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Research Article

Process Optimization for Biosingeing of 100% Cotton Terry Towel Fabric Using Box–Behnken Design

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In the present day, numerous researchers have paid more attention to the dyeing and finishing quality of environmentally friendly textile products in the world because the lack of outstanding products is an alarming problem. Therefore, the purpose of the present study is to treat the fabric with cellulase enzymes to improve the dyeing and finishing quality. The effects of varying chemical concentrations, temperatures, and processing times were examined in the model and different process parameters were optimized in the preparation biosingeing process. The results of the Box–Behnken design were obtained as $R2 = 0.7243$, 0.9027, and 0.9966 for optimum absorbency, weight loss, and tensile strength, respectively. The treated fabric was analyzed using FTIR to know the unknown functional group and the chemical bonds on the fabric molecule. Testing of physical properties of the treated fabric was done and the result was comparable with other untreated fabrics. The treated fabric performance was studied at 40, 50, and 60 minutes and at temperatures of 30, 55, and 80°C. The experimental investigation has been carried out to determine the effect of biosingeing on different physical parameters, such as the tensile strength of treated cotton fabric (437 N), which was almost similar to that of the untreated fabric (443 N), with almost no significant differences. K/S value for the biosingeing fabric of treated fabric was 17.58, but the that of the untreated fabric was 15.6, which was significantly different. Thus, the enzymatically treated fabric is of good quality because the protruding fiber was removed in biosingeing process. This ecofriendly singeing preparatory process is an alternative process for terry towel fabrics.

1. Introduction

In the textile industry, textile processing consists of multistage processes starting from fiber production to the finished fabric. The finishing and dyeing process is a stage where specific properties are imparted into fabrics; changing their appearance and improving their resistance to water, chemical, biological, physical, mechanical, and general wear, which is providing several features producing multifunctional textiles [1]. The wet processing stages facilitate the conversion of the grey fabric into the desired textile products and vary according to the nature of the cellulosic fabrics and the type of finished products [2]. It is a complex process, and its complexity depends on the composition of the textile material. From this point of view, new efficient strategies for cotton wet processing are needed, which are cost-effective and reduce the impact on the environment [3].

In conventional textile wet processing, the grey cotton fabric is subjected to pretreatment processes, including singeing, desizing, scouring, and bleaching. Singeing treatment removes a large amount of hairiness from the grey fabric, which may affect different properties of the fabric, such as appearance, dyeing, water absorbency, and tensile properties [4]. This is a very crucial step in textile successful subsequent coloration and/or finishing with minimal impact on the mechanical properties of the pretreated fabrics [2]. Textile preparatory and finishing processing is a growing industry that traditionally has used a lot of water, energy, and harsh chemicals. The singeing process is replaced with an environment-friendly approach using enzymes [5].

The application of industrial biotechnologies in the textile industry is anticipated to make significant contributions to the enhanced eco-efficiency of the textile processing sector and improve the quality of human life in this decade [6]. Biotechnology has proven to be one of the best approaches to developing a sustainable and greener textile wet processing industry and achieving ecofriendly value-added products. Biotechnology can improve the quality of human life by establishing bio-based products and services from sustainable and renewable materials [7]. The enzyme is an alternative chemical in the textile wet processing department that has added a new line of ecofriendly substances to give a good solution to remove protrude fibers from the surface of the woven fabric without the burn effect on the fabric [8]. It is a sustainable alternative to the harsh toxic chemicals in the textile preparatory process, which have a wide range of applications and a multitude of prospects for their use in textile processing, leading to a positive impact on the environment as they are readily biodegradable [9]. The consumption of energy, raw materials, and also increased awareness of environmental concerns related to the use and disposal of chemicals into the environment, river, landfills, water, or release into the air during chemical processing of textiles are the principal reasons for the application of enzymes in the finishing of textile materials [10]. The advantages of enzyme applications for cotton fabric finishing are as follows: cleaner harness of fiber on the surface of the fabric, shortage of the processes, reduced tendency to pill formation, cost reduction, environmentally friendly process, increase color strength, good tensile strength, and improved handling properties of fabrics [11]. Cellulose enzyme is the preferred and versatile wet process for biopreparation, biopolishing, and softening of cellulosic fabrics without affecting the physical and chemical properties [12, 13]. Cotton fabric treatment before dyeing and finishing using cellulase is an environmentally friendly and economical process of improving the properties of cellulose fibers [10]. Cellulase enzymes have been commercially available for more than 40 years, and these enzymes have been recognized as a target for both academic and industrial applications [5, 14]. Treatment with an enzyme is a powerful cellulose composition, gives a clear look to the pile, and improves absorbency and softness. For this reason, biosingeing removes protruding fibers and slobs from fabrics, significantly reduces pilling, softens fabric hand, and provides a smooth fabric appearance [15]. Some researchers studied how to get quality products in dyeing and finishing process modification of textile fabric with an environmentally friendly process like biofinishing [16]. However, biofinishing textile process conditions have not yet explored and the optimization of process parameters is underexplored in which one variable is varied while the others are kept constant; for example, the temperature is varied but pH is kept constant. There is a time-consuming method with several experiments to optimize parameters [17]. This research is to develop and design biosingeing optimization process parameters.

