REMOVAL OF DYE FROM TEXTILE WASTEWATER BY MODIFIED SUGARCANE BAGASS AS A BIOSORBENT

LOẠI BỎ MÀU THUỐC NHỘM TỪ NƯỚC THẢI DỆT BẰNG BÃ MÍA BIẾN TÍNH NHƯ MỘT CHẤT HẤP PHỤ SINH HỌC

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ABSTRACT

In this study, the sugarcane bagasse grafted with citric acid was used as a low-cost biosorbent for removal of dyes from the textile wastewater. The adsorption parameters such as initial pH values, dyes concentrations, adsorbent dosages and contact times were investigated by the batch experiments. The Freundlich and Langmuir adsorption isotherm models were used to evaluate the experimental data. The results showed that the adsorption process of dyes onto the modified sugarcane bagasse leaned towards Langmuir model for MSB and Freundlich for SB. The maximum adsorption capacity of MSB was found to be 8.40 mg/g, and at pH 9. The results showed that the modified sugarcane bagasse with citric acid could be a potential low-priced adsorbent for removal of the color from the textile wastewater.

Keywords*: *Sugarcane bagasse; adsorption; dyes; textile wastewater; isotherm models.

TÓM TẮT

Trong nghiên cứu này, bã mía được ghép với axit citric đã được sử dụng như một chất hấp phụ sinh học chi phí thấp để loại bỏ thuốc nhuộm từ nước thải dệt. Các thông số hấp phụ như giá trị pH ban đầu, nồng độ thuốc nhuộm, lượng chất hấp phụ và thời gian tiếp xúc được nghiên cứu bằng các thí nghiệm dạng mẻ. Các mô hình đẳng nhiệt hấp phụ Freundlich và Langmuir được sử dụng để đánh giá các dữ liệu thực nghiệm. Kết quả nghiên cứu cho thấy quá trình hấp phụ của thuốc nhuộm tuân theo mô hình Freundlich đối với bã mía chưa biến tính (SB), tuân theo mô hình Langmuir đối với bã mía đã biến tính bằng NaOH và acid citric (MSB). Khả năng hấp phụ tối đa của MSB là 8.40 mg /g tại pH 9. Kết quả cho thấy rằng bã mía biến tính sau khi được xử lý, biến tính bằng axit citric có thể là một chất hấp phụ tiềm năng để loại bỏ màu từ nước thải dệt.

Từ khóa: *Bã mía; hấp phụ, thuốc nhuộm; nước thải dệt; các mô hình cân bằng.*

1. INTRODUCTION

The textile industry plays an important role in Viet Nam economy. In fact, this industry has been incretely received investment. But, its fast growth leads to concerns, in environmental pollution. It was well known that the textile industry consumes a large volume of water and generates a significant amount of wastewater. The wastewater of textile industry contains toxic chemical compounds and high intensity of colors which have complicated structures that are differently treated by convenient methods [1].

There are many methods have been studied to remove the color from the textile wastewaters such as coagulation/ flocculation, flotation, adsorption, membrane filtration, oxidation and biological treatment. Among them, adsorption has been known as an efficient method to reduce the colour [2].

Microwave vacuum drying is method drying materials at low temperature, and it uses the radiation to transfer heat in an electromagnetic environment at the frequency of 2450 MHZ, significantly shortens the drying cycle [5]. The main driving force during the vacuum drying process is the pressure difference, which is generated by vacuum pumping, together with other supporting devices such as condensers, moisture separator and the measuring instruments. They allowed the options to achieve a deep vacuum, drying times and high quality product. On the other hand, at a low vacuum condition, the steam temperature of the water is very low that enhancing the process of separating moisture in dried materials, thus microwave-vacuum drying method can proceed at the temperatures lower than the ambient temperature. It helps to keep the structure, taste, nutrition, colour and shape as fresh fruit. Hence, the microwave-vacuum drying method has the superior quality, compared with other drying methods [5-6]. Moreover, it shortens the drying time and creates a significant improvement in the quality of the product, compared with other hot drying methods [7]. A major advantage of vacuum microwave drying is the short drying time, energy saving, producing better quality products and not injuring the perishable nutrients such as vitamins, amino acids, active enzymatic and pigments [8].

