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IMPACT OF TYPE OF INK AND SUBSTRATE ON COLORIMETRIC VALUES OF INKJET PRINTS

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Abstract: *This research aims to characterize the quality of prints printed with inkjet printing technique, depending on the type of UV ink and printing substrate. Printing substrates were chosen as trending substrates for digital printing used for both indoor and outdoor applications and thus may be affected with a variety of different agents during production and in general use. The results led to the conclusion that on various substrates, HP HDR250 Scitex inks shown better results, as well as that fastness properties very much depend on the type of pigment in ink.*

Key words: digital printing, inkjet, ink, substrate, colour difference

1. INTRODUCTION

In addition to electrophotography, inkjet printing technology is currently one of the simplest and most popular digital printing technique that takes precedence in the field of short runs (Kašiković et al, 2016). The printing process is contactless, which means that there is no need for an intermediate carrier for transfer of the ink on the substrate (Kipphan, 2001). Since this is the main advantage of this printing technique, it allows printing on a large number of different substrates (paper, cardboard, textile, foils, glass, metals etc.) that other printing techniques cannot use. Besides that, inkjet printing enables usage of a large number of different colours, as well as large format prints (Kašiković et al, 2016). Due to all its advantages, this printing technique has broad application – home use (HP, Epson, Canon), printing on textiles (Canon, Seiren, Minolta, Durst), production of printing plates (Polychrome, Iris), 3D printing (3D System, Z Corporation) and printing for medical needs (Iris, Sterling Diagnostics) (Majnarić, 2015).
The main inkjet technologies are continuous and drop on demand inkjet. Continuous inkjet is based on dyeing the substrate with fine droplets that a very brittle oscillating body continually ejects from the nozzle. During this process, it is possible to produce and then transfer thousands of droplets to the substrate depending on the charge – electric field deflects charged droplets, while the uncharged ones dye the substrate. On the other hand, in drop on demand inkjet technology, a droplet is produced when needed. The main drop on demand technologies are thermal, piezo, electrostatic and stream inkjet (Kipphan, 2001; Majnarić, 2015).

1.1 Inkjet inks

The most demanding component in inkjet printing is ink. The chemical composition and ink formulation in inkjet dictate not only the quality of the print but also determine the characteristics of the droplets as well as the reliability of the printing system. All inks for inkjet contain two components – colorants and base. Since low viscosity is the main characteristic of the inkjet inks, the base is the most abundant component. Its task is to ensure the formation of small droplets of colour and their proper distribution from the printheads, as well as the good bonding to the substrate. Use of a large number of different substrates requires the application of different liquids as a base for inkjet – water, microemulsions, oils. As such fluids behave differently in contact with the rigid surfaces, several drying mechanisms are available – penetration, evaporation, phase change from a liquid state to a solid state or gel, and a chemical reaction. Depending on the drying process, it is possible to use different inks (hot-melt, UV, solvent, latex etc.) (Majnarić, 2015).

1.1.1 UV inkjet inks

Unlike other inkjet inks, UV inks dry at the moment under the influence of UV light. Implementing the UV inkjet technology requires adjusting of the composition of UV inks and their compatibility with UV light sources. Since polymerization is the base of the UV drying process, UV inkjet inks must contain the following components: pigments (15-20%), prepolymers (20-35%), monomers and oligomers (10-20%), photoinitiators (5-10%) and accessories (1-5%). The essential component of the ink are photoinitiators which absorb UV light and start the polymerization process. Considering UV light sources, the most effective ones are quicksilver lamps, that have the highest emission in the electromagnetic UV spectrum (200-380 nm), which is why they are often applied. However, as their radiation is detrimental to human health, the use of LED light sources is increasing though they are less efficient. UV inks allow printing of a wide range of materials, including coated and uncoated substrates, flexible materials and rigid individual sheets several centimetres thick (Majnarić, 2015).