This research aimed to provide technical solutions for dyeing and finishing problems of terry towel fabric through enzymatic biosingeing treatment activity. The optimization study of cellulase enzymes was conducted with different parameters like treatment time (40, 50, and 60 minutes), enzyme concentration (1%, 3%, and 5%), and singeing temperature (30, 55, and 80)°C using the Box–Behnken design. After the biosingeing process, the fabric was dried and tested for physicomechanical properties of the treated fabric samples like absorbency property, color strength, stiffness, wash and rub fastener, percentage weight loss of fabric, and tensile strength.

2. Materials and Methods

2.1. Materials and Apparatus. Terry towel cotton fabrics were used for this experiment. The process trials were carried out on the 181.6 GSM fabric of pile weave, 100 percent cotton fabric, and yarns used in 17/2 Tex or (N e 34/2).

Different chemicals are required in this work: a commercial-grade cellulase enzyme for biosingeing sodium hydroxide for conventional scouring, wetting agent, sequestering agent, H_2O, stabilizer, dyestuff, and acetic acid.

Equipment and Apparatus used for this work are as follows: drying oven, electronic balance, pH meter, measuring cylinder, Fourier transform infrared spectrophotometer (FTIR), spectrophotometer, tensile strength testers, stiffness testers, color fastness tester, and fabric drape tester.

2.2. Experimental Design. Design of experiments (DOE) is an effective tool for maximizing the amount of information gained from a study while minimizing the amount of data collected. The Box–Behnken design is an accurate design method with fewer points and is less expensive than central composite designs with the same number of factors; the design ensures that all the process parameters operate at a safe operating level in Box–Behnken design [18]. During the optimization of the biosingeing process, the parameters should be analyzed using Design-Expert® version 11 software (Table 1). During the biosingeing process, select three different factors and three levels for each factor. The independent variables used were treatment time (40, 50, and 60) minutes, enzyme concentration (1%, 3%, and 5%), and singeing temperature (30, 55, and 80°C) [19].

The pH of immobilized cellulase enzyme with maximum activity for the biosinged treatment of cotton fabric was maintained at pH 4.5–5.5 [18, 20]. Cellulase is a class of enzymes that act at 4.5–6 and in the temperature range of 40–80°C [17]. The levels of each factor are low, medium, and high that chosen based on the software recommendation and according to the Box–Behnken design statistical tools [21]. After the biosingeing process, the fabric was dried and tested for percentage weight loss, tensile strength, and absorbency. The mass of liquor (M: L) ratio was 1 : 20 and the pH of the biosingeing bath was 4.5.

2.3. Water Absorbency Test (AATCC 79). The water absorbency of the fabric was measured using a drop test (AATCC 79) method. The substrate for this experiment was cut 20 × 20 cm on each side. The substrate was put on the table in a horizontal direction and dropped water on the fabric. Drop five different places on the surface of the test

Table 1: The independent variables and their responses using BBD.

