Biosorption Processof Synthetic Textile Wastewater using *Bjerkandera Agusta*via Response Surface Methodology (RSM)

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Abstract. Textile industry generates large quantities of wastewater. Discharging effluent of textile industry without treatment is led to the degradation of the quality of receiving water bodies.A high color, high BOD/COD and salt (Total Dissolved Solids, TDS) load are founded in the textile wastewater. Several alternative of methods,including physico-chemical methods such as filtration, carbon activated, coagulation and chemical flocculation have been used to treat textile industry wastewater. Although these methods are effective, but they are expensive and result concentrated sludge that creates a secondary disposal problem. The passive uptake of organic and inorganic species including metals and dyes from aqueous solutions by the use of non-growing/living microbial mass or their derivatives is namely biosorption.The effects of pH, weight of biosorbent, contact time and size of biosorbent in biosorption process using *Bjerkandera adusta* in synthetic textile wastewater were investigated and optimized using response surface methodology (RSM). The optimum removal conditions were determined at pH 4, contact time 90 minutes, weight of biosorbent 3000 mg/L, and size of biosorbent 0.4 mm. Color removal of 53.55% was demonstrated, the experimental data and model predictions agreed well. In the optimization, R^2 and R^2_{adj} correlation coefficients for the quadratic model was estimated quite satisfactorily as 0.988 and 0.977, respectively.

1 Introduction

Textile dyeing processes use water in large quantities, therefore becomeone of the leading generators of liquid pollutants[1]. Textile industries involving dyeing and finishing processes are applied to fabrics that generates around 17% to 20% of industrial waste water estimated by the World Bank[2]. The treatment of waste water generated from textile industries raises a most important challenge in the protection of environment, especially in

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term of cost or quality of the final textile effluent[3]. Textile dyeing industries use sufficient amount of various dyes or auxiliary chemicals during the dyeing process and finally emits strong coloured waste water with a huge number of dye particulates /molecules[4].Textile effluents/waste waters are one of the most difficult to treat because of the presence of suspended solids, dyes, salts, additives, detergents,and surfactants in a massive amount[5].Currently, the larger class of produced synthetic dyes world wide (about 70%) are represented by azo dyes and its large amount generation might be related with its usage by diverse industrial sectors for example textile clothing,paper, cosmetics and food [6]. Various methods are being practiced for the treatment of textile effluents including physico-chemical methods like carbon activated, sedimentation, filtration, activated sludge, chemical flocculation and coagulation. Most of these methods are very effective however, some are costly and result in concentrated sludge by creating secondary disposal complication. The passive intake of organic or inorganic species liked yes and metals from aqueous environment by the application of non-living/non-growing microbial biomass including derivatives are known as biosorption. Fungi, mainly white rot fungi, are being approved for their capacity to degrade a wide range of recal citrant pollutants, such as synthetic dyes[7]. The best degradation rates were reported for *Bjerkandera adusta,* whose strain was able to entirely decolourisea large number of dyes and detoxified three synthetic waste waters [5]. *Bjerkandera adusta*, *Phanerochaete chrysosporium* and *Pleurotus ostreatus* exhibited the best decolorization properties, among thirty different basidiomycetes screened[8]. From the eighteen evaluated fungal stains, *Phanerochaete Chrysosporium, Trametes versicolor* and *Bjerkandera adusta* proved the ability to decolorize all the tested dyes [9].*Bjerkanderaadusta* with its ligninolytic enzyme production point that this strain could be promising for biotechnological development, 98% decolorization was accomplished[10]. Some pre-treatment techniques can improve the biomass adsorption capacity. Otherpre-treatment methods include autoclaving, which could break the structure of the fungus and expose the possibledye binding sites[11].

The main aim of this study is to investigate the effects of pH, weight of biosorbent, contact time and size of biosorbent in biosorption process using *Bjerkandera adusta* in synthetic textile waste water. Among the advanced relevant variable methods employed in analytical improvement, response surface methodology (RSM) was followed here. RSM wasapplied to design the experiments, develop models and determine the optimum conditions.

2 Materials and Methods

2.1 Synthetic Textile Effluent

Synthetic waste water sample with the following content was maintained: K_2HPO_4 0.58 g/L ,NH_4Cl 0.16 g/L, KH_2PO_4 0.23 g/L,$MgSO_4 \cdot 7H_2O$ 0.09 g/L,$CaCl_2 \cdot 2H_2$ 0 0.07 g/L, trace solution 1 ml/L and EDTA 0.02 g/L. The source of carbon considered in this experiment were sodium acetate (0.5 g/L), glucose (0.5 g/L) and ethanol (0.125 g/L). The composition of the trace element was $FeCl_3 \cdot 4H_2O$ (1.5 g/L), H_3BO_3 (0.15 g/L), $MnCl_2 \cdot 4H_2O$ (0.12 g/L), $ZnCl_2$ (0.12 g/L), $CoCl_2 \cdot 6H_2O$ (0.15 g/L), $CuCl_2 \cdot 2H_2O$ (0.03 g/L), $NaMoO_4 \cdot 2H_2O$ (0.06 g/L), and KI 0.03 g/L[12]. Mixed azo dyes consisted of reactive black 5, reactive blue 4 and disperse orange 2 with a total concentration of 60 mg/L was used for this study.

