Humidity Effects on Plain Paper in Inkjet Printing

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Abstract

The aim of this work was to investigate the effect of relative humidity of the ambient air on the initial print quality when printing on multifunctional office papers with the present generation of desktop inkjet printers. A range of multifunctional office papers with known behaviour were chosen to give variations in print quality parameters like optical density, colour-to-colour bleed and wicking. The papers were inkjet printed at various levels of humidity with a standardised test image. Print quality was evaluated visually and by image analysis.

Some properties were clearly humidity-dependent, such as colour density and colour-to-colour bleed, but only for some printers. Other properties, like black optical density, were not effected at all. The difference between paper brands was in all cases larger than the difference between humidities.

Introduction

The term "multifunctional" or "multipurpose" office paper was introduced when plain paper inkjet printers entered the market about ten years ago[1]. It refers to a substrate that is aimed towards more than one printing technology, e.g. electrophotography, inkjet and offset. A majority of the uncoated cutsize papers in the market today are marketed as multifunctional, just as most desktop inkjet printers are marketed as plain paper compatible. The average user would most likely be satisfied with the print quality gained with most printer/paper combinations, but in fact, the actual printing result differs substantially between papers and printer brands. To improve the situation, printer and paper manufacturers must further develop their products, as both still have potential for print quality optimisation.

Paper moisture and humid air have strong influence on the behaviour of paper in most conversion process, digital printing included. Climate effects on paper properties in electrophotography have been thoroughly studied and publications in this field are still frequent.[2-4]

Only a few studies on the impact of climate on inkjet printability have been published. Carlson et al.[5] reported that a hot and humid environment caused decreased print quality on the media-sensitive inkjet printers of the early nineties. Mitani et al.[6] proposed a heated pre-dryer in an inkjet printer to improve print quality and ink drying time. Yuan et al.[7] reported increased drying time at high humidity when inkjet printing on special coated papers. Recent publications on the subject have mostly dealt with the effect of climate on storage stability of photographic inkjet images[8-11]. No publication has so far reported on the effect of climate when printing on multifunctional office papers with the present generation of inkjet printers. The purpose of this study was to evaluate if the strong progress in plain paper inkjet technology during the nineties has eliminated the climate sensitivity reported for early printer generations.

Experimental

Substrates

A set of six papers was selected after a brief pre-screening study at 50 % RH, 23 °C (*table 1*). All papers were uncoated multifunctional office papers, even if some were branded as dedicated inkjet papers. They were chosen because they were ordinary papers and exhibited a certain weakness that might respond to the change in humidity. The papers were unpacked, marked at 50 % RH, 23 °C and then conditioned to the printing climate. Five sheets of each brand were printed on both sides.

Table 1. Papers used in this study.

Code	**Branding**	**Primary purpose**	**Weakness**
A	Inkjet OEM	Inkjet	Multiple
B	Multifunctional	Electrophotography & inkjet	Epson bleeding
C	Multifunctional	Inkjet & electrophotography	Deletions
D	Multifunctional	Electrophotography	HP black mottling
E	Multifunctional	Electrophotography & inkjet	Balanced
F	Experimental	Not sold on the market	Wicking

Printing

Printing took place at five different climates: 20, 35, 50, 65 and 80 ± 2 % RH, all at 23 ± 1 °C. All papers were stored in sealed plastic bags after printing, to preserve the climate for at least one week until testing. An office printer model from each of the three largest suppliers of desktop printers was used: Hewlett-Packard DeskJet 959C, Epson Stylus Color 880 and Canon BJC-6200.

The test image consisted of solid squares of primary and secondary colours, solid bars, halftone patterns and combinations of different colours adjacent to each other. Since the image covered only half of the page, the same sheet of paper could be printed upon both sides.

The original driver software was used to create a print file for each printer, which was then installed on each printing computer. This way, the image would look the same regardless of which computer was used. The default software settings were used for the HP and Canon printers, while the "Quality" setting was used for Epson. For the HP printer, an additional file was created to produce a solid black surface created in Microsoft PowerPoint, as it had been noticed that the HP driver software under the default setting uses a different algorithm to print graphics created in Microsoft Office applications compared to graphics created in other applications. The way this algorithm applies the black ink puts more strain on paper properties.