Run	Temperature (°C)	Concentration (%)	Time (min.)	Absorbency (sec)	Strength lost (N)	Weight lost (%)
1	80	3	40	5.6	4.2	2.1
2	30	3	60	16	2.8	1.8
3	55	1	60	14.9	2.4	1.45
4	80	1	50	8.9	3.2	1.63
5	80	3	60	7.4	3.9	1.96
6	80	5	50	6.5	4.3	2.4
7	30	1	50	13.5	2.1	1.6
8	55	3	50	13.4	3.5	1.7
9	55	3	50	16.2	3.4	1.65
10	55	5	40	6.7	3.6	2.5
11	55	1	40	15.4	2.2	1.67
12	55	3	50	13.2	3.4	1.63
13	30	5	50	11.2	3.7	2.4
14	55	5	60	6.73	4.1	2.2
15	30	3	40	12.9	2.3	2.1

substrate, keeping the dropper at a space of 13 cm from the sample. The wetting properties of the dyed fabric were evaluated as the time required for the dropping water to disappear on the surface and recorded as wetting time [22].

2.4. The Weight Loss Test. The sample was calculated before and after the enzymatic treatment of the fabric using the following equation:

$$\text{Weight loss}\,(\%) = \frac{W_1 - W_2}{W_1} \times 100, \tag{1}$$

where W_1 is the fabric weight before biosingeing and W_2 is the fabric weight after biosingeing.

2.5. The Tensile Strength Test. The tensile strength was measured using the ASTM D 1388–08 test method. The samples were determined on a computerized universal tensile strength tester. Five readings for every sample were taken. The control and the treated samples were tested five times each and calculated mean values [23].

2.6. Functional Group Analysis. The FTIR measurement can be examined and evaluate the functional group of the dyed fabric. In this study, Perkin Elmer spectrum 65 was used at an average wavelength from 4000–600 cm-1. It can be observed that the changes of the functional group before and after the treatment.

2.7. Wash and Rub Fastness Test. The treated fabrics were laundered using the AATCC 61 test method. Laundering was continued at MLR of 1 : 10 with 5 g/L detergent and 10 steel balls at a temperature of 90°C for 30 minutes. The washing cycle is carried out by hot rinsing in water at 40°C for 10 minutes. The color change did observe for the resultant fabrics, and attached multitier staining was also evaluated. The washed fabric and the stained fabric did compare with grey scales for color fading and staining, respectively. A higher grade for both the colored and fabrics after washing indicates better color fastness property.

2.8. The Color Strength (K/S) Value. The dyed terry towel cotton fabric color value was determined using Illuminant light D65 at 10-degree standard observers. The samples were folded into four layers and placed in front of the sample holder of the spectrophotometer machine. The samples were measured randomly in different locations, and the average value of the color can be analyzed based on the Kubelka–Munk theory as follows:

$$\frac{\mathrm{K}}{S} = \frac{(1 - \mathrm{R})^2}{2\mathrm{R}}, \tag{2}$$

where K and S are the light absorption and scattering coefficients of the dyed terry towel fabric, respectively. R is dyed fabric reflectance at the wavelength measured at maximum light absorption [24].

2.9. Stiffness Test. According to ISO 13934 stiffness test method, The tests were carried out with the standard textile testing conditions of relative humidity 65 ± 2% and temperature at 20 ± 2°C to ensure the accuracy and reliability of the results.

A sheer stiffness tester machine can analyze the stiffness of the fabric using a scale of cm as the bending length measurement value. The bending length of the terry towel dyed fabric test result marked was recorded, and its scale mark is opposite to the zero line on the side of the platform. A rectangular sample cut 2.5 cm × 20 cm (template size) in a warp way would be cut. Samples of fabric with a known GSM would be placed on the stiffness tester and moved slightly until it coincides with the inclined indicator. The overhang length of the sample is measured. The flexural rigidity ‘G’ was calculated as follows:

$$G = \mathrm{GSM} \times \mathrm{B.L} \times 9.807 \times 10^{-6}, \tag{3}$$

where G is the flexural rigidity and B.L is the bending length (mm).

3. Results and Discussion

3.1. Water Absorbency of the Treated Fabric. One of the significant parameters after the biosingeing dyed cotton fabric is the absorbency property. The observed and predicted results of the 15 trials are analyzed using analysis of variance (ANOVA). The significance of the model and model terms should be determined using the *P* value of the experimental design. A *p* value less than 0.05 indicates that the model is statistically significant [25]. In this experimental design, the model is statistically significant because the level of *p* value is 0.0056, as shown in Table 2, which means temperature, enzyme concentration, and treatment time have a significant effect on the biosingeing fabric treatment process. The enzyme concentration and treatment time significantly affected the water absorbency properties of the terry towel cotton fabric within the range of values experimented in this study. The increase in cellulose concentration and treatment temperature increases the fiber accessibility by biosingeing, resulting in a higher water absorbency value (Table 1).

