Research paper

Dyestuff Formulation of A Dull Greenish Flora Tape Paper

Lan-sheng Kuo[1] Chun-chia Lu[2] Chien-chih He[3]

【**Abstract**】The authors studied the dyestuff formulation for shade matching of creped dark greenish flora tape paper having metamerism at the request of a big paper mill in Taiwan. According to the color mixing principle and our past experience in paper dyeing, a formulation of 1.80% Direct Sky Blue 5B, 1.71-1.75% Direct Yellow 12, 0.09% Direct Scarlet 4 BS and 0.17% Basic Violet 10 mix can dye the mixed pulp of 70% NBKP and 30% LBKP (freeness: 450 ml CSF) in acidic alum-aided dyeing to the desired shade of flora tape paper (CIE $L^*a^*b^*$ = 48.11/-3.87/13.97) under D65 light with an acceptable color difference ($\triangle E^*<2.0$).

【**Key words**】color matching, dyestuff, flora tape paper, metamerism.

研究報告

深綠花桿紙之顏色配方

郭蘭生[1] 盧俊嘉[2] 何建緻[3]

【**摘要**】作者受國內某大紙廠之託，尋找有著明顯色變之起皺深綠花桿紙之顏色配方。依據作者之長期配色經驗及色混原理，找出利用 1.80 % Direct Sky Blue 5B，1.71-1.75 % Direct Yellow 12, 0.09 % Direct Scarlet 4BS 及 0.17 % Basic Violet10 混合染料染著 70 % NBKP 及 30 % LBKP（游離度 450 ml CSF）混合漿，並藉明礬之固色作用，可抄出與標準紙色（CIE $L^*a^*b^*$= 48.11/-3.87/13.97）色差（$\triangle E^*$）小至 2.0 以下，人眼不易辨識之深綠色花桿色紙顏色配方。

【**關鍵字**】配色、染料、花桿紙、色變

I. INTRODUCTION

While the color of one dyed paper is similar to that of standard observed by customer, it is a fundamental and important optical property of colored paper. Dyestuffs formulation including the absorption of additives influences most color of dyed paper. In response to the request of a Taiwan paper mill to make a matched dull greenish flora tape paper that is widely used by florist and flower arrangement, we intend to use stock dyeing method i.e., to dye the fiber first before the sheet is formed, for shade matching.

1,2 & 3: Professor and graduate students, Department of Forestry, NCHU.
國立中興大學森林學系教授、研究生

The dissolved dye's solution is added to the stock in the pulper. The dye is added before the size, fixing agent and alum for optimum results (Casey, 1981; Kuo, 1987). The dye should be added early in the pulp preparation stage to provide maximum time for mixing and for the dye to exhaust onto the fiber. For good color matching results, the same sequence and time of addition should be followed for all ingredients to minimum shade variations (Kuo, 1991).

In addition, the dull greenish flora tape paper provided by Taiwan papermaker shows utter metamerism when viewing under different lighting conditions (Kuo, 1994). Which light source shall we choose? Of course, the best viewing light is in the morning, northern daylight on a clear day, but this light will change as the day elapses, as the season changes; therefore, a standard lamp such as D65, C and A in a color room is desirable (Kuo, 1998). Nevertheless, the preparation of this metameric dull greenish flora tape paper might trouble us very much.

We aim to prepare a matched color paper as the color of a standard dull greenish flora tape paper by our experience (over 20 years) in paper dyeing and the principle of subtractive color mixing in our laboratory. By developing an optimum laboratory formula, we will know what dyes are required to match the samples and the approximate amounts called for.

II. EXPERIMENTAL

(I) Materials

a. Pulp

NBKP (Canadian Mcanzie Pulp Co.) and LBKP (Chung Hwa Pulp Mill, Taiwan) were beaten in a PFI refiner to 450 ml CSF for handsheet (basis weight: 100 g/m^2) making.

b. Dyestuff

Direct Sky Blue 5B, Direct Yellow 12, Direct Scarlet 4BS, and Basic Violet 10 dyestuffs (powdered form) were purchased from Chung-How Enterprise, Taiwan. These dyestuffs are selected according to the subtractive color mixing principle (Kuo, 1990) and our past experience in paper dyeing. All of the dyestuffs are dissolved in water completely at concentration of 0.5-l.0% (w/v) before adding to the stock.

c. Chemicals:

AK.D (alkyl ketene dimmer, Hercules Co., Taiwan Branch) used as alkaline sizing agent. Aluminum sulfate (E.P., Sunto Co., Japan) and NaCl (Taiwan Salt Corp.) used as dyestuff fixing agent.