Print Quality Testing

Optical density (OD) in solid black, cyan, magenta and yellow was measured by a Gretag D-19 densitometer after compensating for paper OD on each sheet. The lowest reading was used, as this makes the method more sensitive to mottling compared to using the average value. Image analysis on solid black bars was used to measure wicking and black-to-yellow colour bleeding. These properties were defined as line roughness, i.e. the ratio between actual and ideal line perimeter. Strike-through was measured by image analysis and defined as the area percentage of the backside of a solid square that was darker than a fixed grey level threshold. Drying time was estimated as the time from which the paper was ejected to the output tray until the solid black square was free from wet gloss. Deletions were evaluated visually.

Results and Discussion

Optical Density

The most obvious impact of changes in humidity was that all colours of the HP printer except black were clearly more brilliant on all papers at higher humidity levels (*figure 1*). For Epson, the same trend was observed with magenta and yellow ink, while cyan was not effected. The results were somewhat confusing for the Canon printer and no clear trend could be observed.

Table 2 collects the average values with standard deviations of black optical density taken over the whole humidity range. The standard deviation values are small and this indicates that there was only a small effect of humidity on optical density of black ink. The strongest variation in black density among the papers was found for the HP printer.

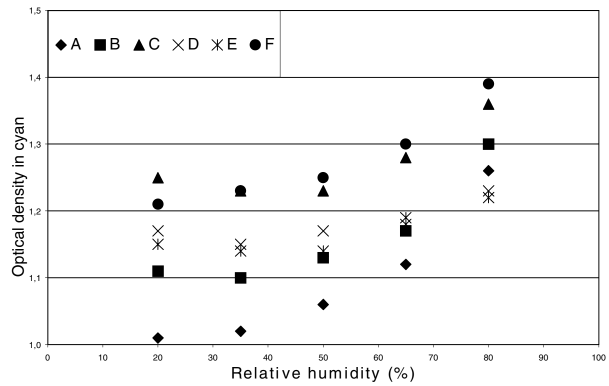

Figure 1. Optical density in cyan for HP DeskJet 959 C on paper A-F as a function of relative humidity.

The fact that most coloured inks excepting black ink obtained increased optical density with increasing humidity could be explained by a higher lateral spreading of the colour ink compared to the black ink. High moisture content of the paper and low surface tension of the ink favour spreading and coloured inks usually have much lower surface tension than black inks.

Table 2. Average value and standard deviation for optical density in black on each paper regardless of humidity.

Black OD	**Paper**					
	A	**B**	**C**	**D**	**E**	**F**
HP	2.05	1.90	2.15	1.46	2.35	1.43
Std. dev	0.05	0.05	0.05	0.12	0.05	0.03
Epson	1.76	1.84	1.86	1.70	1.72	1.90
Std. dev	0.04	0.02	0.02	0.07	0.04	0.03
Canon	2.12	2.07	2.46	2.19	2.34	1.88
Std. dev	0.06	0.01	0.06	0.05	0.02	0.07

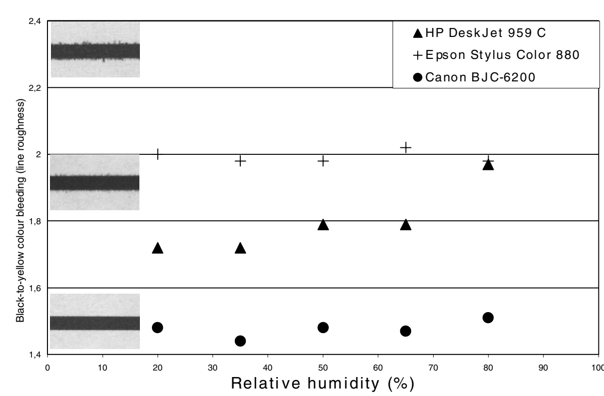

Figure 2. Black-to-yellow bleeding on paper B for each printer as a function of relative humidity.