2.1 Colour fastness to rubbing

The fastness of the colour is crucial in attaining commercially acceptable prints which may be affected with a variety of different agents during production and in general use. Exposure of the colour to these agents can induce both change in and loss of colour from the substrate, producing variation in saturation and hue. Measuring colour fastness is essential to assess the durability of a colorant (Valldeperas-Morell et al, 2012). Colour fastness refers to the resistance of colour to fade or bleed of a printed substrate to various types of influences e.g. water, light, rubbing, washing, perspiration etc. Colour fastness to rubbing (also known as the "Crock test") is commonly tested to determine the quality of a collared substrate regarding the fixation of the colour to the substrate. The fastness properties depend on the properties of the substrate, as well as on the composition of ink (mainly the type of pigment). For example, black colour is carbon-based; therefore the pigment particles are large which is the main reason for its poor rubbing properties (Kiron, n.d.).
This research aims to characterize the quality of prints printed with inkjet printing technique, depending on the type of UV inks and printing substrate.

2. MATERIALS AND METHODS

Rubbing fastness was studied on two sets of six different substrates – paper, cardboard, akyplac, printolyte, forex and plexiglass. All substrates were printed with HP Scitex 11000 Industrial Press with two different types of ink. One set was printed using HP HDR230 Scitex inks (hereinafter referred to as P samples) optimized for paperboard applications and other using HP HDR250 Scitex inks (hereinafter referred to as U samples) optimized for flexible and rigid media, including paperboard and plastics. Properties of used substrates are presented in the continuation.

- Paper – coated, grammage (weight) 250 g/m^2 (hereinafter referred to as sample 1),
- cardboard – three-layers, thickness: 1.6 mm, grammage 600g/m^2 (hereinafter referred to as sample 2),
- akyplac – thickness: 3 mm (hereinafter referred to as sample 3),
- printolyte – thickness: 2.6 mm (hereinafter referred to as sample 4),
- forex – thickness: 3 mm (hereinafter referred to as sample 5) and
- plexiglass – white, thickness: 3 mm (hereinafter referred to as sample 6).

These substrates were chosen as trending substrates for digital printing used for both indoor and outdoor applications. Printed test form (Figure 1) included four measuring fields sized 12 x 4 cm with 100% tone value of all process colours (cyan, magenta, yellow, black).

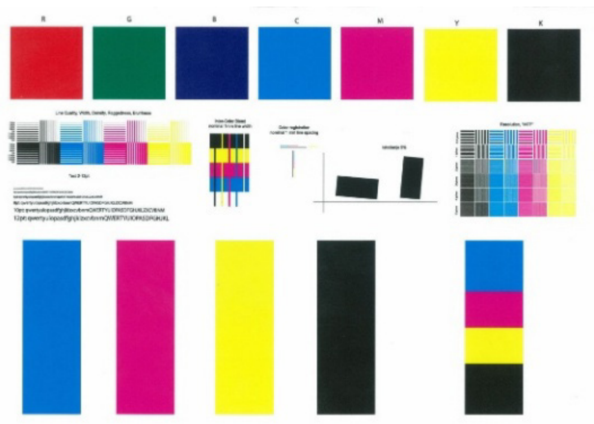

Figure 1: The appearance of the used test form

The samples were tested using Testex TF411 electronic crock meter in three cycles with different number of strokes depending on the substrate (Table 1). The number of strokes was determined with first noticeable changes within the first cycle.

The test method used in this paper is the standard colour fastness to rubbing dry method according to the ISO 105-X12:2016 (ISO, 2016). Crockmeter, consisting of a flat surface to hold the specimen and circular rubbing surface (rubbing finger), covered with a white cotton fabric, exerts a downward force on a specimen when moving back and forth along the straight line of 100 mm (Yogesh, 2017).

