

The Image Quality and Lightfastness of Photos from Digital Camera Appliance Printing Systems

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Abstract

The creation of inkjet prints from digital cameras has generally required the intermediacy of a PC, often gives variable results dependent on the familiarity of the user with necessary software, and has been less than user friendly. Camera appliance printers like the KODAK Personal Picture Maker by Lexmark have introduced user friendly printing to digital camera owners by allowing printing directly, simply, and inexpensively from camera flash cards.

In this study, we discuss the attributes customers require of photographs from digital camera appliance systems, and how well commercially available and two Kodak prototype systems fulfill those requirements. We will specifically discuss the selection and invention of magenta dyes, which give state-of-the-art lightfastness and color. We will compare the consumer-judged image quality of prints from various appliance printer systems to those typically obtained from a silver halide system. The effects of illuminant intensity on the fade of printed images will be discussed, and the lightfastness of a variety of systems will be compared.

Introduction

Because prints from camera appliance printers are meant to satisfy the requirements of a silver halide photograph, many of the same system performance criteria apply: performance for price; ease of use; the image quality and color of a photograph; and image permanence. This paper focuses on customer perceived image quality, color, and lightfastness. A major hurdle preventing delivery of the best color and lightfastness in a single system has been the lack of suitable magenta dyes.

Color

Measurements of color reproduction are problematic. Projections of the outside boundaries of color gamuts in L*a*b* space into the a*b* plane, like those commonly used in marketing literature or summary reports[1] make assumptions about the effects of lightness. Total volume color gamut calculations ignore the ability to accurately reproduce certain colors contained within the gamut and ignore customer preferences of which colors need to be reproduced accurately. In order to effectively choose colorants apart from system constraints, and at a fundamental level related to properties of the colorants themselves, we have chosen to compare the reflection spectral curve shapes of colorants to "ideal" shapes required for good reproduction. Such ideal shapes have been patented by McInerny, et al.,[2] and that of the ideal magenta dye is shown as the solid trapezoidal curve in Fig. 1. Note that this is not a true block dye, but rather a block-type dye with sloping sides.

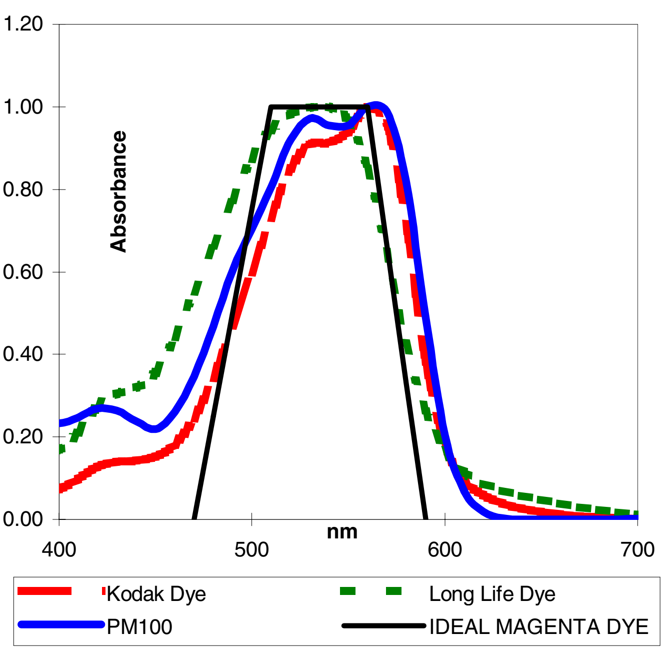

Figure 1. Spectral curves of comparison magenta dyes giving either high color or good lightfastness.

There are combinations of wide format inkjet inks and media that are claimed to have very long print lifetimes.[3] The spectral curve of the magenta ink of one of those sets is shown as the dotted curve in Fig. 1. Note that, while the absorbance maximum is almost centered within the ideal, there are significant unwanted absorptions outside the ideal, which desaturate the dye and give it a muddy-brown appearance. Compare this shape to the high color magenta ink from the KODAK Personal Picture Maker PM100 (dot-dash curve). The dye in this ink is slightly bathochromic to the ideal, but has a cut on the long wavelength edge, which parallels the ideal. It also has fewer unwanted absorptions on the long wavelength side than the long life dye. However (see below), this ink has poor lighfastness. The final curve (shown as the solid line in Fig. 1) is from the magenta ink from a set of inks under development for future KODAK Personal Picture Makers. It uses a proprietary colorant[4] designed and manufactured by Kodak for this purpose. Very little of its spectral envelope is outside the ideal, and the cut of the dye on the long wavelength side is especially sharp.

