Journal of Korea TAPPI
Vol.37.No.5, 2005
Printed in Korea

Effect of Fluorescent Whitening Agent and Tinting Dye on Optical Properties of Paper

Li-JunWang[*1] and Byung-Ho Yoon[†]

(Received on May 7, 2005: Accepted on November 15, 2005)

ABSTRACT

The difference of whiteness, brightness and lightness was clearly explained in this paper by use of a tinting dye and a fluorescent whitening agent which are commercially widely used to make paper look whiter. Other optical properties such as tint, color shade, and color difference were also discussed. It is concluded that in comparing two tinting dyes, lightness (L*) is the most important property to be compared, while whiteness data should be used in caution in order not to surpass its significant range, and a*, b* values can also be used to find the change of color shades together with ΔE as color difference. In comparing two fluorescent whitening agents, whiteness or brightness values are most important to be compared, but lightness values are not suitable for this purpose; a*, b* and color difference ΔE can also be referred, but with less significance.

Keywords: fluorescent agent, tinting dye, opical properties, brightness, UV light, green light

1. Introduction

Even fully bleached pulp remains certain yellowish hue. Therefore many pulps need to be tinted by blue or violet tinting dyes, or brightened by florescent whitening dyes to make the paper products look whiter. Brightness, whiteness, or even lightness is often used to express the efficiencies of the tinting or brightening processes. These concepts have different meanings and can not be used equivalently. Unfortunately, it is often bewildering what the differences are, and whenor where should one concept be used instead of another (1-2). This study intended to clarify this problem through simple laboratory experiments. Other optical properties such as tint, color shade, and color difference were also discussed and their contribution to tinting or brightening process evaluation suggested.

• Department of Paper Science & Engineering, Kangwon National University, Chunchon, Kangwon, 200-701, Korea
*1 Tianjin Key Laboratory of Pulp & Paper Engineering, Tianjin University of Science & Technology, 300-222, Tianjin, China
† Corresponding Author : E-mail ; bhyoon@kangwon.ac.kr

2. Experimental

The fluorescent whitening agent and tinting dye used in this study were both products from Sungchang Fine Chemical Co., South Korea. Before application, the tinting dye was dissolved to be a solution of 10 mg/L and the FWA was diluted to be 1.4 g solid/L.

SwBKP and HwBKP were mixed in the ratio of 25%/75% and disintegrated according to Tappi Standard T 205 sp-02. Then tinting dye or fluorescent whitening agent was added into the above disintegrated pulp slurry. The dosages of tinting dyes were 3.8, 7.5, 15.0, 30.0, and 60 ppm, while the dosages of FWA (solid part) were 0.14%, 0.28%, 0.42%, 0.56%, 0.70%, all based on dry pulp weight. After mixing 2 min, hand-sheets were made according to Tappi Standard T272 sp-02.

Optical properties were measured with a Spectrolino Spectrophotometer made by GretagMacbethTM. Light reflectance, x, y, Y and L^*, a^*, b^* values were measured directly, while CIE whiteness, CIE tint and color difference ΔE were calculated according to the following formulas (3-5).

$$\text{Whiteness}=Y+800(x_n-x)+1700(y_n-y)$$

$$\text{Tint}=900(x_n-x)-650(y_n-y)$$

$$\Delta E=((L_2^*-L_1^*)^2+(a_2^*-a_1^*)^2+(b_2^*-b_1^*)^2)^{1/2}$$

3. Results and Discussion

3.1 Reflectance curves of tinting dye or FWA added paper

Fig. 1 clearly shows that the tinting dye significantly absorbs lights in the range of 500 ~650 nm, with the maximum at 590 nm which is typically in the yellow light (580-595 nm) area, therefore the tinting dye absorbs yellow light and makes the paper whiter (6).

On the other hand, Fig. 2 shows that FWA absorbs UV lights under 420 nm and changes it into visible lights in the range of 420~500 nm, with the maximum at 440 nm. As a result, the papers are whiter and brighter.

