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Optimization of Dyed Extract Condition from Nypa Palm Bark using Central Composite Design

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ABSTRACT

Nypa palm, a kind of palm usually found in mangrove forests in the Pacific Oceans. Bark of Nypa palm contained concentrated dyes that can be used as source of natural dye. The aim of this study was to optimize Natural dye extracted from bark of Nypa Palm by using Central Composite Design (CCD) method. The result showed that the condition of 22-28% Nypa palm bark and heat at 100°C for 20-95 min gave the maximum color on the cotton fabrics after dying. The treatment combinations between bark concentration and extracted time showed that a regression model of optimization of extraction as lightness of dyeing cotton fabrics (L-value) were in agreement to experimental results with R^2 = 0.639. The minimum L-value was between 62-64.

Key words: Natural dyes, *Nypa fruticans*, cotton fabric, mordant, response surface

INTRODUCTION

Dyes were classified to two types namely, synthetic dyes obtained from chemical substance and natural dyes obtained from natural sources. The synthetic dyes such as reactive dyes are very efficient but it also hazardous to human and animal health (Uddin *et al*., 2014). There are wide spread interest in the natural dyeing because of their biodegradability and high compatibility with the environment (Prusty *et al*., 2010). The studies of natural dyes were investigated in various kind of plant such as bitter leaf, osage orange, butterfly pea, dragon fruit etc. (Boyo *et al*., 2012; Mansour and Gamal, 2011; Sinha *et al*., 2012; Harivaindaran *et al*., 2008). Nypa Palm is a species of native palm grown on the coastlines and estuarine habitats of the Pacific Oceans. This plant has a brown color as sticky substance in the bark but surprisingly delicious in meals. No information regarding the natural dye extracted from Nypa palm bark is available. Moreover, optimum conditions for dye extraction from Nypa palm bark were necessary to improve the efficiency of dye extract. The Central Composite Design (CCD) was used as a tool to find out an optimum condition in various research studies. The CCD analysis was done between the relationship of a number of parameters in the process (Couto *et al*., 2006; Heck *et al*., 2006; Khucharoenphaisan *et al*., 2008; El-Hersh *et al*., 2014; Musa *et al*., 2015).

This research was aimed to optimize the condition for extracted process using Nypa palm bark as raw material for natural dye. The combination of Nypa palm bark concentration and extracted time were used. Response Surface Methodology (RSM) based on CCD was applied to identify optimum conditions for maximum color extraction and analysis was done between the relationship of a number of extraction parameters in the process.

MATERIALS AND METHODS

Nypa palm bark sampling: The healthy Nypa Palm was collected from fields in Samutsakorn provinces of Thailand and the bark was separated from whole Nypa Palm and kept at 4°C until use. Optimization of Nypa palm bark concentration and time for dye extraction: Central Composite Design (CCD) was used to generate 13 treatment combinations, with Nypa palm bark concentration and time for dye extraction as independent variables using Minitab version 15. Table 1 shows the experimental matrix, which corresponded to design with coded variables containing star points (= 1.414) and five replications of the central point. The data of experiments were analyzed by SPSS software version 10 (Khucharoenphaisan *et al*., 2008).

Each dye extraction experiment was done in 1000 mL beaker containing 200 mL of 0.2 M NaOH with various amount (g. wet weight) of Nypa palm bark and then heat treatment at 100°C at different time intervals with the condition as mentioned above and a total of 13 treatment combinations were obtained. The dye solution was immediately used for straining cotton fabrics. Four replicates were done for each experiment.

Dyeing cotton fabrics: Extracted dyes obtained from above-mentioned 13 treatments were used for dying cotton fabrics by using 0.02% NaCl as a mordant. Fabrics (10×10 cm) were dyed with 200 mL of dye solution in a beaker (1000 mL) with temperature of 32°C for 10 min. Dye absorption on cotton fabrics was evaluated in term of CIELab color coordinated as lightness (L-value) using Data color Spectrum Spectrophotometer. The data of experiments were analyzed by SPSS software version 10.

RESULTS AND DISCUSSION

Optimization of Nypa palm bark concentration and time for dye extraction: Two principal factors affecting dye extraction viz., Nypa palm bark concentration and extracted time were analyzed in order to determine the optimal condition of dye solution extraction. The result of experimental design was shown in Table 2 whereas, significant coefficients determined using p-values was shown in Table 3.

Nypa palm bark concentration showed high significance of dye extraction. This indicates that concentration of Nypa palm bark act as limiting factors and small variations in their values will alter dye extraction to a considerable extent. The model clearly revealed no significant interactions between Nypa palm bark concentration and time. Treating them separately did not reflect their real influence on the extraction. The equation model of color concentration using lightness value was obtained.