2.2 Biosorbents Preparation

The fungi *Bjerkandera adusta* was grown in malt extract agar (prepared in laboratoryby following the descriptions of DMZS media number 90) at a pH equal to 5.6, 25°C in stationary condition. When sporulation occurred at the end of seven days [13], and then in order to kill the fungal biomass, the fungal biomass was autoclaved for 45 min at 121 °C, 103.42 kPa [14]. Then this autoclaved nonviable biomass was thoroughly washed with double distilled water and kept in the oven at 70 ± 1 °C for 36 hours. The dry fungal biomass was after wards crushed to powder form and sieved to get a granular size of 0.2-0.6mm.

2.3 Batch Experiments

Batch experiments were operated by shaking 50 ml of synthetic textile waste water with biosorbent in a flask at 25 ± 2 °C temperature in the presence of 160 rpm shaking speed[15]. The flasks were then withdrawn and centrifuged to getliquid-solid separation, after shaking the flask for predetermined time intervals, and then ready to be analyzed. Beside color removal, the morphologicalstructure was analyzedby using scanning electron microscopy (SEM) (TM3000 Hitachi High Technologies America, USA) and chemical characterization was analyzedby fourier transform infrared (FTIR) spectroscopy (Nicolet iS10 FT-IR Spectrometer, USA).

2.4 Experimental Design

A four-factor having five-level CCD that required almost 30 experiments were used in this experiment.The variations and variables were as follows; A: pH (4-8), B: weight of biosorbents, C: contact time (30-150 minutes), D: size of biosorbents (0.2-0.6 ± 0.05mm). For statistical reasons the experiments were randomized and each of the test was run in duplicates. A software package, named Design Expert Version 11 (Stat-Ease, Statistic Made Easy, MN, United States) was used.

3 Results and Discussions

Response surface methodology could be an assortment of mathematical and applied mathematics techniques supported the work of a polynomial equation of the experimental information, that should define the behaviour of a knowledge set with the target of creating applied mathematics previsions[16]. RSM is a no table section of experimental design as well as an important means in optimizing its performance, developing new processes, formulation of new products or improving the design. The biggest application in industrial research, particularly in situations where a huge number of variables affect system features [17]. In this study, the predicted data values were attained bya model-fitting method that used Design Expert software. After fitting these data to differents model for example cubic, two factorial, linearand quadratic and their successive ANOVA exhibited that the whole reaction is most suitably explained with a mathematical quadratic polynomial model. This quadratic modelstated in coded variables and is described by the mathematical equation (1) as follows:

$$\text{Color Removal (\%)} = +17.84 - 11.09A + 4.88B + 0.775C - 1.87D + 3.88A^2 + 0.25B^2 + 0.1013C^2 + 0.6338D^2 - 2.54AB - 0.325AC + 2.03AD - 0.2075BC - 0.6888BD + 0.1863CD \tag{1}$$

where A is pH, B weight of biosorbents, C is contact time, and D the size of biosorbents. In ANOVA, a ratio between regression mean and error mean sum of squares i. e the distinction between the predicted values and experiment derived values provide F-value, while P-value denotes the probability value of corresponding F-value. The software produces model coefficients, P-values and F-values (Prob.> F) for the model fitted, which point to aninsignificant probability and support each of the experimental variable's significance. If the P value is less than 0.05 (i. e very small), itdenotes that each term of this model has a significant outcome on the response.
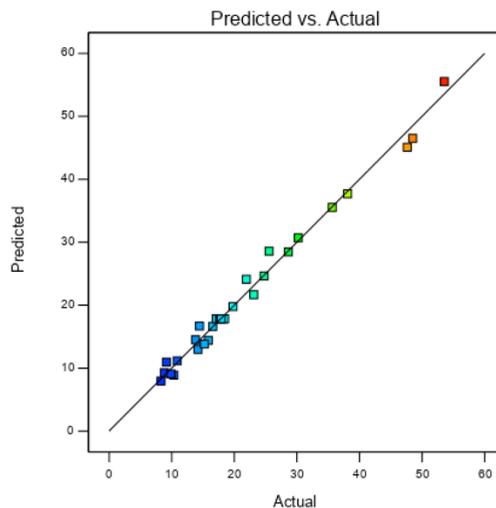
Table 1. Analysis of variance (ANOVA) and model coefficients found from Dye Biosorption Process using *Bjerkandera Adusta*