Table 1: The number of strokes within one cycle depending on the substrate

Substrate	Number of strokes within one cycle
Paper	1500
Cardboard	500
Akyplac	100
Printolyte	500
Forex	50
Plexiglass	300

The instrumental measurement (CIE L*a*b*) was conducted with SpectroDens directional 0°/45° measurement geometry, D50 standard illuminant and 2° standard observer. The following formula was used to calculate the colour difference based on the measured CIE Lab components:

$$\Delta E = \sqrt{\Delta L^* + \Delta a^* + \Delta b^*} \quad (1)$$

where L* represents the achromatic coordinate of the light, and a* and b* chromatic coordinates of the CIE Lab colour space (Smyth, 2009). The values measured after each rubbing cycle are compared with the values measured before rubbing, as well between the 1st and the 2nd, and the 2nd and 3rd rubbing cycle.

The colour differences can be classified into certain categories depending on their values:

- 0 < ΔE < 1 - the imperceptible difference,
- 1 < ΔE < 2 - very small difference,
- 2 < ΔE < 3,5 - medium difference,
- 3,5 < ΔE < 5 - big difference and
- ΔE > 5 massive difference (Smyth, 2009).

3. RESULTS AND DISCUSSION

3.1 P samples

Figure 2 gives a graphic representation of the colour difference values for the Black process colour of the P samples. When compared to the initial values, the values measured on all samples after each rubbing cycle are greater than 5, which belongs to the domain of massive visual differences. The measured values compared to the previous rubbing cycle are in the field of medium and big differences for samples P1 and P5, while the difference for other samples remains massive.

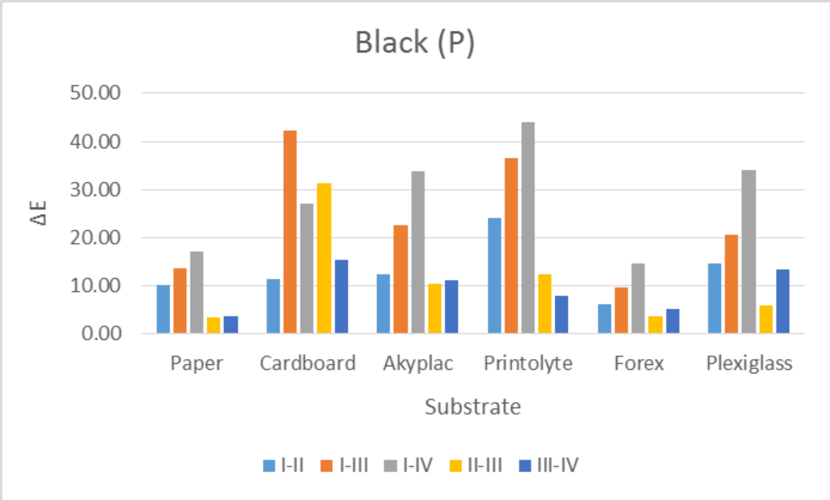

Figure 2: Graphic representation of the colour difference values for the Black process colour of the P samples

Figure 3 gives a graphic representation of the colour difference values for the Cyan process colour of the P samples. When compared to the initial values, the values measured on all samples after each rubbing cycle vary from medium to massive difference. The measured values compared to the previous rubbing cycle vary from the imperceptible to massive differences. The graphic shows that the lowest colour difference values are measured for samples P1 and P2.

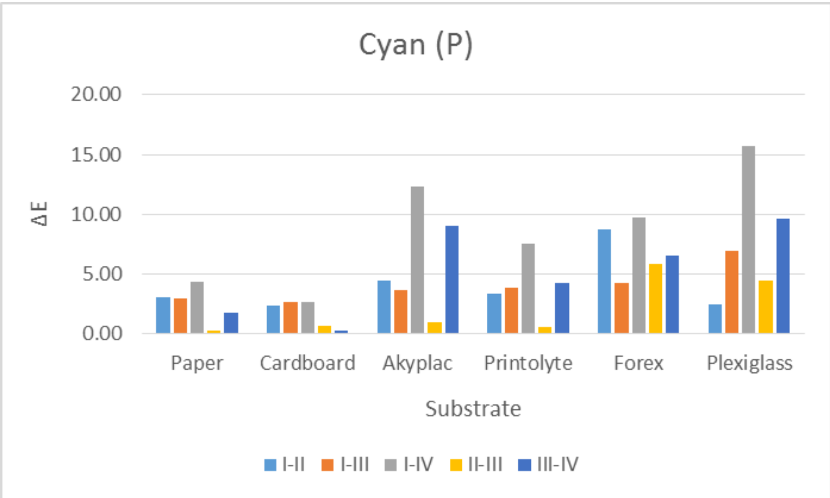

Figure 3: Graphic representation of the colour difference values for the Cyan process colour of the P samples

