Influence of Media on the Color Balance of Inkjet Printing

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Abstract

In some cases the color balance of original data cannot be reproduced on inkjet media.This is the result of a difference between the original dot size and the dot size on the media. It is thought that one reason for this difference is the interaction between the ink and media, which is the dot forming processes such as ink droplet impaction, spreading and penetration.

The coating layer of microporous inkjet media for photo printing consists mainly of pigment, binder, and a cationic ink fixative agent. The influences of these components on the dot formation were investigated.

As a result, the color balance was determined by the dot size of each color ink, and a close relationship between the dot size and the ink penetration was observed. The cationic demand was the major property difference in each color ink, thus the amount of ink fixative agent was the determining factor.

Introduction

In recent years, the performance of inkjet printers has continuously improved. This is due to the printers having more ink nozzles, smaller volume of individual ink droplet, and higher driving frequency. Nowadays, the image quality by inkjet printers is comparable to that of silver halide photography.

However, in some cases the color balance of original data cannot be reproduced on inkjet media, especially halftone prints such as gray and flesh colors tinged with red or yellow. Recent studies show that the color reproduction is affected by optical dot gain and dot spreading[1].

The objective of this work is to reveal the factors that affect color reproduction, especially the reddish hue of gray tones.

Relationship between Reddish Hue and Color Ink

Gray tones consist of cyan, magenta and yellow dots. Figure 1 shows the a* and b* value of cyan, magenta and yellow gradation patterns. The reddish hue has a relation to the a* value. The cyan and magenta ink affect the a* value, while the yellow ink does not affect it. Thus only cyan and magenta inks were used in this study.

Experimental

Samples

Papers: Two gloss-type and two matte-type commercial inkjet papers were selected. In addition, four different coated papers were made for this study in order to understand the influence of the materials in the coating layer (see Table 1). The coat weight of these papers was 11g/m^2.

Printers: A dye-type inkjet printer (Canon Inc.) was used. The printer had four inks (cyan, magenta, yellow and black) and the printed gray images were considerably reddish. The gray halftone pattern was printed on these papers by this printer.

Print Quality Evaluation

The reddish hue was evaluated as the a* value of CIELab with spectrophotometric colormeter. The dot area was measured by the following method. The magnified image of gray halftone pattern was taken by optical microscope. Since the image consisted of cyan, magenta and yellow dots, these three images were separated using Adobe Photoshop. Each image was converted into binary image by using image analysis software, LUSEX_SE (Nireco Co.), and the dot areas were calculated.

Ink Property Evaluation

The cyan and magenta inks from the printer referenced above were used. The cationic demand was measured using a particle charge detector, PCR-03 (Mutek Co.), and 1/1000 N poly-DADMAC was used as a titrant. The contact angle was measured with DAT 1100 (FIBRO system AB) using a control sample (see Table 1) as a basesheet.

Evaluation of Reaction between Ink and Ink Fixative Agent

The cyan and magenta ink solution was combined with the ink fixative agent solution using a voltex mixer. Then the aggregate of reaction products was generated. The aggregate was removed by centrifuge, and the non-reactive ink that remained was measured. The amount of non-reactive ink was detected using an absorption spectrometer.

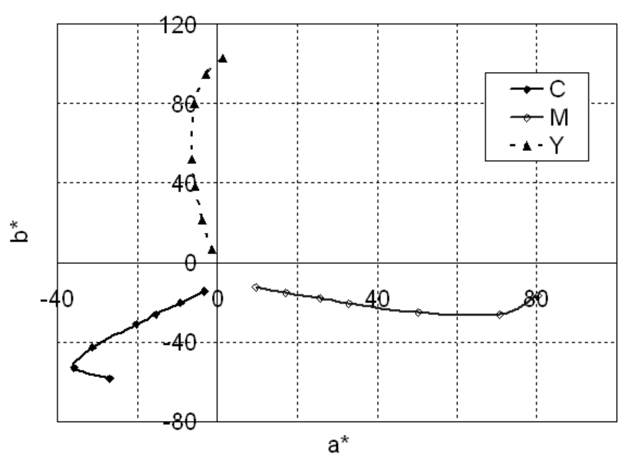


Figure 1. The relationship between color inks and hue.

Table 1: Summary of coating formulations on paper (pph).