(II) Method

Add optimum amounts of dyestuffs into the stock according to the principle of subtractive color mixing and our experience in paper dyeing, and then followed by size (AKD) addition (2% by weight), 2% NaCl respectively. We also add 1,2,3,4, and 5% alum (based on o.d. weight of pulp) into the dyed stock respectively for color matching. Mixing each ingredient in stock for 5 minutes with stirrer (500 rpm) thoroughly for each step during stock preparation.

Making a 100 g/m^2 handsheet in a standard handsheet mould in our laboratory in accordance with TAPPI standard T220. Measuring the color (expressed as CIEL*a*b*) of colored paper samples with Spectrophotometer (Mcbeth Color-Eye 3000, USA) in accordance with TAPPI standard T442 and comparing their color to that of standard for shade matching ($\triangle E^* < 2.0$).

III. RESULTS AND DISCUSSION

(I) Effect of creping on paper shade

Due to the creped standard paper provided by papermaker, the shade of smooth handsheet prepared in laboratory looks somewhat different from the standard. Usually creping doctor on Yankee dryer helps the paper crepe, but it is hard to form creping pattern on paper with a handsheet mould in our laboratory. Nib the paper samples with our hands to crepe for shade comparison. Table 1 indicates that creping reduce the density of the smooth paper but increase lightness (lighter) and b^* values (yellower) apparently and decrease a^* values (greener) slightly. Surprisingly, even the shade of some smooth alum-treated sample papers seems to be agreed well with the standard sample, the discernible color differences between standard and creped samples (alum used as dye fixing agent) lie in the range of 3.89-5.70, which are beyond the acceptable color difference ($\triangle E^*>2.0$). Based on this fact, we nib each sample paper with our hands for shade comparison.

(II) Color of flora tape paper

When light enters a sheet of paper it is scattered by refraction and internal reflection. Part of it is absorbed, part is transmitted, and the remainder is diffusely reflected. The portion of light that is absorbed determines the color of the paper. A dull green flora-tape paper preferentially absorbs red and blue lights, it will be colored. The flora tape paper has appreciable amount of green light in the range of 500-580nm (see Fig. 1). As a result, the low reflectance of flora paper resulting from the use of particular dyes depends on the amount of light that the dyes absorb over the entire spectrum, as shown in Figure 1. In practice, this flora tape paper that reflects less than 50% of the light at all wavelengths will be considered dull. Interestingly, the spectral reflective curves between 640-700nm uprising abruptly, so it is not easy to attain color matching.

(III) Matching shades in laboratory

Before color matching, it is easier to understand that blue adds to yellow produces a green based on the principles of color blending. Opposite color (red) absorb the light reflected by each other. This causes dulling the shade by bringing the color more toward the neutral or gray area. The same is true if a blue is added to an orange. Likewise, a yellow will dull a violet and a red will dull a green. Considering the spectral reflective curves of standard colored paper i.e., reddish green flora tape paper, there are two questions related to the essential factors

Table 1. Effect of creping on paper shade.

	Smooth paper			Creped paper			
Samples	L^*	a^*	b^*	L^*	a^*	b^*	$\triangle E^*$
CP-068	45.98	-8.41	12.01	48.12	-9.10	17.02	5.49
CP-069	44.27	-6.97	11.35	46.67	-7.56	14.36	3.89
CP-070	45.10	-7.62	12.90	48.02	-9.02	16.11	4.56
CP-071	43.87	-7.30	10.82	47.40	-8.56	15.12	5.70
CP-072	44.73	-7.09	11.73	47.12	-7.98	14.85	4.03