Figure 4 gives a graphic representation of the colour difference values for the Magenta process colour of the P samples. When compared to the initial values, the values measured on all samples after each rubbing cycle vary from big to massive difference. The measured values compared to the previous rubbing cycle vary from the medium to massive differences.

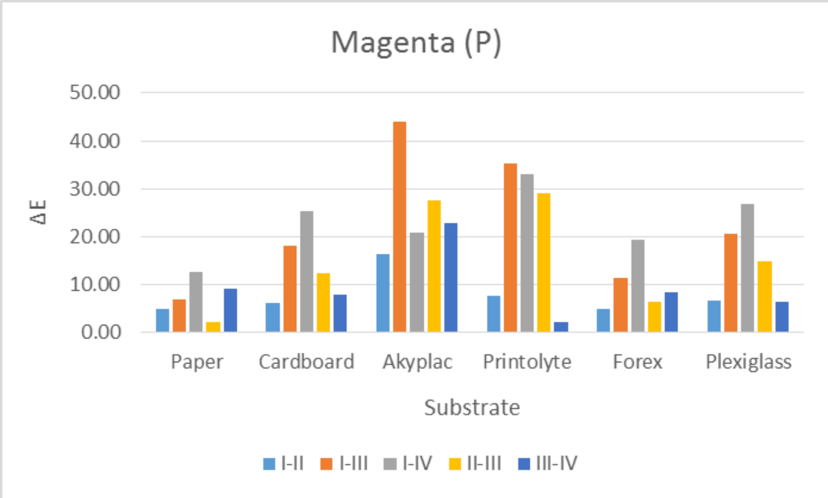

Figure 4: Graphic representation of the colour difference values for the Magenta process colour of the P samples

Figure 5 gives a graphic representation of the colour difference values for the Yellow process colour of the P samples. When compared to the initial values, the values measured after each rubbing cycle vary from medium (for P1 and P5 samples) to massive difference. The measured values compared to the previous rubbing cycle vary from the imperceptible to massive differences. The graphic shows that the lowest colour difference values are measured on the P5 sample, with no measurement showing a massive difference.

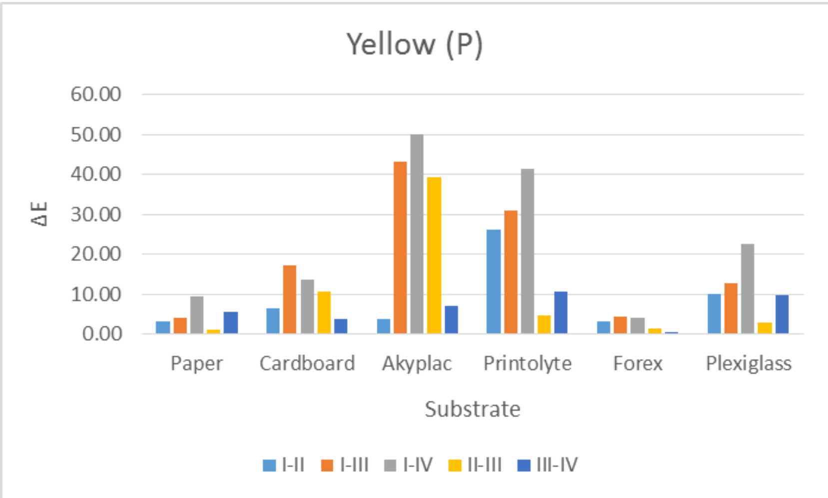

Figure 5: Graphic representation of the colour difference values for the Yellow process colour of the P samples

3.1 U samples

Figure 6 gives a graphic representation of the colour difference values for the Black process colour of the U samples. When compared to the initial values, the values measured after each rubbing cycle are greater than 5, which means that there is a massive visual difference between the cycles. The measured values compared to the previous rubbing cycle vary from medium to massive differences.