Table 1: Code values of variables, maximum and minimum Nypa palm bark concentrations and times used in the central composite experimental design

	Code level				
Independent variables	-1.414	-1	0	1	1.414
Nypa palm bark concentration (%)	2.6	6	20	34	39.74
Time (min)	7.2	40	120	200	232.80

Table 2: Results of the experimental plan used in CCD, showing the 13-treatment combination

	Code setting level		Actual level		Lightness of dyeing cotton fabrics (L-value)	
Experiment No.	NPB (%)	Time (min)	NPB (%)	Time (min)	Actual[a]	Predicted
1	0	0	20	120	64	64
2	0	0	20	120	64	64
3	1.414	0	39.74	120	65	68
4	0	0	20	120	62	64
5	0	0	20	120	64	64
6	-1.414	0	0.26	120	75	73
7	1	1	34	200	70	70
8	-1	-1	6	40	67	69
9	0	0	20	120	64	64
10	0	-1.414	20	7.2	65	64
11	0	1.414	20	232.8	67	70
12	-1	1	6	200	69	72
13	1	-1	34	40	65	64

NPB: Nypa palm bark concentration (%), [a]Data average values of four replicates analysis

Table 3: Coefficient estimates by the regression model

	Lightness of dyeing cotton fabrics (L-value)		
Independent variables	Coefficient (B)	Standard error	Significant value (p-value)
Intercept	75.0792	6.249	0.000
NPB	-0.8774	0.202	0.040
Time	-0.0367	0.035	0.348
NPB' Time	0.0007	0.032	0.026
NPB^2	0.0164	0.027	0.032
$Time^2$	0.0002	0.014	0.015

NPB: Nypa palm bark concentration (%)

- Lightness of cotton fabrics dyeing (L-value, L):

$$L = 75.0792-0.8774'NPB-0.0367T+0.0007'(NPB)'(T)+0.0164NPB^2+0.0002T^2$$

This equation model of color concentration using lightness value indicated that a remarkably high correlation between observation and prediction exists ($R^2 = 0.639$). With the help of the model, interaction between Nypa palm bark concentration and Nypa palm bark concentration was found to be critical factor for dye extraction process. To further understand the relationships between the extraction parameters and the response, the 3D response surface curves and contour plots were done using Statistica 8 software (Fig. 1), which shows optimum levels with optimal responses. The data of equation model and 3D response surface curves of dye extraction showed that in the range of 22-28% Nypa palm bark and heat at 100°C for 20-95 min gave the maximum color on the cotton fabrics after dying. Over concentration of Nypa palm bark to reduce density of extracted color because of Nypa palm bark absorbed extracting alkaline solution. This result was similar to Suabjakyong *et al*. (2011) that successes to extract natural dye from black plum fruit with 45% glacial acetic acid at 100°C for 60 min appropriate percentage of fresh and dry black plum were 20 and 10%, respectively. However, the dye extraction from fresh petal of butterfly pea was maximal at 2% (Sinha *et al*., 2012) while dye extraction in both of conventional and microwave methods from fresh stem of *Pterocarpus osun* require up to 200% to reach the maximal condition (Avwioro *et al*., 2005). The maximal dye extract from dry flower of *Butea monosperma* was obtained at 5.88% (Saxena *et al*., 2012). From overall comparison, it was found that the appropriate of plant material to act maximal dye extraction was depend on type of plant, extracted solution, temperature and method.

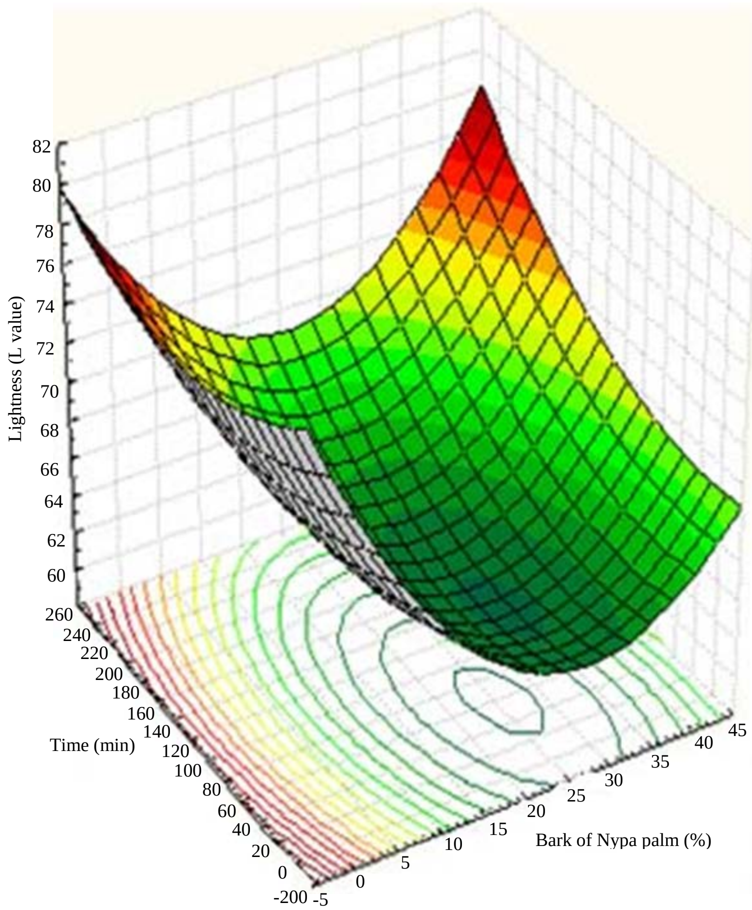

Fig. 1: Response surface and contour plot for the effects of Nypa palm bark concentrations and times on lightness after cotton fabric dyeing

CONCLUSIONS

The optimum condition for dye extract from Nypa palm was successes by using central composite design and regression analysis. Maximum of dye was obtained from the condition consisting of 22-28% Nypa palm bark and heat at 100°C for 20-95 min. In the future, we will investigate the fabric dying condition with suitable mordant and stability of dyed fabric.

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