ANOVA in Table 2 shows that in the two linear terms, A (temperature) and B (enzyme concentration), the *p* values are less than 0.05, meaning that these two factors significantly affect the experiment design. However, the p value of treatment time is 0.5889, which is higher than 0.05, indicating an insignificant effect for the model. This means that treatment time was not important for the absorbency of the fabric within the range of values experimented in this study. The coded factors of the regression equation model are as follows:

$$\text{Absorbency} = 11.21 - 3.2A - 2.7B. \tag{4}$$

The lack of fit of this experimental design: the F-value of 2.58 suggests the lack of fit is insignificant compared to the pure error. There is a 31.03 percent chance that a lack of fit F-value this large could occur due to noise. An insignificant lack of fit is recommended.

The graph of the predicted response values vs. the actual response values is primarily used to detect a response value or a group of response values not predicted by the model. The observed (experimental) results and the predicted values obtained using these model equations of absorbency are summarized in Figure 1. The predicted value has good agreement with the experimental results, which indicates that the developed regression linear model can be accurately used to calculate the response factors for any given variable in the interval of experimental design. The experimental data were closely related to the data predicted from the model. As shown in Figure 1, almost all data points are close to the line of the perfect fit.

Response Surface Analysis Model Graph. The 3D surface plot was a projection that gave a shape in addition to the color and contour. The graph can reach a better understanding of the effect of the independent variable and their interactions. In this study, illustrating the response surfaces as three-dimensional (3D) plots determined the importance of the two independent factors (enzyme concentration and temperature) on the removal of absorbency. The 3D graph shows that the water absorbency efficiency of the terry towel fabric is increased at a treatment time of 50 minutes with the increased concentration of enzyme. At low temperatures and minimum concentration, the efficiency of the absorbency is low (Figure 2).

3.2. Weight Loss. The ANOVA in Table 3 shows that the corresponding variables significantly affect this experiment analysis. To determine the models of the experiment, a higher F-value and a *p* value lower than 0.05 indicate that the model type and the models are significant model designs. In this case, B, C, A^2, B^2, and C^2 were significant models, which means that each group's *p* values are less than 0.05 and A, AB, and AC are insignificant effects.

The final equation for the prediction of the response variables based on coded factors was as follows. A second-order polynomial equation was used to find a suitable approximation of these process parameters and the response surface as follows:

$$\begin{aligned}\text{Weighlost} = 1.66 + 0.3937B - 0.12C + 0.1913A^2 \\ + 0.1563B^2 + 0.1388C^2.\end{aligned} \tag{5}$$

A graph of the predicted response values versus the actual response values primarily indicated that the a value is detected and the scatter of the plot lies almost on the diagonal line, showing that the model was designed very well; i.e., the experimental data were closely related to the data shown in Figure 3. Examining Figure 4(a), it appears that both concentration and temperature have an effect on weight loss. Accordingly, it has been seen that the weight loss increases seriously when the time rate is increased and observed that the temperature of cotton fabric increases at a constant concentration of 3%. In the same way, in Figure 4(b), both the results regarding the combined effect of time rate and increased temperature on weight loss are presented. From the interaction effect of time and concentration in Figure 4(c) (contour), it is found that the percentage of weight loss increases as increasing cellulose structure or molecule degradation increases, with the increase of time and concentration. Therefore, their interaction affects weight loss.

3.3. Tensile Strength Test. The model *F*-value of 28.73 implies the model is significant. There is only a 0.01% chance that an *F*-value this large could occur due to noise. *P*-values less than 0.0500 indicate model terms are significant. In this case, A, B, and C are significant model terms in Table 4. An experimental relationship stated by the equation with interaction terms was fitted between the obtained results as follows:

$$\text{tensile strength} = 3.23 + 0.5875A + 0.7250C. \tag{6}$$

The practical (experimental) results and the predicted values obtained using these model equations are given in Figure 5(a); the predicted values were in agreement with the experimental results, which indicates that the developed regression linear model can be accurately used to calculate

Table 2: Analysis of variance (ANOVA) for water absorbency of enzyme-treated dyed fabric.

