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Application of rice straw as biosorption for removal of dyeing aqueous solution and for improving the fastness property of dyed fabric

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Abstract. Fabric dyeing industry has been widely located throughout Thailand and the treatment of polluted water after dyeing process has been a primary focus. The objectives of this study were to study on factors affecting treated (acidic and alkaline) and non-treated rice straw on aqueous solution quality and fastness quality of dyed fabric. The results showed that increasing the absorption time increased the percentage of color removal efficiency until it was stable at 80 min soaking time onward. The alkaline treated rice straw gave the highest percentage of the percentage of color removal efficiency. Determination on the fastness quality of dyed fabric; it was found that, non-treated, acidic treated and alkaline treated rice straw potentially removed the excess color from the dyed fabric which the fastness quality of dyed fabric was improved.

1. Introduction

Natural color dyed fabric is one of the small industrialization activities which have economically driven for Thailand. The business has been widely located throughout the country. The process of dyeing; gradually, disposes the excess color liquid to the environment which influences the natural resource security enormously. This disposed waste liquid includes not only the toxic color that prevents the photosynthetic of the water plants, but also the heavy metal and other kinds of dangerous liquid solution which harm the aquatic animals. The color liquid solution in the water resources is difficult to be treated because it contains the aromatic substances which avoid the microorganism digesting and the oxidation [1]. Generally, the polluted water from color dyeing fabric manufacturing in waste has been treated via chemical approaches, for instance, flocculation, electro-flotation, precipitation, electro-kinetic coagulation, ion exchange, membrane filtration, electrochemical destruction, irradiation and ozonation, which these approaches are costly and are not appropriate for the small-scale industry [2].

With the biological structure (fiber structure) of the bio-material and agricultural residue are perfectly used as an absorbent; therefore, they have been studied for removing dye color and some heavy metals from manufacturing wasted water [3-8]. Rice straw is one type of agricultural residues (cheap and short life cycle) and used as an adsorbent to treat polluted water after the dyeing process [9-10]. Nevertheless, these studied approaches were only focus on the improving the quality of aqueous solution, but not improving the quality of fabric. Applying the rice straw during the dyeing process providing potentially



improving both the quality of solution and also fabric. However, increasing of absorption capability of rice straw by acid or alkaline solution treatment needs to be studied.

Mostly, the process of color dyeing for the small garment industry uses direct color dye. The fabric is placed on the heated aqueous solution (direct color dye and the presence of an electrolyte (NaCl)) for 60 minutes. The aqueous solution and fabric are, then, left until reaching the ambient temperature (cooling down process). The fabric is removed for washing. At this stage, the absorption color efficiency of fabric reaching the maximum capacity which means there will be no color absorption process after this point. The excess color in the solution will only be attached on the surface of fabric which will be easily removed when fabric is washed (fastness property). Adding treated rice straw during cooling down process could improve the quality of both solution and fabric.

The hypothesis was set that adding rice straw on the process of cooling down, its fiber structure (treated and non-treated) tends to expand and increases the absorption possibility of excess color in the aqueous solution and the attached color on the fabric. This solution could treat the polluted water and increase the fabric quality in terms of fastness property. Thus, the objectives of this study were to evaluate effects of treated and non-treated rice straw on quality of polluted water after treatment and fastness quality of dyed fabric.

2. Materials and methods

2.1. Acidic treated and alkaline treated samples preparation

Rice straw samples were cut to remove the node remaining the 2 cm length of internode and cleaned to remove the dusty and foreign materials before washed in rinse water in order to adjust the pH to be 7.0. The cleaned rice straw samples were, then, dried in hot air dryer at 100°C for 24 h and left in the ambient atmosphere allowing their moisture content to become equilibrium for 24 h. The cleaned rice straw samples were separated in three groups for non-treated samples, acidic-treated samples and alkaline-treated samples.

The samples were treated by soaking in an acidic solution with 3 M concentration of H_2SO_4 for 24 h. The acidic treated samples were washed until the pH of the rinsed water became 7. Then, they were dried in the hot air dryer at 100°C for 24 h and kept in sealed plastic bag protecting the samples from the interference atmosphere. For the alkaline treated samples, it was prepared with the same process as acidic treated sample, only the solution was changed from H_2SO_4 to 3 M NaOH instead.

2.2. Experimental methodology

Direct orange 39 was used as the dyeing color throughout this experiment. The color solution with $0.8\text{ g}\cdot\text{L}^{-1}$ concentration mixed with $2\%\text{ w}\cdot\text{w}^{-1}$ of NaCl was prepared in the beaker and placed it in the 90°C water bath. Three grams of cotton fabric sample was put in the beaker and leaved it for 60 min of dyeing. After that, the beaker was removed from the water bath and the prepared rice straw samples (non-treatment, acidic treatment and alkaline treatment) were put in the beaker where the ratio of absorbent : color solution dose were 0.01, 0.03 and $0.05\text{ g}\cdot\text{mL}^{-1}$ for 0, 5, 10, 15, 30, 45, 60, 80, 100 and 120 min with 3 replications.