3.2 Effect of tinting dye and FWA on CIE whiteness and CIE tint properties

Fig. 3 shows that adding tint dye increases whiteness dramatically. However, observing the paper samples, one is easy to see, dosages under 15 ppm make paper whiter, over 15 ppm, paper becomes dim, over 30 ppm, violet-blue tint can be noticed easily, over 60 ppm, the

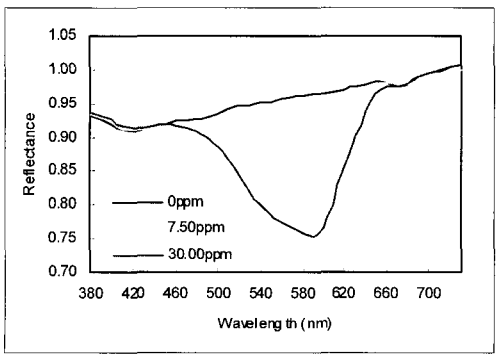

Fig. 1. Reflectance curves of tinting dye added paper.

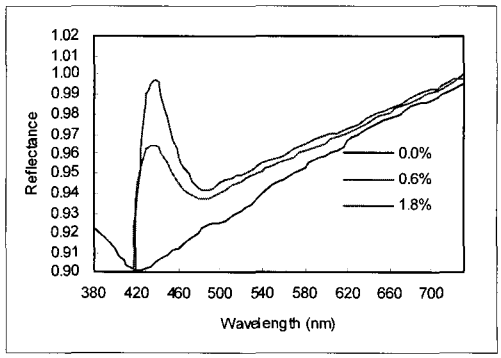

Fig. 2. Reflectance curves of FWA added paper.

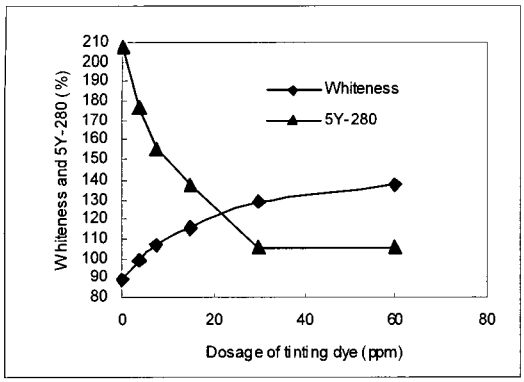

Fig. 3. Effect of tinting dye on whiteness.

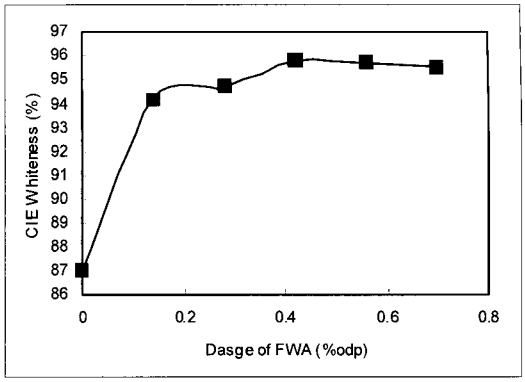

Fig. 5. Effect of FWA on brightness.

paper was clearly dyed to violet blue. Therefore, the whiteness concept can only be used to near white papers, i.e., it is only meaningful in the range from 40 to 5Y-280 (3-4). The data of 5Y-280 is also shown in Fig. 3, where it can be seen that when the dosage is over 30 ppm, the whiteness data already surpasses 5Y-280.

Fig. 4 shows that adding the tinting dye not only increases the CIE tinting value dramatically, but also changes it from negative (reddish) to positive (greenish). It is also worthy of mentioning that CIE tint is also used for near white paper, it is only meaningful in the range of -3.0~+3.0 (3-4). In Fig. 4, when the dosage is over 30 ppm, the tint value is very near 3.0 therefore it is almost meaningless to use tint value in such a high dosage.

Fig. 5 shows increase of whiteness with the increase of FWA dosage. This result is same as that of tinting dye on whiteness. However, the effect of FWA on tint is different, as Fig. 6 shows, where increase of FWA almost has no significant influence on tint. All the papers treated with the FWA kept negative tint values, indicates that the paper kept reddish tint.