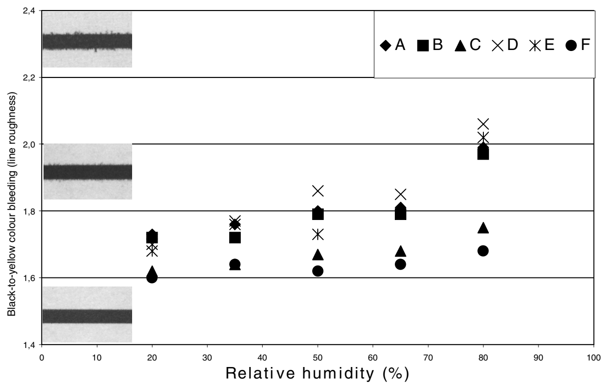

Figure 3. Black-to-yellow bleeding on HP DeskJet 959C for paper A-F as a function of relative humidity.

Black-to-Yellow Bleeding

A large difference in bleeding between the three printers used in this study was observed. Bleeding was most critical on the Epson printer. The results showed that only bleeding of the HP printer was humidity sensitive, while Epson and Canon were not (*figure 2*). The difference between the papers was however larger than the difference between humidities (*figure 3*).

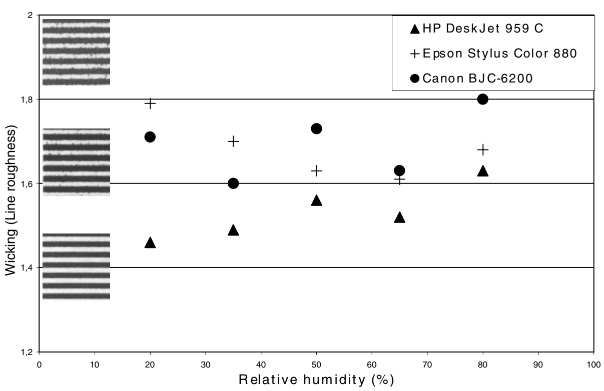

Figure 4. Wicking on paper F for each printer as a function of relative humidity.

Wicking

This property was mostly an issue for the Epson printer, while only the experimental paper F had noticeable wicking on HP and Canon. There was a trend towards more wicking at high humidity for paper F with the HP printer (*figure 4*) but the values are quite low. Also paper C printed with the Canon printer had slightly more wicking at high humidity, but the increase was minimal. No clear indication of humidity-dependent wicking was observed for any other printer/paper combination.

Deletions (White Spots)

This phenomenon has to our knowledge not yet been described in the literature. It refers to small areas in the paper surface that refuse to absorb the ink, leaving white spots in the print. These spots are believed to consist of vessel cells from certain hardwood species or agglomerates of hydrophobic sizing agents. In this study, paper C was included due to a high number of deletions. Visual evaluation gave no clear evidence that the number of deletions is humidity-dependent on any printer (*figure 5*).

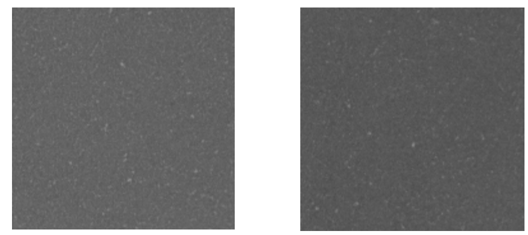

Figure 5. Deletions in a blue solid square for paper C on Epson Stylus Color 880 at 20 and 80 % RH.

Strike-Through

Only black ink printed with the HP printer on paper D and F and red ink on paper A using the Canon printer had enough strike-through to be measurable. Even if the results were somewhat confusing at low humidity, strike-through was in all cases clearly worst at 80 % relative humidity as can be seen in *Table 3*.

Table 3. Strike-through for some printer/paper combinations at different relative humidities.

Strike-through, %	RH, %				
	20	35	50	65	80
Paper D on HP	4.8	6.1	7.4	1.3	8.7
Paper F on HP	1.0	1.2	2.1	1.3	3.7
Paper A on Canon	20.5	17.0	22.4	21.7	35.8

Table 4. Dry time for paper A on Hewlett Packard DeskJet 959 C at different relative humidities.