	CTL	1	2	3
silica (small particle size)	80	70	80	80
silica (large particle size)	20	30	20	20
binder	10	10	8	12
ink fixative agent	0, 10	0, 10	0, 10	0, 10

Results and Discussions

Dot area

The relationship between dot area of cyan (C) and magenta (M) and the reddish hue on gray print was assessed with matte and gloss type commercial papers. As shown in Figure 2, the ratio of C dot area to M dot area strongly correlated with the a* value. The lower ratio caused more of a reddish hue. In contrast, only C and M dot area did not correlate with the a* value (data not shown). This result shows that C and M inks behave differently during penetration and fixation. As the result, these dot areas are different and the hue tinges with red. Next, the factors which caused the difference were investigated in the viewpoint of ink property and coating layer formulation.

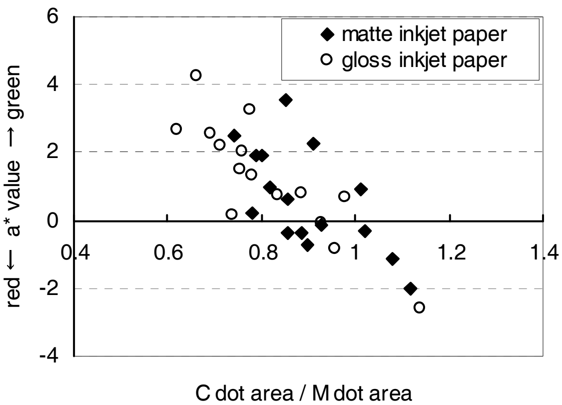


Figure 2. The relationship between dot area and hue.

Influence of Ink Properties on dot area

In general, ink penetration can be described using the Lucas-Washburn equation[2,3] (Equation 1).

$$h = \sqrt{\frac{r\gamma \cos\theta \cdot t}{2\eta}} \qquad (1)$$

where; h: depth of penetration, r: capillary diameter, t: time, γ: surface tension, η: viscosity of liquid, θ: contact angle.

The parameters in this equation were examined. The properties of C and M inks are shown in Table 2. The physical properties such as surface tension, contact angle, viscosity and density were quite similar between the two inks. This shows the penetration into pores in the coating layer is also equal between the two inks.

In contrast, cationic demand was quite different. That of M ink was much higher than that of C ink. In general, the coating layer of inkjet papers consists of pigment, binder, and ink fixative agent. Ink fixative agents are cationic polymers. The demand of ink fixative agent potentially could be different between the two inks.

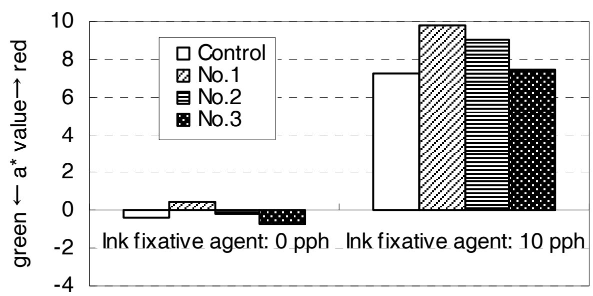
Table 2: Comparison to ink properties.

		Cyan	Magenta
Surface tension	mN/m	32	34
Contact angle	°	22	23
Viscosity	mPa・s	4.4	4.5
Density	g/cm3	1.04	1.07
Cationic demand	meq/L	143	263

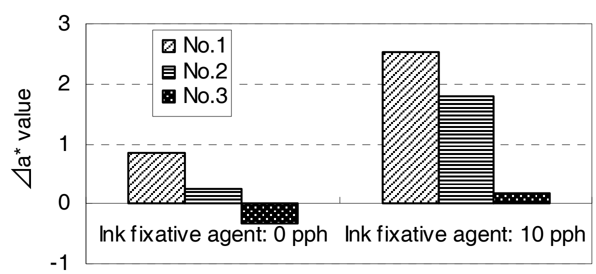
Influence of Coating Layer Formulation on dot area

In order to investigate the influence of materials in the coating layer on the difference of C and M dot areas, inkjet papers were made with varying amounts of pigment, binder, and ink fixative agent. Pigment and binder affect ink absorbency while ink fixative agent affects cation quantity. Figure 3a shows that the presence of an ink fixative agent was the major factor in generating a reddish hue.

Ink absorbency was another factor. The ink absorbency was higher when using large size silica or less binder. As shown in Figure 3b, under the existence of ink fixative agent, higher ink absorbency caused a higher a* value.