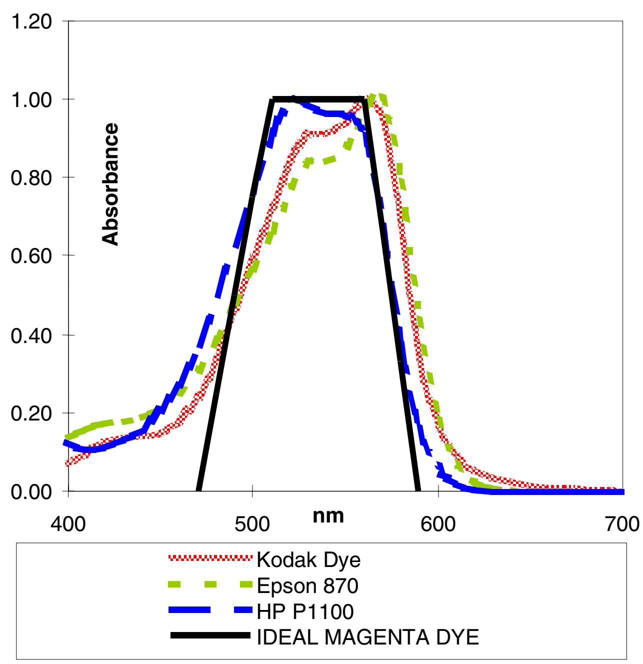

Figure 2. A comparison of the spectral properties of magenta dyes from appliance printers.

In Fig. 2, we compare the spectral curve shape of this ink to inks from two competitive appliance photo printers. The HP P1100 is a true appliance printer that prints directly from flash cards, while the Epson 870 takes flash cards, but requires the intermediacy of a computer. All three inks have narrow spectral distributions approaching the ideal, although their absorption maxima are different. The effect of the absorption maximum on color gamut (as in ref. 2) depends on the spectral shapes and maxima of the other dyes used in the ink set, so in the right combination, all three inks have the potential to produce good color gamuts.

Image Quality

Even though there are a variety of objective metrics for judging the quality of photographs,[5] the best way to find out what consumers really prefer is to ask them. Our goal in seeking the voice of the customer was to compare the image quality of digital photo inkjet appliance systems available on the market at the start of the year 2000. The KODAK Personal Picture Maker PM100 and all available competitive systems were chosen for evaluation. Also included were two new prototype Kodak printers. The nineteen systems tested are identified in Table 1.

Scenes were chosen to represent a variety of photographic conditions such as outdoor close, outdoor infinity, indoor flash in tungsten lighting, indoor flash close, and indoors at a public building. All scenes were shot with the appropriate system camera within minutes of each other to capture the same lighting conditions, and great care was taken to match the subject size as captured by the various cameras. The prints for these scenes were all processed in the stand-alone appliance mode (not PC connected) and were printed on the premium photo paper recommended for that system. We chose 5 x 7 inch prints for the customer evaluation since inkjet prints tend to be larger than the 3 x 5 or 4 x 6 inch photographs that are typical of minilab processed prints today.

To evaluate the image quality, 40 typical snapshot picture takers compared images from the 19 represented system combinations one scene at a time. The scenes were first sorted in order of preference and then given a numerical rating of 0-100 with the highest number being absolute perfection. The subjects were instructed to rate overall image quality and were not asked to rate any particular attribute.

The results of the study are summarized in Table 1. The letter grades are assigned to systems that are in statistically similar groupings. Group A is comprised of the Kodak 6-ink prototype system coupled with both a 1.6 and 2.0 megapixel camera. These systems are judged statistically superior in comparison to all the other systems tested. Group B contains the Kodak prototype three-ink system, and the KODAK PM 100 as well as the HP P1100. Some of the systems among the lowest groupings exhibited outstanding image structure, but had poor color reproduction, and that probably explains why they fell to near the bottom of the ranking. This would imply that color is an important customer attribute. The Kodak prototype systems offer both outstanding image quality and, as we will show, colors that last longer than the competition.