Source	Sum of square	Degree of freedom	Mean square	F-value	P-value
Model	4223.68	14	301.69	91.5	< 0.0001
A-pH	2953.93	1	2953.93	895.88	< 0.0001
B-Weight Biosorbent	570.57	1	570.57	173.04	< 0.0001
C-Contact Time	14.41	1	14.41	4.37	0.054
D-Size of Biosorbent	84.15	1	84.15	25.52	0.0001
AB	103.43	1	103.43	31.37	< 0.0001
AC	1.69	1	1.69	0.5125	0.485
AD	66.02	1	66.02	20.02	0.0004
BC	0.6889	1	0.6889	0.2089	0.6542
BD	7.59	1	7.59	2.3	0.15
CD	0.555	1	0.555	0.1683	0.6874
A^2	412.39	1	412.39	125.07	< 0.0001
B^2	1.71	1	1.71	0.5199	0.482
C^2	0.2812	1	0.2812	0.0853	0.7743
D^2	11.02	1	11.02	3.34	0.0875
Residual	49.46	15	3.3		
Lack of Fit	48.35	10	4.83	21.76	0.0017
Pure Error	1.11	5	0.2221		
Cor Total	4273.14	29			

A Model F-value equal to 91.50 recommends that this model is significant having only 0.01% (very small) chance that an F-value of this amount could developas a result of noise. P-values lower than 0.0500 (approx.) specify the model terms are not in significant. In such case, A, B, D, AB, AD, A^2 were significant terms of the model. A bigger value than 0.1000 shows the model terms are in significant. If there found several in significant model terms (excluding those terms required to support hierarchy), there might be a need for model reduction to improve the model.A F-value equal to 21.76 suggests the Lack of Fit was
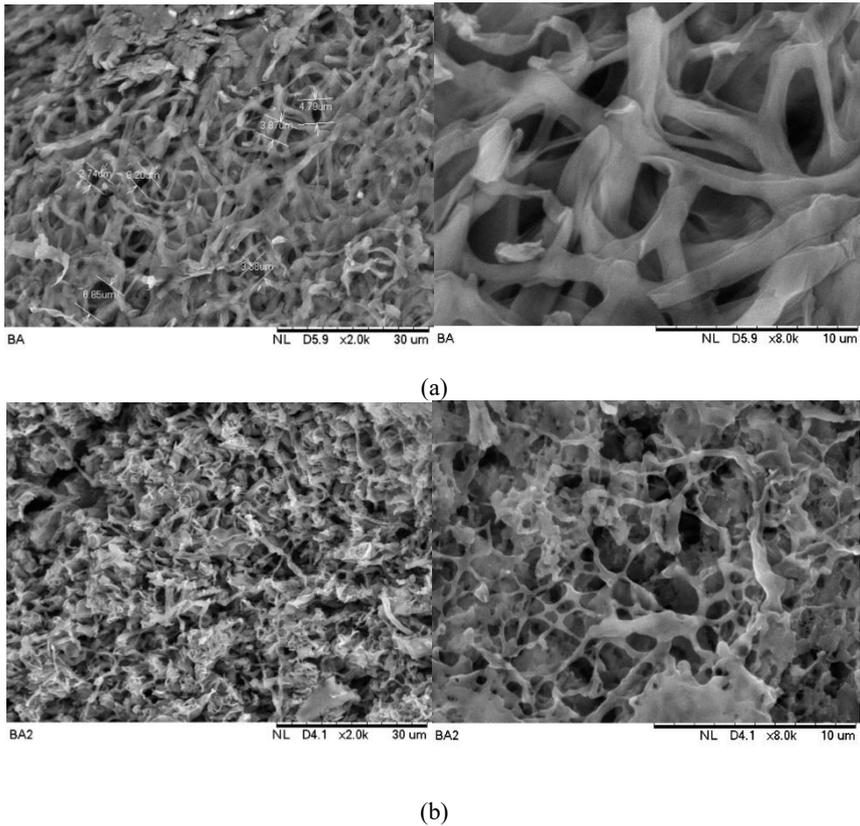
significant. Moreover, there is 0.17% chance only that a Lack of Fit F-value of this amount might occur owing to surrounding noise.