$\triangle E^* = (\triangle L^{*2} + \triangle a^{*2} + \triangle b^{*2})^{0.5}$

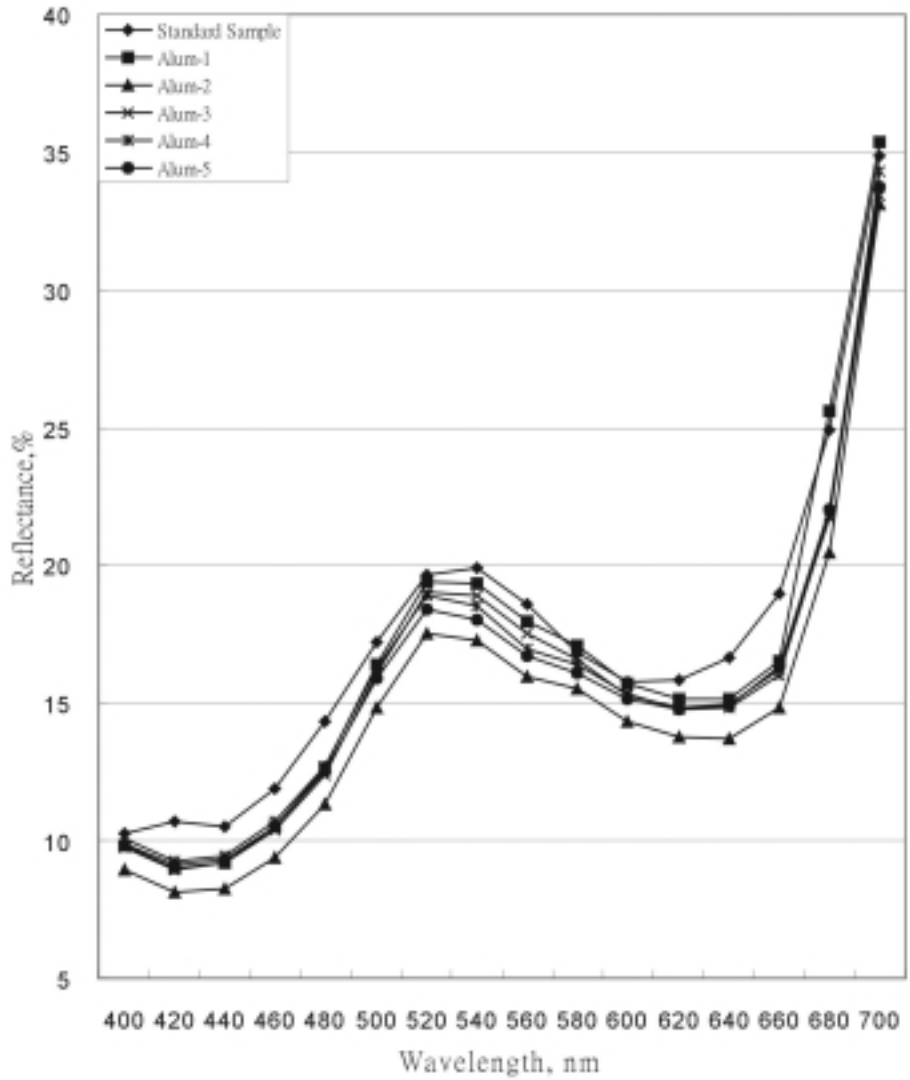

Fig. 1. Reflective curves of various matched dull greenish paper.

in the comparison of colored papers:

1. How does this dark reddish green flora tape paper compare?
   Is it yellower, bluer or redder?
2. How much duller or brighter is the sample than the standard as determined by the preceding rating system?

a. Effect of sizing

After the dye is added to the stock, the size should follow, the pH range is relating to the kind of size i.e., AKD, ASA or rosin used in the dyeing system. For instance, direct dyes do not develop their true shade or strength when added to stock containing alum. In addition, most direct dyes will tend to granite (selectively dye a few fibers to a deep shade) if added after the alum. Therefore, it is always best to add the alum last, and preferably late in the preparation cycle. We

used AKD alkaline size, NaCl neutral dyeing and alum acidic dyeing to prepare dyed stock for matching shade. The shade of the alkaline colored samples (see Table 2) could not be matched even the dosages of Direct Sky Blue 5B and Direct Yellow 12 are greater than 6%. In NaCl-aided dyeing, the lower lightness of colored paper sample (CP-043) was obtained on the similar a^* and b^* values, as shown in Table 2. It seems that NaCl could not fix more direct dyes well on fibers for deep shade paper dyeing. On the contrary, alum helps more direct dyes absorb on pulp fibers (CP-073 and CP-074) for the low dyestuffs levels (0.09-1.81%) for insignificant color difference ($\triangle E^*<2.0$).

b. Tolerance of color difference

Kuo, *et al*. (1994) found that the dark shades exhibit higher color difference than those of light tones on visual color matching. So a less than 2.0 of color difference should be regarded matching shade for the deep shade of dark greenish flora tape paper.

To obtain satisfactory matches, it is essential that the sample shows the same shade as the standard to be matched under natural light or artificial light source C or D65. Therefore, we used D65 that is similar to sky light as the standard light source for shade comparison.