We need to rapidly cool the materials to a low temperature before drying. This method can be used in order to modify the structure of food. Thus, it will affect the drying kinetics which changes the structure and crispness of the products [8-9]. The optimization also can be added to select the best technology mode [10-11]. Hence, the microwave vacuum drying method always keep the nutrient loss at the lowest to make the structure better Adsorbent usually used is activated carbon, which can effectively remove types of contaminants and can be reused after regeneration process. But after each regeneration, there was a slight decrease in adsorption capacity of the activated carbon, which means after several times used, the carbon need to be replaced. The main disadvantage of this adsorbent is its price. On the other hand, the technology to produce the high quality activated carbon is complicated, expensive and hard to achieve in some developing countries [2, 3]. Therefore, many researches have been conducted to find out alternative low-cost adsorbents. To achieve this, researchers usually use adsorbent that is the waste from some industries, available at large quantity such as sawdust [1], coconut[3], orange and banana peel [4], tea waste [5, 6], walnut shell [7], sugarcane bagasse pith [8, 9]. Meanwhile, they use agricultural waste such as rubber seed coat [10], mangosteen peel [11], bagasse pith [2] to prepare low-cost activated carbon which is very potential.

Sugarcane bagasse, waste from food, sugar and beverage industries, is a potential adsorbent to remove dyes and metals. It usually is modified to enhance its adsorption capacity or used to prepare cheap activated carbon.[2, 8, 9]

In this study, sugarcane bagasse was modified by NaOH, grafted with citric acid. and then used for adsorption of the Direct Fast Turquoise Blue (FBL). Adsorption parameters such as pH, initial dye concentration, adsorbent dose, contact time were investigated by batch experiments. The experimental data obtained were modeled by Langmuir and Freundlich adsorption isotherm to elucidate the adsorption process.

2. MATERIALS AND RESEARCH METHOD

2.1. Materials

The dye used in the experiments was the Direct Fast Turquoise Blue (FBL).

2.2. Preparation of adsorbent

The clean bagasse pith selectively collected from the university's canteen was washed 2 times with distilled water, then left to dry in the oven at 60^{O}C overnight. After that, the bagasse was ground and sieved. The fraction of 0.2 – 0.45 mm sizes were collected for experiment then the material was boiled with distilled water at 100^{O}C to removal all the sugar in its structure and labeled as SB.

The sugarcane bagasse (SB) was treated with NaOH 0.1M (solid SD/solution = 1/20 w/v). The mixture was agitated at 250 rpm in 2 hours at room temperature. The mixture was filtered and washed with deionized water to neutral and dried at 55^{O}C in the oven.

In order to enhance the adsorption capacity of sugarcane bagasse, the citric acid was used for modification of the SB surface. The proportion of 25 mL solution per each gram of adsorbent was taken and added into glass beakers with capacity 250 mL. The mixture was shaken at 250 rpm overnight at room temperature. After shaking, the residue was separated and put in the oven at 60^{O}C. Again, the resulting residue was washed several times, then the material was placed in the oven at 60^{O}C again afterward. Finally, the material (modified sugarcane bagasse labeled as MSB) was used for the investigation [12].

2.3. Experimental methods

All the experiments were performed in batch mode at room temperature (31^{O}C±2). For the pH investigation, a wide range of pH (1 – 11) was used. HCl 1M and NaOH 1M were used to adjust the pH. For each pH, 0.1g adsorbent was added into of each of 50mL dye solution at concentration 20mg/L. The mixtures were shaken overnight at speed of 250 rpm.

For studying the effect of adsorbent dose, different bagasse pith dosages (0.1 – 1.2g) were added to 50mL dye solution at concentration 50mg/L, then the mixtures were shaken overnight at speed of 250 rpm. For the investigation of the effect of initial dye concentrations. The range of initial dye concentrations was from 40 to 160 mg/L. The effect of contact time was examined by added 0.4 g adsorbent to 50 mL of adsorbate at concentration 20 mg/L.