2.3. Indicators for the experiment

The indicators of this experiment were 1) amount of color removal from aqueous solution and 2) fastness property of color dyed fabric. All samples (rice straw and fabric), also, were examined on its surface using the scanning electron microscope at the magnitude of 1,000x. The apparatuses for obtaining these indicators are described:

2.3.1. Amount of color removal from aqueous solution. Reduction the color concentration of aqueous solution before dispose to the natural water resources is essential as the high concentration affects the life and its ecosystem. The UV-Vis spectrophotometer was used for evaluating the percentage of color removal following equation (1).

$$\text{Removal Efficiency(\%)} = \left[\frac{C_o - C}{C_o} \right] \times 100 \quad (1)$$

Where: C_o = Concentration of color in aqueous solution before being absorbed by prepared rice straw samples.

C = Concentration of color in aqueous solution at particular time.

2.3.2. Fastness property of dyed fabric. Fastness testing is one of the majorities testing for dyed fabric to see the amount of dissolved color from dyed fabric. The fastness property was examined following ISO 105 C06 by stitching the color dyed fabric with the white fabrics (acetate, nylon and cotton). Then, they were soaked in the room temperature water with the ratio of 1:50 for 30 minutes. The samples were pressed under acrylic plates with 12.5 kPa applied; then, they were dried for 4 h in 37 °C drying chamber. The changing color of white fabrics were examined by colorimetric spectrophotometer (HunterLab) under CIE scale (L^* , a^* and b^*).

3. Results and Discussions

3.1. Surface examination of rice straw under scanning electron microscope

The surface of treated rice straw samples before using in this experiment were examined 1,000× of scanning electron microscope and they were illustrated in figure 1. The surface of non-treated rice straw (figure 1A) appeared the have two sizes of cone shape objects the tip of cone directed in the same direction which this resisted the reverse moving (this happened when moving on the rice straw and it felt rougher on one direction and another). The surface of acidic treated rice straw was similar to the non-treated sample. The cone shape appeared to be more swollen while some of the cones were broken losing the shape of perfect cone as the non-treated sample. While, the surface of the alkaline treated rice straw showed that the cone shapes (both larger and smaller size) appeared to be more misshape of cone as they were broken.

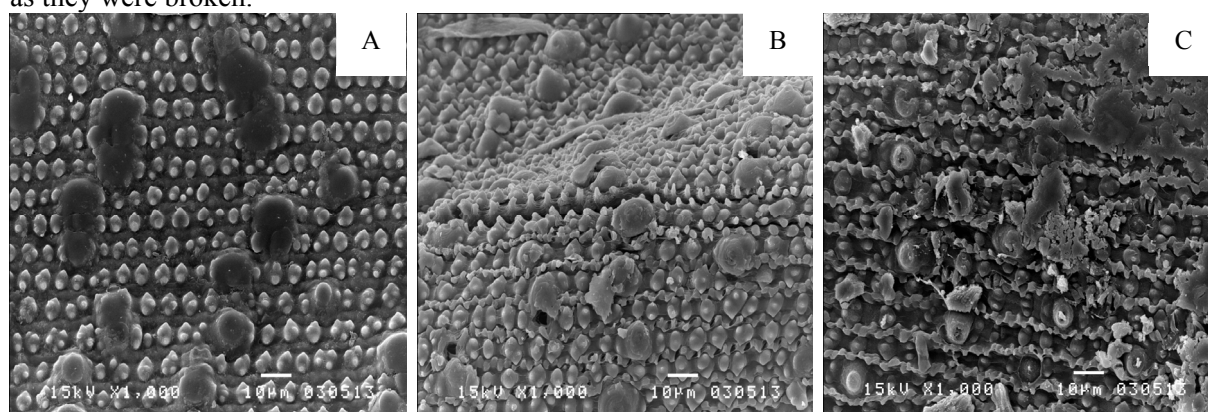


Figure 1. Scanning electron micrographs of rice straw under 1,000× magnification. A = Non-treated, B = Acidic treated, C = Alkaline treated.

3.2. Amount of color removal from aqueous solution

Removing the color from aqueous solution was examined preventing the polluted water delivery to water resources. The removal efficiency (%RE) was calculated from equation (1) and the relationship of %RE against absorption time at difference of dose usage was plotted in figure 2A-2C.

The results demonstrated that treated rice straw tended to have potential to absorb color in the aqueous solution remove. Larger dose of rice improved more on percentage of color removal efficiency. Determination that all experimental sets the percentage of removal efficiency reached the maximum from absorption time of 80 minutes. Therefore, applying rice straw in the color aqueous solution must be shorter than 80 minutes.