Source	Sum of squares	df	Mean square	F-value	p value	
Model	142.27	3	47.42	7.35	0.0056	Significant
(A) Temperature (°C)	82.11	1	82.11	12.72	0.0044	
(B) Concentration (%)	58.16	1	58.16	9.01	0.0120	
(C) Time (minute)	2.00	1	2.00	0.3099	0.5889	
Residual	71.00	11	6.45			
Lack of fit	65.37	9	7.26	2.58	0.3103	Not significant
Pure error	5.63	2	2.81			
Cor total	213.27	14				

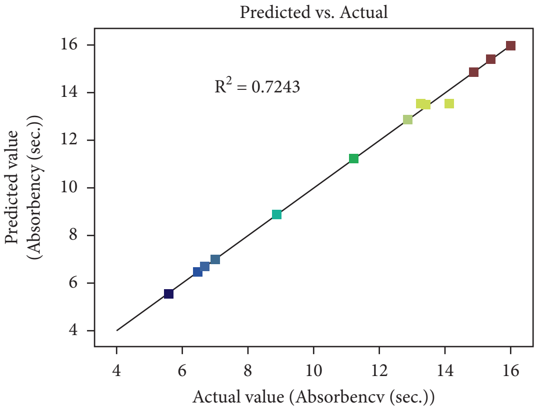


Figure 1: Correlation between the actual value and predicted value of the absorbency of the fabric.

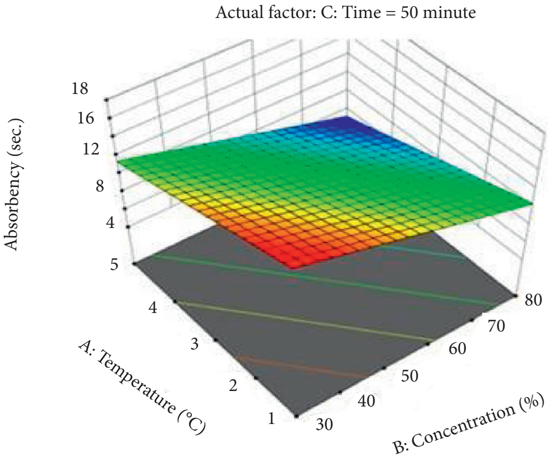


Figure 2: Factor interaction effect on 3D surface graph absorbency.

Table 3: Analysis of variance (ANOVA) for weight loss of enzyme-treated dyed fabric.

Source	Sum of squares	df	Mean square	F-value	p-value	
Model	1.63	9	0.1807	163.52	<0.0001	Significant
(*A*) Temperature (°C)	0.0045	1	0.0045	4.08	0.0993	
(*B*) Concentration (%)	1.24	1	1.24	1122.45	<0.0001	
(*C*) Time (minute)	0.1152	1	0.1152	104.25	0.0002	
AB	0.0002	1	0.0002	0.2036	0.6707	
AC	0.0064	1	0.0064	5.79	0.0611	
BC	0.0016	1	0.0016	1.45	0.2827	
A^2	0.1351	1	0.1351	122.22	0.0001	
B^2	0.0901	1	0.0901	81.58	0.0003	

Table 3: Continued.

Source	Sum of squares	*df*	Mean square	*F*-value	*p*-value	
C^2	0.0711	1	0.0711	64.33	0.0005	
Residual	0.0055	5	0.0011			
Lack of fit	0.0029	3	0.0010	0.7500	0.6148	Not significant
Pure error	0.0026	2	0.0013			
Cor total	1.63	14				