In addition, Fig. 5 shows that the optimum dosage of the FWA was 0.42% on dried pulp. Dosages over 0.42% decreased whiteness. This is because too high dosages of FWA cause

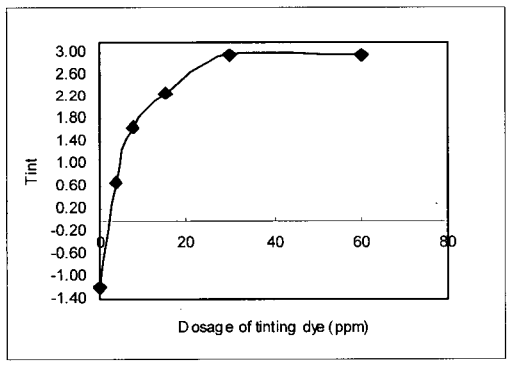

Fig. 4. Effect of tinting dye on CIE tint value.

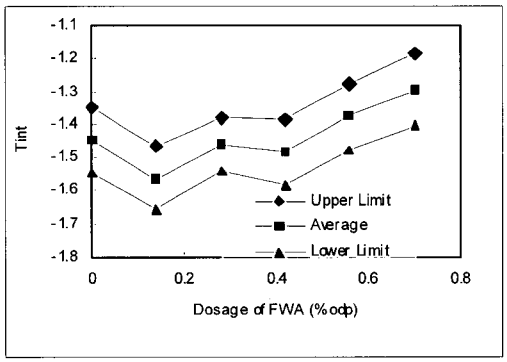

Fig. 6. Effect of FWA on CIE tint.

agglomeration, reflected light excited by a part of FWA will be absorbed by another part of FWA, and the brightening effect is decreased.

Fig. 6 shows that increasing the dosage of FWA has little influence on CIE tint.

3.3 Effect of tinting dye and FWA on brightness properties

Fig. 7 shows that adding tinting dye significantly decreases brightness. This can be explained from the reflectance curve in fig. 1. Although the tinting dye has strong absorption mainly in the wavelength range of 500~650nm, it also has certain absorption under 500nm, since brightness is measured in the range of 457 ± 44 nm, the absorption of tinting agent under 500nm decreases brightness values.

Fig. 8 shows that adding FWA increases brightness. Apparently this is very contrary to the result by the use of tinting dye.

3.4 Effect of tinting dye and FWA on lightness properties

Fig. 9 shows thatadding the tinting dye decreased lightness dramatically. Comparing with Fig. 7, it is seen the effect is much larger on lightness than on brightness. This is because brightness is calculated with blue light (457 ± 44nm) reflectance, while lightness is calculated with the green light (500-560) reflectance. Since the tinting dye has large absorption in the yellow-green range, its effect

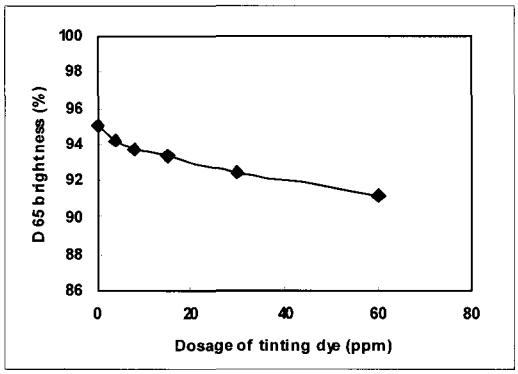

Fig. 7. Effect of tinting dye on brightness.

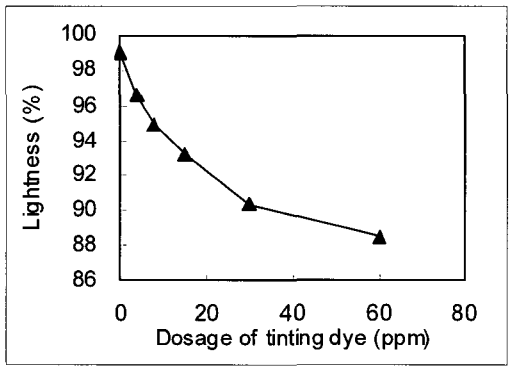

Fig. 9. Effect of tinting dye on lightness.