The lack of fit (LOF) F-test portray the data variation inside the fitted model. Here, if the model data does not match the given data correctly, its hall be significant. On the other hand, the small values of P due to LOF <0.05 displayed in Table 1 indicate that the F-value is significant, suggesting a significant model correlation amongst the variable's responses and process responses. A R^2 coefficient indicates the portion of total variation of the response predicted earlier by the model, showing the ratio of the sum of squares from regression (SSR) to the total sum of squares (SST). The Predicted R^2 value of 0.9345 lies in rational agreement with Adjusted value of R^2 equal to 0.9776; it means the difference is below 0.2. Further more, A deq Precision calculates the ratio of signal to noise. Here, a ratio >4 is desirable. A value of the ratio equal to 37.058 specifies a satisfactory signal. Hence, this model may be applied to navigate the experimental design(Fig 1).
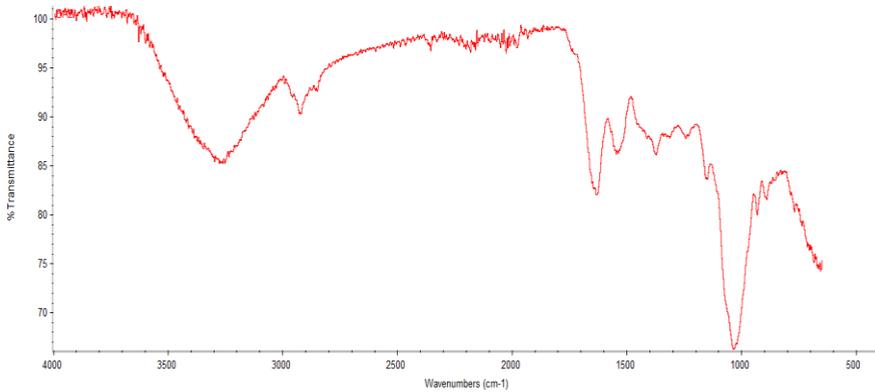

Fig. 1. A Graph of The Predicted Vs Experimental Values fo rColor Removal in Biosorption Process Using *Bjerkandera Adusta*

SEM analysis was carried out to explain the morphological characteristics including surface features of the used adsorbent sample. This also projects the surface porosity and structure/texture of the treated adsorbent [18]. Capacity of adsorption depends on particle size, pore size distribution, and surface area or micro / meso porosity [18]. SEM analysis was done for biosorbent *B.adusta* before and after biosorption process of synthetic textile effluent/waste water at various magnification (8000X and 2000X). Control and treated biosorbent were verified to observe transformations in the biosorbent after certain contact with the pollutant dye (Figure 2). Figure2 (a and b) illustrates the morphology of biosorbent*B. adusta* showing the pores. Size of pores biosorbent*B. adusta*was ranged 2.74-8.30μm and after biosorption process become 1.31-2.14 μm. It is clear that the dye deposits between biosorbent *B.adusta* show it self as crystalline form. Therefore, SEM micrograph confirmed the maximum affinity to the studied dye. These resultsupport previous researchby other investigators, Mahmoed*et al*. , 2017 that use baker's yeast[19].

(a)

(b)

Fig. 2. Before (a) and after (b) biosorption process magnification powers (2000X and 8000X)

Fig. 3. FTIR spectrum of biosorbent *B. adusta*

Functional groups in biosorbents *B. adusta* were analyzed using FTIR spectroscopy in order to discover the functional groups which may bond with dyes in synthetic textile wastewater. The IR spectrum of the sample adsorbent was recorded in a range of 4000 - 400 cm^{-1}.The O-H stretching adsorption band in the crystal structure of biosorbent is observed at 3270 to 3000 cm^{-1} which indicates the presence of an OH group.From Figure. 3 It could be discovered that the most prominant bands detectedat 3270, 2920, 1640, 1580,

1160, and 1030 cm^{-1}.However, a weak absorption peak at 2920 cm^{-1}normallyindicates to aliphatic groups (symmetrical and asymmetrical stretch/vibration of CH_3). A cluster of water molecules that was assigned to free hydroxyl on biosorbents *B. adusta* represented by the peak at 1640cm^{-1}. The peak at 1160 cm^{-1} may indicate to stretching band of C-O of alcohol or hydroxyl or ether groups. Therefore, above results show that the presence of functional groups onto the biosorbent *B. adusta*surface affected the biosorption mechanism. There are similarities between the results in this study and those described by Mahmoud, 2016 [19] and K. Jain, 2007 [20].

4 Conclusion

From the study found that variables such as pH, weight of biosorbent and size of biosorbent were the major factors that affected the color removal in biosorption process using *Bjerkandera Adusta*. Under the optimized conditions, experimental values are as predicted, indicating the model suitablity and the success of RSM in optimizing the condition of the biosorption process using Bjerkandera Adusta. R^2 and R^2 adj correlation coefficients for the quadratic model was evaluated having quite satisfactory valua as 0.9776 and 0.9345, respectively.SEM micrographs observation and FTIR observation permitted us to conclude that the process that occurs during colour removal followed biosorption mechanism.

Acknowledgments

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