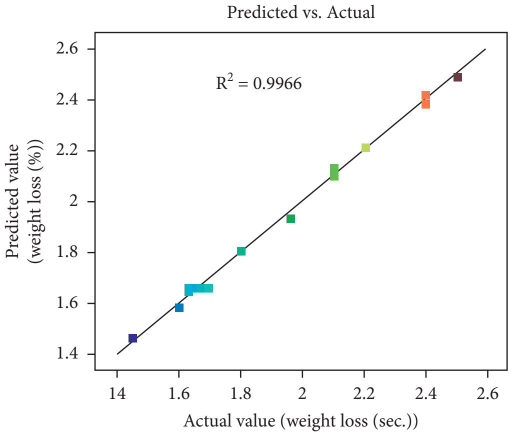
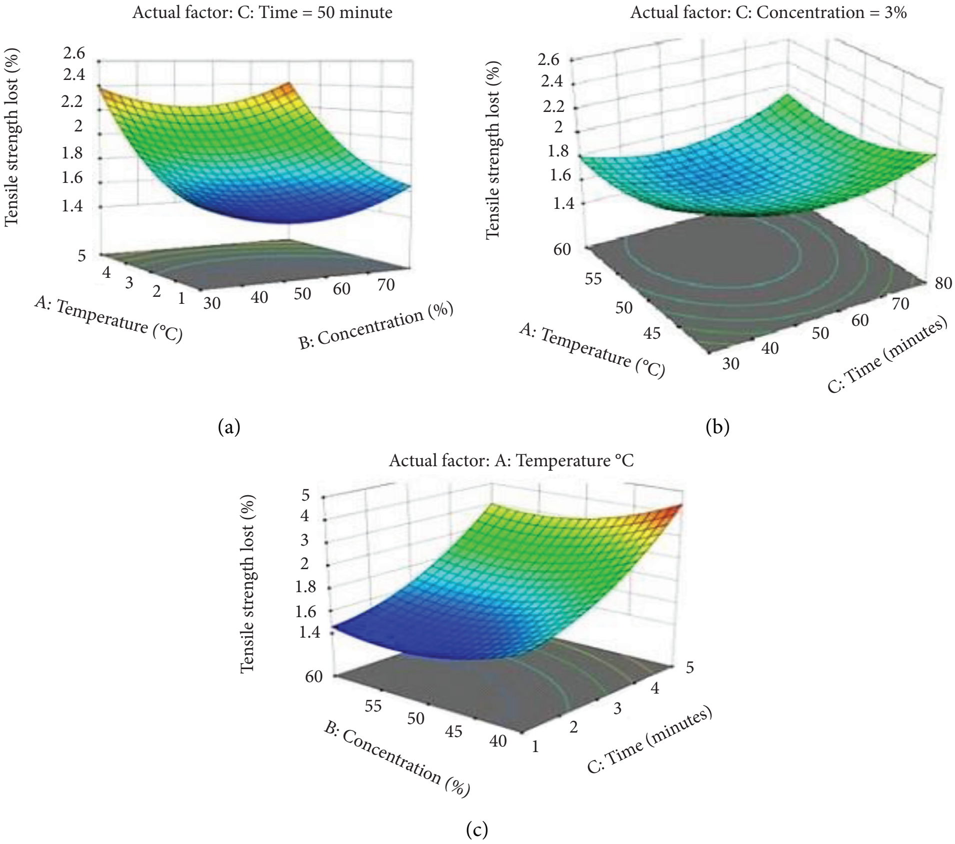


Figure 3: Correlation between the actual value and predicted weight loss.



(a)

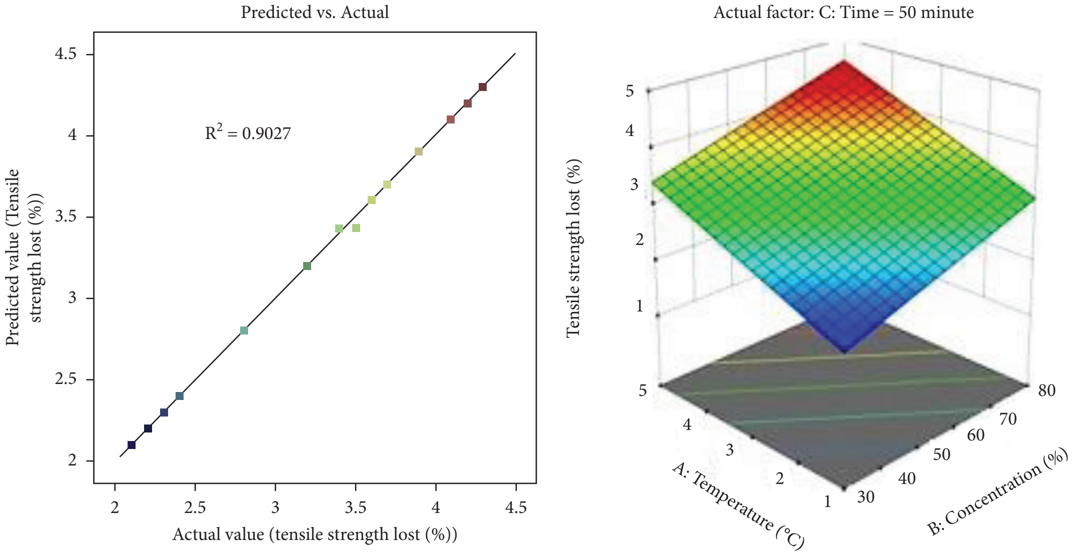
(b)