Table 1 Mean Rating for Overall Quality for All Scenes

Rank	Camera - Printer System	Statitical Grouping
1	Kodak DC265-Kodak 6 Ink-	A
2	Kodak DC290-Kodak 6 Ink-	A
3	Kodak DC265-Kodak PM100-	B
4	Kodak DC265-HP Photosmart P1100-	B
5	Kodak DC265-HP Photosmart P1100-	B
6	Kodak DC215-Kodak 6 Ink-	B
7	Kodak DC290-HP Photosmart P1100-	B
8	Kodak DC265-Kodak 3 Ink-	B
9	Kodak DC290-Kodak PM100-	BC
10	Kodak DC290-Kodak 3 Ink-	BC
11	Epson PC800-Epson Color 740-	CD
12	Epson PC800-Epson Photo 700-	CDE
13	Kodak DC215-Kodak 3 Ink-	DEF
14	Epson PC800-Epson Photo 750-	DEF
15	Kodak DC215-Kodak PM100-	DEFG
16	Kodak DC215-HP Photosmart P1100-	FG
17	Epson PC750Z-Epson Photo 700-	FG
18	Epson PC750Z-Epson Color 850-	FG
19	Epson PC750Z-Epson Color 740-	G

Lightfastness

The prediction of keeping properties by accelerated means is always difficult. Natural aging can literally take a lifetime, but the degradation mechanisms of accelerated tests may not mimic those of natural aging. With these cautions in mind, we have adopted the general light fade methodology of Bugner and Suminski[6] for exposure conditions and data analysis. Samples were faded under Plexiglas filtered 67 klux fluorescent, Plexiglas filtered 5.4 klux fluorescent, and office fluorescent lights, with diffusers. The samples kept in the office saw an average intensity of 450 lux, and were rotated manually to ensure homogeneous exposure As per Bugner, fade is reported as a percentage change in initial density and cumulative exposure is measured in klux-hrs.

A comparison of the fade properties of the Kodak magenta ink printed onto KODAK Premium Picture Paper for Inkjet Prints and the cyan ink from the Epson 870 printer printed onto the recommended glossy photo paper are shown in Fig. 3. These are the most rapidly fading inks in their respective systems. Both inks show reciprocity failure between the 67 and 5.4 klux exposures, with the fade more rapid under conditions of lower intensity. The change in slope as a function of intensity is much greater for the Epson 870 ink than for the Kodak. At 67 klux exposure, the Epson cyan dye is fading more rapidly than the Kodak magenta. At 5.4 klux the difference between the Epson and Kodak is even greater. Only one office-kept point for the Kodak ink is shown as there was only 3.5% density loss after 6 months of constant exposure to 450 lux fluorescent. Several points are shown for the more rapidly fading Epson cyan. After a month of office keeping, prints from this system are unusable. Interestingly, the office-kept Kodak sample shows no reciprocity failure when compared to the 5.4 klux sample, indicating that 5.4 may be a reasonable accelerated test for comparing many systems.

The large reciprocity failure of the Epson 870 cyan was recently discussed by Wilhelm (see ref. 3). He speculated that prints from these inks have a particular sensitivity to ozone and other airborne contaminants, and that they should be displayed under glass. We are presently testing this hypothesis.