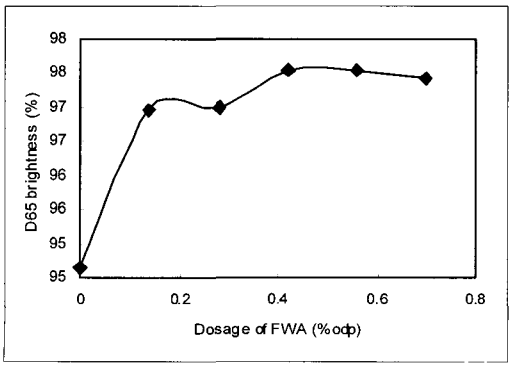

Fig. 8. Effect of FWA on brightness.

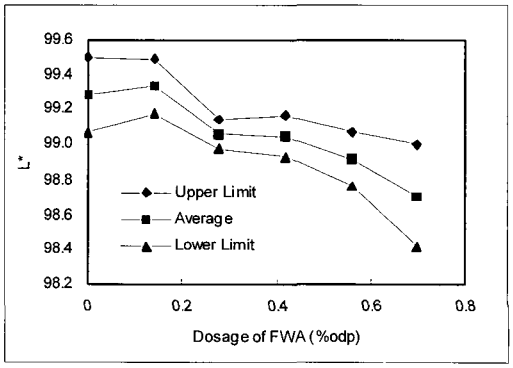

Fig. 10. Effect of FWA on lightness.

on lightness is larger than that on brightness. Based on this, one may also conclude that in comparing two tinting dyes, using lightness data would be better than brightness data.

Adding tinting dyes decreases lightness and brightness but increases whiteness is the reason why paper looks whiter but dimmer when tinting dye is used.

Fig. 10 shows that adding the FWA decreases lightness very slightly. This tendency is very different to that of brightness and whiteness. The lightness formula, $L^* = 116 (Y/Y_0)^{1/3}-16$, tells that L^*value is only related to Y value. Y is the green part of the tristimulus values (in addition, X is the red and Z is the blue one), since the florescent effect of FWA occurs in the range of blue to violet range, one is able to understand why FWA has very little effect on lightness. On the other hand, because FWA is also a kind of dye which absorbs visible light, although not to great extend as tinting dyes do, the addition of FWA do decrease lightness.

3.5 Effect of tinting dye and FWA on a*, b* properties

Fig. 11 shows that adding the tinting dye increases a^* and decreases b^*values. Therefore the shade of paper shifts from reddish-yellow to bluish-violet.

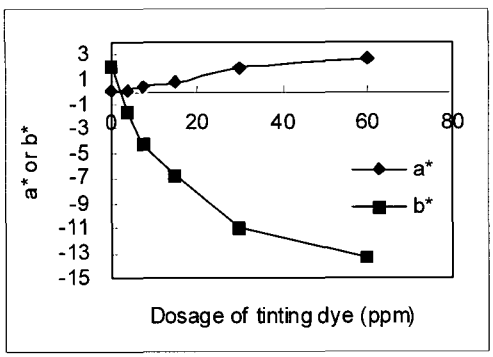

Fig. 11. Effect of tinting dye on a* and b* value.

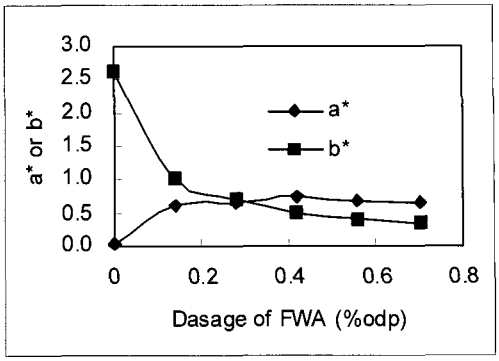

Fig. 12. Effect of FWA on a* and b* values.

Fig. 12 also shows that adding the FWA increases a^* and decreases b^* values, however, compared with that of tinting dye, the changes on a^* or b^* by the FWA are much smaller than those by the tinting dye.

3.6 Effect of tinting dye and FWA on color difference ΔE

E is used to indicate the degree of color difference. Normal human eyes can tell the difference if E is larger than 1. Fig. 13 shows the color difference between the tinted paper and the original un-tinted paper. Increasing the dosage of tinting dye greatly increases color difference. Fig. 14 also shows that increasing

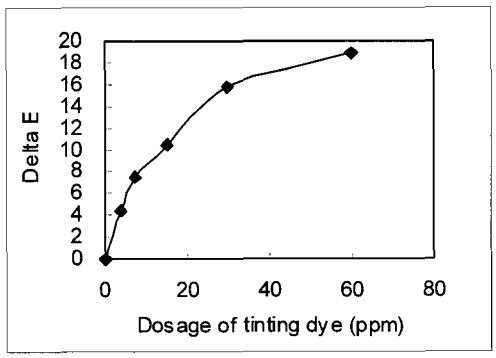

Fig. 13. Effect of tinting dye on color difference ΔE.