(c)

Figure 4: Factor interaction effect, (a) temperature and concentration, (b) temperature and time, and (c) time and concentration on 3D surface graph effect on weight loss.

Table 4: Analysis of variance (ANOVA) for tensile strength of the enzyme-treated dyed fabric.

Source	Sum of squares	d*f*	Mean square	*F*-value	*p* value	
Model	7.07	3	2.36	28.73	<0.0001	Significant
(*A*) Temperature (°C)	2.76	1	2.76	33.68	0.0001	
(*B*) Concentration (%)	4.20	1	4.20	51.29	<0.0001	
(*C*) Time (minute)	0.1012	1	0.1012	1.23	0.2901	
Residual	0.9018	11	0.0820			
Lack of fit	0.6618	9	0.0735	0.6128	0.7515	Not significant
Pure error	0.2400	2	0.1200			
Cor total	7.97	14				



(a)

(b)

Figure 5: (a) Predicted probability plot of actual for tensile strength and (b) factor interaction effect with on 3D surface graph effect on tensile strength.

the response factors of any given variable (Figure 5(b)) in the interval of our experimental strategy.

In general, the enzyme activities increase with temperature, but above a particular temperature, the thermal agitation disrupts the tertiary structure of enzymes. Acid celluloses exhibit the greatest activity generally in the pH range of 4.5–5.5 at 45–55°C, whereas neutral celluloses require a pH of 4.5–8.0 at 50–60°C. A prolonged treatment time, excessive cellulose dosage, and vigorous agitation may increase fiber loss significantly. Moreover, acid cellulose requires that washing time is short, 40–55 min [26]. The optimum conditions are a temperature of 55°C, the concentration of cellulose enzyme 3%, and treatment time of 50 min, which is obtained from the optimization process of in this.

3.4. *FTIR Analysis of the Fabric.*

The hydrolysis of cellulose leads to a decrease in the O-H stretch. The cellulase enzyme could be more easily digested through the weak point region than the highly ordered crystalline region of cellulose. The FTIR results of this experiment showed comparable values of the treated and untreated lignocellulose of the cotton fabric. The FTIR spectra of the treated sample change the structural and functional properties of the cotton fabric. Hence, the spectrum at a wavelength of 400 to 4000 cm^{-1} provides information about the functional group changes that occurred during biosingeing. After biosingeing, the absorption bands in the region 600 to 4000 cm^{-1} can be attributed to the O-H stretching, as shown in Figure 6, a few changes in the position of the absorption bands, and a slight change in the intensity of the peaks. After biosingeing, the absorption bands in the region 3200 to 2800 cm^{-1} can be attributed to the O-H stretching, showing a few changes in the position of absorption bands and a slight change in the intensity of the peaks.

3.5. *Wash and Rub Fastness.*

The wash and rubbing fastness of the samples dyed with treated and untreated fabrics is shown in Table 5. From the results, it can be understood that reasonably good fastness can be obtained in dyeing with treated fabric. The good fastness to rubbing and washing is a desirable property in dyed textiles after the biosingeing process. However, a few changes were observed after washing, leading to a greyscale rating. This change may be attributed to the longer exposure (30 min) to a high temperature at 60°C during standard washing.

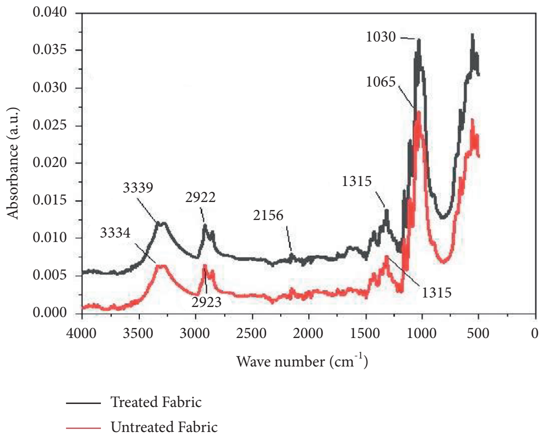


Figure 6: FTIR spectra of untreated fabric and treated fabric.