(a)



(b)

Figure 3. The Influence of coating layer formulation on a* value. (a) a* value, (b) the difference of a* value based on the a* value of Control.

Reaction between Ink and Ink Fixative Agent

We showed that ink fixative agents affected the C/M dot area ratio, resulting in a change in color balance. However, it is still not clear which factors of ink fixative agents cause the difference of C and M dot areas. Ink fixative agents have various monomer compositions, molecular weights and anionic demands. We investigated the reaction between ink and ink fixative agents.

As shown in Figure 4, this reaction depended on only anionic demand of the ink fixative agent, and did not depend on the monomer composition or molecular weight. Therefore it was thought the reaction was an ionic reaction. The cationic amount in a coating layer depended on amount of ink fixative agent and the anionic demand of the ink fixative agent itself. Therefore we investigated hue, dot area, and ink penetration by changing these two factors.

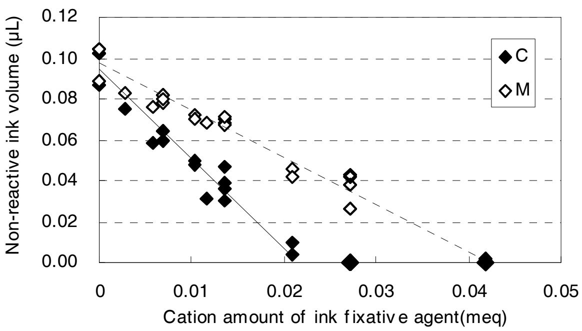


Figure 4. Reaction between ink and ink fixative agent. Fifteen ink fixative agents were used in this experiment.

Changing Amount of Ink Fixative Agent

Figure 5 shows the behavior of the a* value when increasing the amount of ink fixative agent. The a* value was the lowest when no ink fixative agent was used. As the amount was increased, the a* value also increased until it reached a maximum of 9.0, where it then declined.

As shown in Figure 6, the amount of ink fixative agent affected the ink penetration into the coating layer. Without ink fixative agent, the penetration of C and M ink were similar. On the other hand, as the amount of ink fixative agent was increased, the penetration decreased. C ink showed to be more sensitive than M ink. In other words, lower amounts of ink fixative agent caused less penetration of C ink. As a result, a difference between C and M dot area was generated.

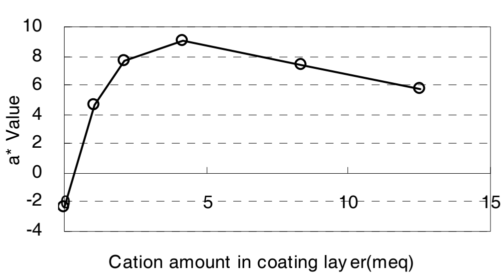
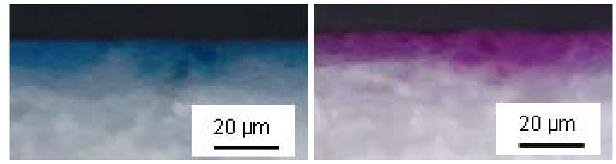
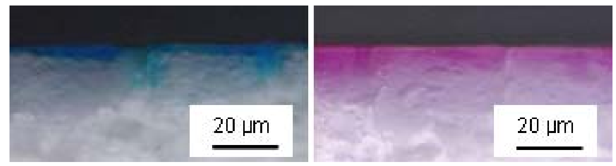


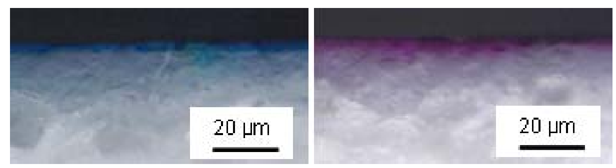
Figure 5. The influence of the amount of ink fixative agent on reddish hue.



(a) Without the ink fixative agent



(b) The cation amount in the coating layer: 4.2 meq



(c) The cation amount in the coating layer: 8.4 meq

Figure 6. Cross Section of Printed Paper by changing the amount of ink fixative agent. Left: C ink, Right: M ink.

Changing Component of Ink Fixative Agent

To examine the influence molecular weight and monomer component on the a* value, six paper samples were made with different ink fixative agents. Figure 7 shows the behavior of the a* value when changing molecular weight and monomer component of ink fixative agent. The anionic demands were 3, 5 and 7 meq/g, and molecular weights and monomer components were different. Comparing at equal cation amounts in the coating layer, the ink fixative agent with a lower anionic demand gave a lower a* value. If the cation amount were the sole factor, these six lines in Figure 7 should have corresponded. However, the behavior did not correspond. The reason is not clear, but we hypothesize that the following factors might affect this phenomenon; distribution of the ink fixative agent in the coating layer, reaction velocity between inks and the ink fixative agent, and/or the pore size of the coating layer.