For all the experiments, the supernatant was used to check the colour removal efficient which was measured by the initial and the final concentration (C_0 and C) of the dye solution. The formula was:

$$\text{Efficiency } \% = \frac{C_0 - C}{C_0} \times 100$$

3. RESULTS AND DISCUSSION

3.1 Effect of pH

The removal efficiency of the sugarcane bagasse (SB) and the modified sugarcane bagasse (MSB) at different pH is shown in Figure 1.

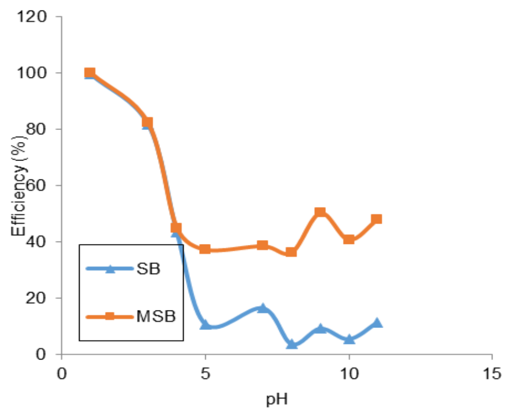

Figure 1. *The dye removal efficiency at different pH, adsorbent mass = 0.1g, C_0 = 20 mg/L.*

The results showed that the percentage of dye removal decreased with increasing pH values. At the low pH(1 – 4), the same adsorption efficiency of SB and MSB shows the modification became meaningless. When the pH reached to 5, the removal efficiency of two SB and MSB started to be different, the percentage of colour removal of MSB is higher comparing with those of SB. As shown in Fig. 1, at pH 1-2, at the dye was removed completely for both SB and MSB

At pH 9, the maximum percentage efficiency of dye removal was observed, 18% for SB and 64% for MSB. As shown in Fig. 1, at pH 1-2, the dye was removed completely for both SB and MSB.

This phenomenon can be explained that at the pH low, the dye became active and it attached to the cellulose structure of the materials. However, the adsorption process at very low pH is not usefulness due to a large amount of acid must be used to neutralize, leading to high cost of treatment. Therefore, at pH 9 was used for investigation of the adsorption process.

3.2. Effect of adsorbent dosage

Figure 2 illustrates the adsorption efficiency of the modified sugarcane bagasse at different dosages.

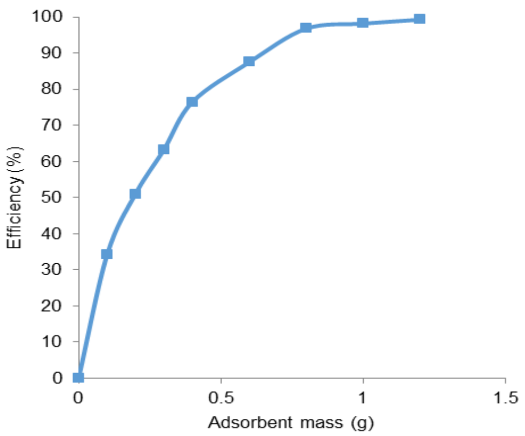

Figure 2. *The dye removal efficiency at different adsorbent dosages pH = 9, C_0 = 50 mg/L.*

It was observed that the adsorption efficiency increased with increasing the mass of the adsorbent. The percentage adsorption increased from 34.1% at a dose of 0.1g to 99.3% at a dose of 1.2g. Obviously, the more material added, the more active site for the dye to attach on. After dose of 0.4g, the adsorption reached equilibrium as the increase became stable.

3.3. Effect of initial dye concentration

Figure 3 represents the change of adsorption ability at different dye concentration. The higher initial concentration was, the less dye was removed. With the range of initial concentration was 40 – 160 mg/L, the efficiency dropped from 69% to 35.8%.

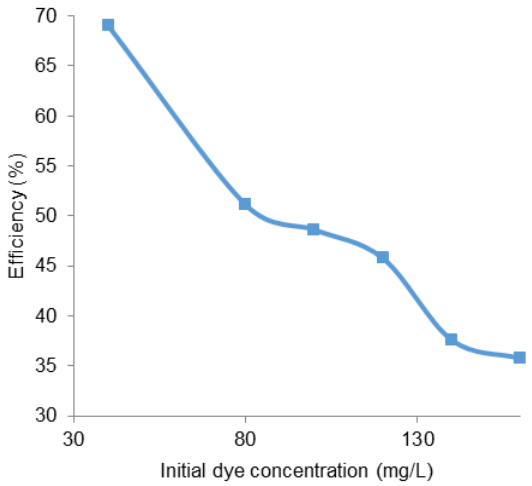

Figure 3. *The dye removal efficiency at different initial dye concentrations, pH = 9, adsorbent dose = 0.4g.*

This resulted from the surface active sites of adsorbent was limited since the dose was constant. When the color increased, there was not enough space to adsorption, which led to the decline in the efficiency.