(IV) Metamerism

Table 3 shows that this dark greenish flora tape paper frequently appear as different shades when viewed under different light sources i.e., C, D65 and A. For instance, two shades, paper CP-073 that appear to match standard under light D65 ($\triangle E^*<2.0$), but may not match under A ($\triangle E>2.45$), and C ($\triangle E>2.23$) light sources. This is metamerism, or artificial light change. Metameric paper has been described as a pair that have different spectral reflectance curves, but the same coordinates for (at least) one illuminant. This metameric flora tape paper appears different under different lights by which making color matching of this dark greenish flora tape paper more difficult. We assume the papermaker had a

Table 2. Color formulations of various paper samples.

Samples	D-SB 5B[a]	D-Y 12[b]	D-Sc 4BS[c]	B-V 10[d]	Size or Fixing agent, %	CIE $L^*a^*b^*$			
						L^*	a^*	b^*	$\triangle E^*$
Standard	-	-	-	-	-	48.11	-8.37	13.97	0
CP-032	9.00	6.75	0.30	-	1.0(AKD)	44.30	-5.32	7.69	8.00
CP-043	16.25	11.25	0.32	0.88	2.0(NaCl)	41.85	-7.77	15.16	6.40
CP-070	2.00	2.00	0.10	0.15	2.0(Alum)	48.12	-9.10	17.02	3.10
CP-071	1.80	1.79	0.08	0.17	2.0(Alum)	48.02	-9.02	16.11	2.20
CP-072	1.75	1.75	0.10	0.15	2.0(Alum)	46.67	-7.56	14.36	1.69
CP-073	1.81	1.71	0.09	0.17	2.0(Alum)	47.12	-7.98	14.85	1.50
CP-074	1.80	1.75	0.09	0.17	2.0(Alum)	47.40	-8.56	15.12	1.36

[a]D-SB 5B: Direct Sky Blue 5B, [b]D-Y 12: Direct Yellow 12,

[c]D-Sc 4BS: Direct Scarlet 4BS, [d]B-V 10: Basic Violet 10.

Table 3. Metamerism of flora tape paper samples.

Light	D 65				A				C			
source	L^*	a^*	b^*	$\triangle E^*$	L^*	a^*	b^*	$\triangle E^*$	L^*	a^*	b^*	$\triangle E^*$
Standard	48.10	-8.37	13.97	0	48.93	-4.58	12.63	0	48.93	-8.53	14.02	0
CP-074	47.40	-8.59	15.12	1.36	47.56	-4.85	14.12	2.04	47.01	-8.92	15.66	2.56
CP-073	47.12	-7.98	14.85	1.38	47.09	-4.25	14.21	2.45	47.28	-8.25	15.49	2.23

difficulty in looking for the dyestuff formulation.

IV. CONCLUSIONS

The authors studied the dyestuff formulation for shade matching of dark greenish flora tape paper at the request of a big paper mill in Taiwan. Since metamerism plays a major role during dull greenish paper dyeing in which making the color matching more difficult, a spectrophotometer (light source: D65) and our much experience in paper dyeing help us find the optimum dyestuff formulations by subtractive color mixing principle i.e., when blue and yellow are mixed, green is observed. Accordingly, a formulation of 1.80% Direct Sky Blue 5B, 1.71-1.75% Direct Yellow 12, 0.09% Direct Scarlet 4 BS and 0.17% Basic Violet 10 mix can dye the mixed pulp of 70% NBKP and 30% LBKP (freeness: 450 mL CSF) in acidic alum-aided dyeing to the desired shade of flora tape paper (CIE $L^*a^*b^*$ = 48.11/-8.37/13.97) under D65 light with an acceptable color difference ($\triangle E^*$<2.0).

V. REFERENCES

Casey, J.P. (1981) Pulp and Paper Chemical Technology, 3"* edition, Vol. 3, New York, pp. 1655-1660.

Kuo, Lan-sheng and Hong-ming Duh (1987) Factors affecting paper dyeing. Pulp and Paper Monthly, Jan. issue: 1-18. (TAIWAN)

Kuo, Lan-sheng and Yue Yu (1991) Dyestuff formulations of green jigsaw puzzle paperboard. Bulletin of Experimental Forest of National Chung Hsing University 13(2):95-103. (TAIWAN)

Kuo, Lan-sheng and Wen-jenn Shiau (1994) A relationship between lightness variations and color difference while performing visual matching for various colored paper, Bulletin of Experimental Forest of National Chung Hsing University, 16(l):97-102. (TAIWAN)

Kuo, Lan-sheng (1998) The ways expressing newsprint shade. Pulp and Paper Monthly, Sept. issue, pp.26-33. (TAIWAN)

Kuo, Lan-sheng and Haw-farn Lan (1990) The manufacture of heavy shaded paper with cationic direct dyes, Forest Product Industries, 9(l):l05-114. (TAIWAN)