Figure 8 shows the penetration depth by changing components of the ink fixative agent. For the paper using ink fixative agents with low anionic demands, the penetration of C and M inks were deeper than when using it with high anionic demand. In the case of using ink fixative agents with high anionic demand, M ink penetrated deeper than C ink, so a difference of dot areas might be generated.

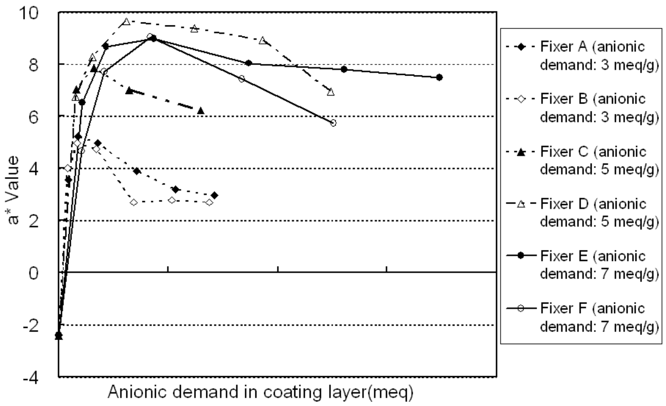
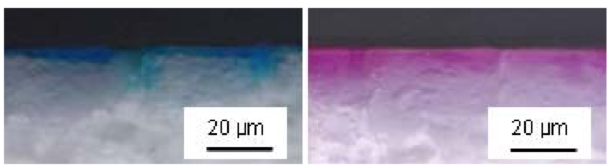


Figure 7. The behavior of reddish hue using various ink fixative agents.

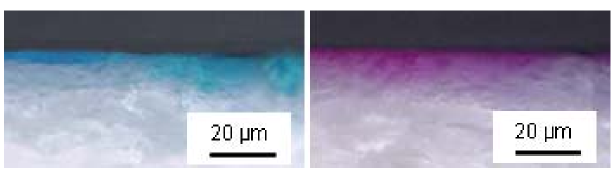
Cation amount	(1) low	(2) intermediate	(3) high
Ink penetration	C : deep M : deep	C : shallow M : deep	C : shallow M : shallow
Dot area	C≒M	C<M	C≒M
C/M dot area ratio	high	low	high
Reddish hue	weak	strong	weak

● Cyan ink ● Magenta ink

Figure 9. Presumptive mechanism of reddish hue.



(a) The anionic demand of ink fixative agent: 7 meq/g



(b) The anionic demand of ink fixative agent: 3 meq/g

Figure 8. Cross Section of Printed Paper using two ink fixative agents which have different anionic demand. Left: C ink, Right: M ink

Model of Color Balance

Figure 9 shows the model of changing color balance by the ink fixative agent.

(1) If the cation amount is low, the reddish hue is low. In this case, ionic reaction does not affect the penetration of ink. Therefore, C/M dot area ratio becomes high.

(2) If the cation amount increases more than (1), the reddish hue sharply rises. In this case, ionic reaction affects the penetration of ink. The cationic demand of M is higher than that of C, thus the penetration of M is deeper than that of C. Therefore, C/M dot ratio becomes low.

(3) If the cation amount is much higher than (2), the reddish hue is low. In this case, the penetration of both C and M are similar.

Conclusion

It was found that the reddish hue on gray halftone print has a close relationship with the C/M dot area ratio. When the C/M dot area ratio was low, the hue of the print was tinged with red.

The major factors were the difference of cationic demand of the ink and the existence of ink fixative agents in the coating layer. If the amount of the ink fixative agent was much lower or much higher, the penetration of C and M ink were similar. Thus the printed image did not take on a red tinge. Contrarily, if the amount is intermediate, the penetration of M is deeper than C, thus the printed image would be tinged with red.

References

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Author Biography

Kimiko Imura received her MS in Agriculture from Kyoto University, Kyoto Japan (2004). Since then I has worked in the Research and Development Division at Nippon Paper Industries Co., Ltd., in Tokyo, Japan. Her work has focused on the development of inkjet paper.