Dry time, s	RH, %				
	20	35	50	65	80
Paper A on HP	17	16	15	17	29

Dry Time

Only paper A printed on the HP printer had any notable drying time. This was increased at the highest humidity (*table 4*).

Conclusions

Changes in relative humidity in the printing room clearly effected inkjet print quality of many tested printer/paper combinations, while other combinations were unaffected. The difference was in many cases visible to the naked eye, thus of importance for the end user.

The observations may be summarized as:

- Optical density of colours was generally, but not always improved by high humidity. Optical density of black was unaffected by humidity.

- Wicking, bleeding, print-through and dry time normally were worsened or unaffected by increased humidity.
- The difference between paper brands was in all cases larger than the difference between humidity.
- The HP printer was the most humidity sensitive printer.

The observations reported are most likely due to an increased lateral spreading of ink droplets at high humidity. Such spreading is promoted by high moisture content of the paper and also affected by the properties of the ink and paper. A low dynamic surface tension of the ink and a high surface energy of the paper promote spreading. Such properties are expected to vary among the material used and thus we can not expect all ink-paper combinations to act in the same way.

Excessive ink spreading could be more annoying than dull but uniform colours. Thus, minimised spreading would normally have higher priority than maximised colour brilliance. The generic recommendation would therefore be to avoid too high humidity since most detrimental effects showed up at 80 % RH. However, as inkjet print quality is normally not the decisive factor for climate control settings at the office, a more useful recommendation based on our results is that inkjet print quality testing labs must be set up at controlled climatic conditions. As the difference between printers and paper brands was in all cases larger than the impact of humidity, the right choice of paper for a given printer would minimise the detrimental quality effect of high humidity.

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References

1. Y. Alwarsdotter, O. Högberg: "Development of the First Multipurpose Paper", IS&T's NIP 10, p. 488 (1994)
2. C. Green: "Curl in paper", Appita vol. 53 no. 4, July 2000, p.272 (2000)
3. S. Simula: "Electrical properties of digital printing paper", IARIGAI 26th international research conference, advances in digital printing (2000)
4. P. Sirviö: "The Effects of the Process Parameter Adjustments on Print Quality in a Web Fed Electrophotographic Color Printing Process", IS&T's NIP 16, p. 293 (2000)
5. S. A. Carlsson et al: "Environmental Effects on Image Bleed with various Ink Jet Imaging Substrates", IS&T's 46th Annual Conference (1993)
6. M. Mitani et al: Rapid Drying and Low Feathering in a Plain Paper Ink-jet Printer", Journal of IS&T, vol. 40 no.1, Jan/Feb 1996, p. 26 (1996)
7. S. Yuan et al: "The Development of Receiving Coatings for Inkjet Imaging Applications", IS&T's NIP 13, p 413 (1997)
8. R. Hofmann et al: "Print Performance Evaluation of Ink-jet Media: Gamut, Drying, Permanence", IS&T NIP 15, p. 408 (1999)
9. P. Hill et al: Measurements of Humidity Effects on the Dark Keeping Properties of Inkjet Photographic Prints", IS&T's NIP 16, p. 70, (2000)
10. M. McCormick-Goodhart, H. Wilhelm: "Humidity-Induced Color Changes and Ink Migration Effects in Inkjet Photographs in World Environmental Conditions", IS&T's NIP 16, p. 74, (2000)
11. P. Wight: "Issues in Ink Jet Image Stability", IS&T's NIP 16, p. 86 (2000)

Biography

Olle Högberg received a B.Sc. degree in Paper Technology from University of Karlstad in Sweden 1991 and a M.Sc. degree in Paper Chemistry from Åbo Akademi University in Finland 1995. He joined his present employer Stora Enso Fine Paper, Nymölla Mill, in 1991. His first position as laboratory engineer focused on development of image analysis methods and improvement of inkjet print quality for multifunctional office paper. His current position as R&D engineer includes co-ordination of inkjet printing research within the Stora Enso Office Paper business unit. He is a member of IS&T, TAPPI (Technical Association of the Pulp and Paper Industry) and SPCI (The Swedish Association of Pulp and Paper Engineers).