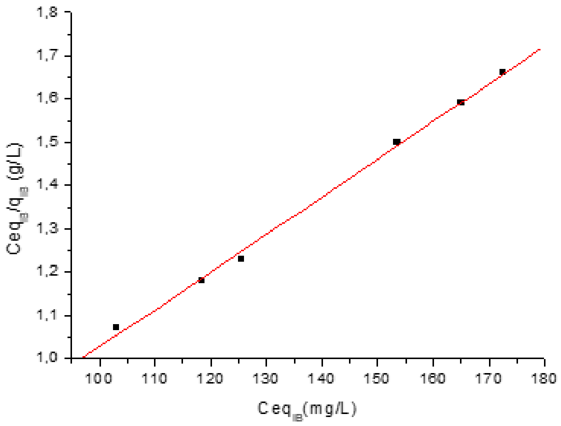
The same equations (4), (5), (6), (7), and (8) were utilized to obtain the parameters from MB adsorption by BJBP. Through the values of coefficients from linearized isotherm (equation 4B) for adsorption of MB by BJBP, and molecular weight of this dye (319.85 g/mol) was possible to obtain the same parameters obtained for IB, but with different values (Table 1).

After linearization (Figure: 11), the equation 4 ($y = a + bx$) for interaction between BJBP and MB showed the follow values for angular and linear coefficients:

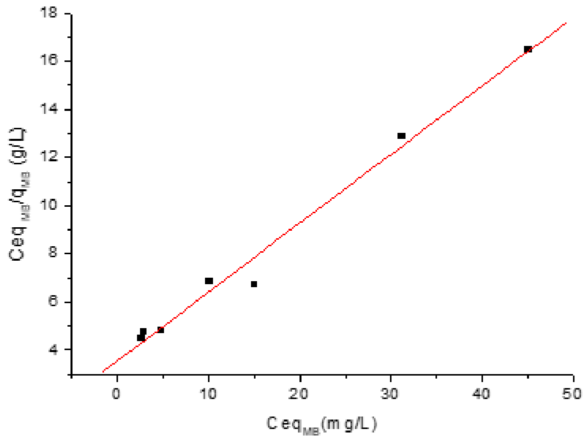
$$Ceq_{MB} / q_{MB} = 3.56611 + 0.28537.Ceq_{MB} \text{ with } R^2 = 0.98594 \quad (4B)$$

Figure 11. The linearized isotherms for adsorption of IB (A) and MB (B) by BJBP

(A)



(B)



The values presented in Table 1 reveal that the *MAC* of BJBP for IB (115.21 mg/g) is considerably more increase than *MAC's* BJBP for MB (3.50 mg/g). The structural difference between IB and MB (Figure 1) can be the motive for about it. It's possible that apolar interactions between IB and BJBP, as well as others chemical and physical interactions can be more significative than MB's interactions with this adsorbent. The MB structure can be favor to the interactions between MB and MB, and MB with water more than the interactions between MB and BJBP. These observations are according with the *RL's* values showed for both dyes (Table 1). Finally, in the Table 2, the IB MAC value is much higher than other authors. However, for MB, it's MAC value is smaller than others founded in the literature. Therefore, BJBP can be considered an excellent IB scavenger in aqueous media, but a less efficient MB scavenger than others present in the Table 2.

Table 1. Parameters obtained from adsorption of IB and MB by BJBP

Parameters	IB/BJBP	MB/BJBP
R^2	0.99756	0.98594
MAC (mg/g)	115.21	3.50
K_L (L/mg)	0.084	0.080
ΔG (KJ/mol)	-27.71	-25.16
R_L	0.084	0.333

Tabe 2. Different MAC values for IB and MB from adsorption by others adsorvents

Adsorbent	MAC for IB (mg/g)	MAC for MB (mg/g)	References
polymeric natural carbohydrate of turmeric powder (TP) adsorbent.		157.33	Kubra et al., 2021
Cellulose-derived carbon/montmorillonite nanocomposites		138.1	Tong et al., 2018
Tunics of the Corm of the Saffron		137.00	Dbik et al., 2020
Brazil nut shells		7.81	Brito et al., 2010
BJBP	115.21	3.50	In this work
Natural clay	57.00		Mahzoura et al., 2019
Activated carbon	53.00		Mahzoura et al., 2019
Zizyphus joazeiro peel	50.00		Ribeiro et al., 2019
Vermicompost	40.39		Ribeiro et al., 2021

4 CONCLUSION

The values of R^2, K_L, ΔG, *and* R_L suggest the BJBP as a new and possible alternative for IB and MB dyes removal from aqueous media. However, for MB, the MAC showed a small value when compared to the others present in the literature. For the IB adsorption this natural adsorbent can be considered very efficient to removal it and less efficient for MB removal because its small MAC value

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