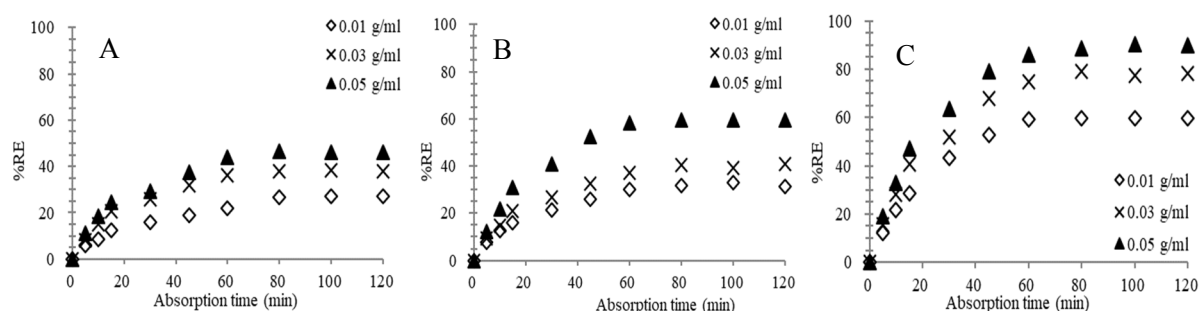


Figure 2. percentage of removal efficiency of treated rice straw on dyeing color aqueous solution with the absorption time (0-120 min): A = non-treated, B = acidic treated and C = alkaline treated.

3.3. Surface examination of dyed fabric sample under scanning electron microscope

Figure 3 illustrated that the color particles (small spots) remained attach on the dyed fabric. These particle specks caused the problems of the fastness quality of the dyed fabric. These small specks were leachable from the fabric during washing of even soaking in water. Therefore, first washing color clothes were able to bleed to other clothes; particularly, white clothes. Using the rice straw as the biosorption removing the color specks during the dyeing process was success to solve this problem as shown in figure 4.

Figure 4 showed the surface of dyed fabric under 1000 $\times$ of scanning electron microscope using the rice straw during dyeing process improve the quality of fabric in term of less amount of fastness. The results confirmed by the fastness test which the results shown in table 1.

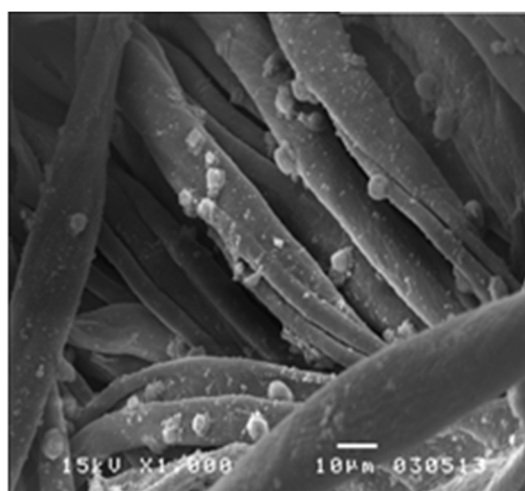


Figure 3. Scanning electron microscopy of dyed color fabric under 1,000 $\times$

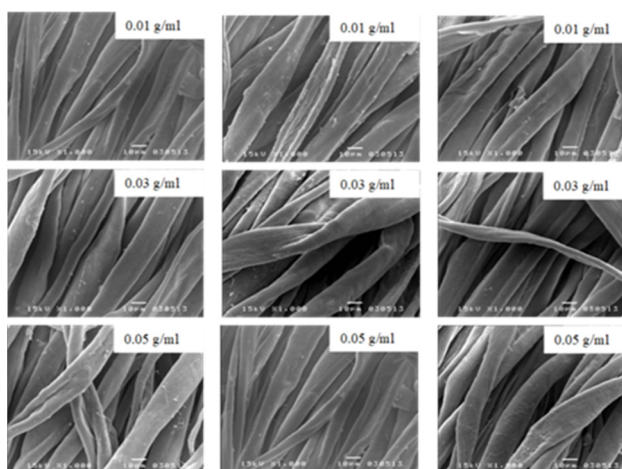


Figure 4. Scanning electron microscopy of dyed color fabric under 1,000 $\times$ applied with left column = Non-treated, Middle column = Acidic treated, Right column = Alkaline treated.

Table 1. Fastness testing of color dyed fabric which non adding rice straw and adding the rice straw during dyeing process for 80 minutes.

Type of biosorption treatments	Dose (g/ml)	Level of color change ¹	Fastness degree ²			Remarks:
			acetate	cotton	nylon	¹ Level of color change
control	0.00	4	3	1-2	2-3	5: no color changed
Non-treated	0.01	4-5	3-4	2	3	4: color slightly changed
						3: color changed by visual observation
	0.03	4-5	3-4	2	3	2: obviously color changed
NaOH-treated	0.05	4-5	3-4	2	3	1: greatest contrast color
	0.01	4-5	3-4	2	3	² Fastness degree
	0.03	4-5	3-4	2	3	5: no fastness
H ₂ SO ₄ -treated	0.05	4-5	3-4	2	3	4: color slightly changed
	0.01	4-5	3-4	2	3	3: color changed by visual observation
	0.03	4-5	3-4	2	3	2: obviously color changed
	0.05	4-5	3-4	2	3	1: greatest contrast color

4. Conclusions

The color dyed aqueous solutions was treated with longer than 80 minutes of absorption time and with alkaline treated rice straw solution gave the highest percentage of removal efficiency. The fastness quality of dyed fabric was better one level on the degree of fastness obviously as there were no color specks on fiber.

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