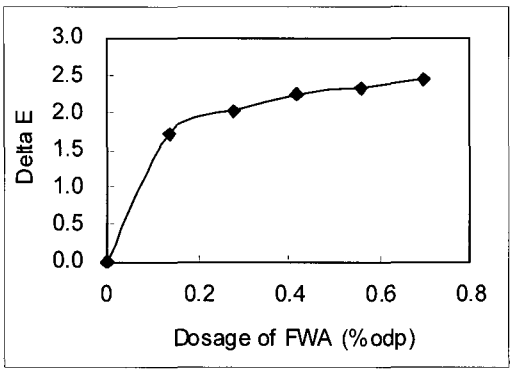

Fig. 14. Effect of FWA on color difference ΔE.

the FWA dosage increases color difference, however, compared with the tinting dye, its effect on color change is much less.

It is necessary to point out that although ΔE effectively shows the extent of color difference or color change, it does not tell where two colors differ. L^*, a^*, b^* values, or the L^*, a^* and b^* values, should be referred againin order to know that exactly (5).

4. Conclusions

Applying tinting dye and florescent whitening agent (FWA) both increase whiteness, however with different mechanisms. The tinting dye used in this study has significant light absorption in the range of 500~650 nm, with the peak at 590nm, therefore, the tinting dye absorbs yellow light and makes the paper look whiter. On the other hand, the FWA used in this study absorbs UV light and changes it into 420~500 nm visible blue light (peak at 440 nm), which makes paper looks whiter and brighter.

Investigation on brightness value showed the difference of brightness and whiteness. Tinting dye decreases brightness while increasing whiteness, but FWA increases both brightness and whiteness, although at very high FWA dosages, brightness and whiteness decrease again. Therefore, proper use of FWA makes paper look whiter and brighter, but tinting dye makes paper look whiter but dimmer. In addition, whiteness concept is only used for nearly white paper; values lower than 40 or higher than 2Y-280 are meaningless.

Regarding lightness, the tinting dye decreases it significantly but FWA only decreases it very slightly. Therefore, the meaning of lightness is also different from brightness and whiteness.

The effect of tinting dye on E is much larger than that of FWA. E effectively tells the extent of difference between two colors, but it does not tell how the two colors differ. L^*, a^*, b^* values or the L^*, a^* and b^* should be referred in order to know the differences exactly. Using the tinting dye and FWA both increase a^* value and decreases b^* value, but the effect of tinting dye is much larger than that of FWA.

This study also indicates that in comparing the performance of two tinting dyes, lightness values are most important to be compared, while whiteness data should be used in caution in order not to surpass its significant range, and a^*, b^* values can be used together to see the change of color shades, together with ΔE showing color difference. In comparing the performance of two FWAs, whiteness or brightness values are most important to be compared, but lightness values are not suitable, and a^*, b^* and ΔE can be referred with less significance for this purpose.

Literature Cited

1. J. Anthony Bristow, What is ISO brightness, Tappi J. 77 (5): 174 (1994).
2. J. Anthony Bristow, ISO brightness-a more complete

definition, Tappi J.82 (10): 54 (1999).
3. SCAN-P 66:93 CIE-Whiteness (D65/10o).
4. J. Anthony Bristow and Christos Karipidis, ISO brightness of fluorescent papers and indoor whiteness; proposal for illuminant, Tappi J., 83 (5): 183 (1999).
5. S. Jerry Popson, David D. Malthouse, and Patric C. Robertson, Applying brightness, whiteness and color measurements to color removal, Tappi J. 80 (9): 137 (1997).
6. Leo Neimo,Papermaking Chemistry, Chapter 14. Dyes and Florescent Whitening Agents, p306, Finnish Paper Engineer`s Association and TAPPI (1999).