Table 5: Wash and rub fastness of untreated and treated fabrics.

Fastness	Washing fastness	Rubbing (wet) fastness	Rubbing (dry) fastness
Treated fabric	5	4	5
Untreated fabric	4	3–4	4

Table 6: K/S values of dyed, treated, and untreated fabric.

Treated and untreated fabric	Color strength (K/S) value
Treated fabric	17.58
Untreated fabric	15.6
Treated fabric bulk	13.9
Untreated fabric bulk	12.1

Figure 7: Difference between fabrics: (a) before biosingeing, light and uneven shade; (b) after biosingeing, a deep and uniform shade.

The wash fastness of biosingeing or treated fabric showed better dyeing and rubbing fastness results. Five dyed fabric samples (obtained from the experimental design) were analyzed for wash and rubbing fastness. Substantivity and affinity of the fabric enable the auxochromes to diffuse and desorb from the dyed treated fabrics, whereas in the untreated dyed cotton fabric, washing and dry rubbing fastening was found to be 4 and twet rubbing was of a good grade (3-4). Dry rubbing fastness provided a better result than the wet rubbing test (Table 5).

3.6. Color Strength (K/S Value) of the Dyed Fabric. The color efficiency (K/S) of treated terry towel fabric was slightly higher than that of untreated fabrics (Table 6). It means that

Table 7: Stiffness properties of untreated and treated fabrics.

Fabric sample	Bending length (cm)	Flexural rigidity (μNM)
Treated fabric	2.68	0.049
Untreated fabric	3.2	0.057

the cotton fabrics made from treated were colored in a deeper shade (more saturated) than that of untreated cotton fabric. The color strength of the treated and untreated/conventional fabric process significantly differed between its color values. The minimum amount of enzyme for the biosingeing process of the cotton fabric resulted in a much better dye quality. However, the conventional preparatory process is next to dyeing and a light and not uniform shade is observed, as shown in Figure 7.

3.7. Stiffness or Flexural Rigidity Test. The average bending length of the untreated dyed fabric was 3.2 cm in a warp direction [15]. The bending length of biosingeing dyed fabrics decreased compared to that of untreated dyed fabric in the warp direction. The minimum average bending length was 2.68 cm (Table 7), which is lower than that of the untreated sample in a warp direction. All treated dyed fabrics were stiffened by removing or reducing the amount of protruding fibers or wake points of fiber deposit on the surface.

4. Conclusion

Biosingeing of cotton fabric, consequences of fabric dyeing, and finishing quality removal of hairiness or protruding fiber due to the breaking of weak chain change the physical properties. The effect of independent variables on response variables was examined, and the model's optimum points of operational parameters were predicted. The treatment optimizations concerning time, temperature, and amount of enzyme concentration using the significance of the optimization methods were checked through ANOVA analysis and 3D plots can be drawn for a different combination of parameters that exhibit the trend of variation of response within the selected range of input parameters and the influence of each parameter over the other parameters.

The most important parameters were checked after biosingeing of 100% cotton twill woven fabrics. The design, experiments, and results of the 15 trials are presented. The tests were performed in the standard testing atmosphere, i.e., 65 ± 2% R.H. and 20 ± 2°C. Five samples of each shade of twill fabric samples were taken for this experiment. The color yield (K/S values) significantly changed for samples shown after treatment. Pilling resistance of the fabric shows higher pilling in the untreated fabric; however, after treatment, the pilling has been reduced. Abrasion resistance of the fabric shows a higher mass loss in untreated fabric, while after treatment, the mass loss has been reduced. The flexural rigidity was more improved using the cellulase treated fabric compared to the untreated fabric. Hence, biosingeing of cotton twill fabric with enzymes modifies the structural and physical properties of the fabric treatment, improving the physical properties with improved surface modification. Therefore, an increasing trend of using alternative methods to improve dyeing and finishing goods of fabric was investigated in this study.

Data Availability

All data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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