3.4. Effect of contact time

The contact time effect on the adsorption is shown in Figure 4. As shown in the results, from 15 minutes to 4 hours, the adsorption percentage of removal increased from 72.5% to 91.5%. The longer shaken time was, the more contact between the adsorbent and the adsorbate, which means the dye had more chances to attach onto the material's cellulose chains. Hence, more dye was adsortbed, made the colour removal efficiency higher. After 15 mins, the efficiency still rose, but not much. So, 15 mins could be considered as the optimum contact time.

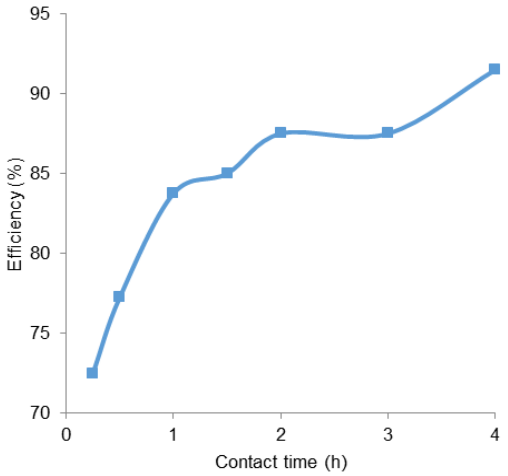

Figure 4. *The dye removal efficiency at different contact times, pH = 9, adsorbent dose = 0.4g, C_0 = 20 mg/L.*

3.5 Adsorption isotherm

Freundlich and Langmuir adsorption isotherm models were used to evaluate the experimental data. Table 1 shows the Freundlich and Langmuir isotherm parameters fixed the data. The maximum adsorptive capacity of MSB was nearly twice as SB. This improved the efficiency of the modification of MSB.

Table 1. Freundlich and Langmuir isotherm parameters.

	Parameter	SB	MSB
Freundlich	K	20.2675	0.4271
	n	1.4546	2.7273
	R^2	0.9896	0.9582
Langmuir	k_L	0.0137	0.0503
	Q_{max} (mg/g)	4.57	8.40
	R^2	0.9601	0.9848

From the R^2, the result showed that the adsorption process of both SB and MSB were followed both isotherm models. But the SB seemed to fit the Freundlich model more while MSB more fitted the Langmuir model.

The MSB's Q_{max} is compared to other adsorbents in Table 2. Comparing to other materials used to remove dyes from aqueous solution, the results showed that, the MSB can be used for removal of dyes from the textile wastewater.

Table 2. *Comparision the maximum adsorptive capacity of different adsorbents.*

Adsorbent	Q_{max} (mg/g)	Reference
Activated carbon prepared from bagasse pith	3.48	[2]
Coconut bunch waste	70.92	[3]
Banana peel	0.1808	[4]
Orange peel	0.0647	[4]
Tea waste	85.16	[5]
Modified sugarcane bagasse pith	202.43	[9]
MSB	8.396	This study

4. CONCLUSION

The normal sugarcane bagasse pith (SB) and the modified sugarcane bagasse with NaOH, citric acid (MSB) have been studied for adsorption of textile dye (FBL). The adsorption efficiency of the MSB increased with increasing the contact time while decreased with increasing the initial dye concentration The optimum condition for adsorption was pH 9, and the adsorbent mass was 0.4g. The results obtained from the studies shown that the adsorption process of MSB for the Direct Fast Turquoise Blue (FBL) followed the Langmuir and the

Freundlich isotherm models in the order of Freundlich < Langmuir. The results showed that the bagasse pith had potential to be a competitive alternative natural adsorbent.

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