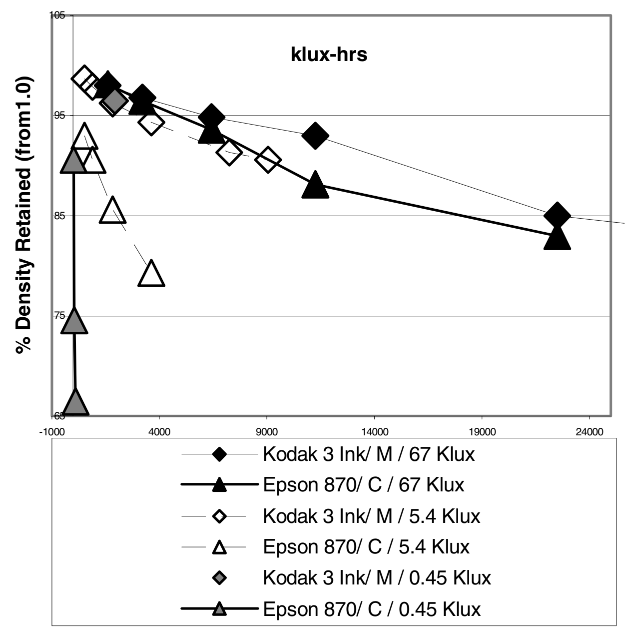

Figure 3. Lightfastness at three illuminant intensities.

Figure 4 shows a variety of inks from appliance printers faded at 5.4 klux fluorescent. These were the inks that were first-to-fail in the faded prints as judged by the criteria proposed by Zinn.[7] Note that four separate experiments with Kodak inks give very similar results and compare favorably to an experiment from a Kodak six ink printer, which also used a light magenta. Replicates of the HP P1100 and Epson 700 inks are also similar. Qualitatively, the Epson 870 inks failed first, the HP P1100 inks next, and the Kodak inks last. The Kodak dye is fading linearly while the P1100 fade profile is exponential. More quantitatively, the klux-hrs needed to reach Zinn endpoints are summarized in the Table 2. The Kodak inks are three times more stable than the Epson 870 inks and twice that of the HP P1100 inks under these testing conditions.

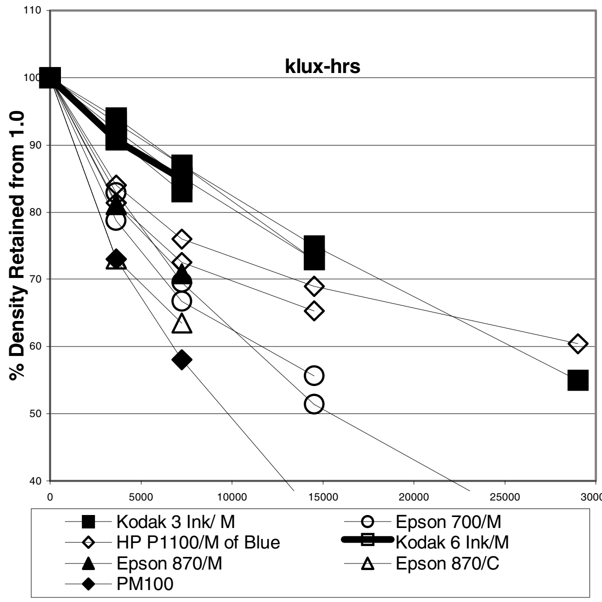

Figure 4. Lightfastness of first-to-fail colors of printer appliance system prints.

Table 2 Print Lifetimes at 5.4 Klux Fluorescent

Printer	Color	Klux-hrs to endpoint
Epson 870	Cyan	3500
Epson 870	Magenta	4000
HP P1100	Magenta	5100
Kodak 3 or 6 Ink	Magenta	11000
Epson 700	Magenta	4000

Conclusions

The image quality of all of these printers when mated to a mega-pixel camera was judged acceptable by consumers. The Kodak prototype 6 ink printer was statistically better than the rest, with these cameras. The magenta ink under development at Kodak compares favorably for color to the state of the art magenta inks from other camera appliance printers. This ink is significantly more lightfast than the comparisons, establishing a new benchmark for the combination of color and lightfastness in inkjet photo applications. Lightfastness reciprocity effects are shown to be a factor for all inks, but especially for the cyan ink of the Epson 870 on its own matched paper. Accelerated keeping at 5.4 klux is shown to be a predictor for the Kodak inks

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Biography

Michael J. Carmody received his B.S. degree in Chemistry from the University of Detroit in 1972, and a Ph.D. in Organic Chemistry from The Ohio State University in 1976. Since 1976, he has worked in the Research and Development Laboratories of Eastman Kodak Company in Rochester, NY. His work has focused on the synthesis, mechanisms, and performance of colorants and color formers in silver halide films and papers. He joined the Inkjet Materials and Systems Division in 1997, where he is presently Manager of Ink Processes.