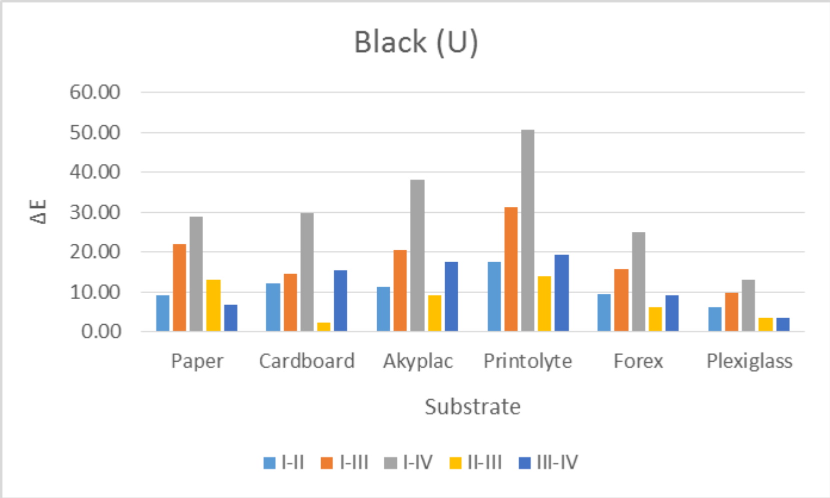

Figure 6: Graphic representation of the colour difference values for the Black process colour of the U samples

Figure 7 gives a graphic representation of the colour difference values for the Cyan process colour of the U samples. When compared to the initial values, the values measured on all samples after each rubbing cycle vary from medium to massive difference. The measured values compared to the previous rubbing cycle vary from the imperceptible to massive differences. The graphic shows that the lowest colour difference values are measured on the U5 sample.

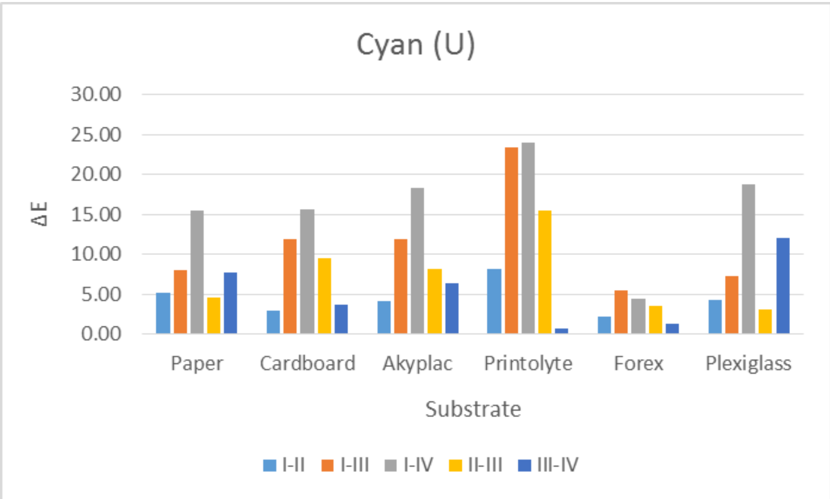

Figure 7: Graphic representation of the colour difference values for the Cyan process colour of the U samples

Figure 8 gives a graphic representation of the colour difference values for the Magenta process colour of the U samples. When compared to the initial values, the values measured on all samples after each rubbing cycle vary from medium to massive difference. The measured values compared to the previous rubbing cycle vary from the imperceptible to massive differences. The graphic shows that the biggest colour difference values are measured on the U2 sample.

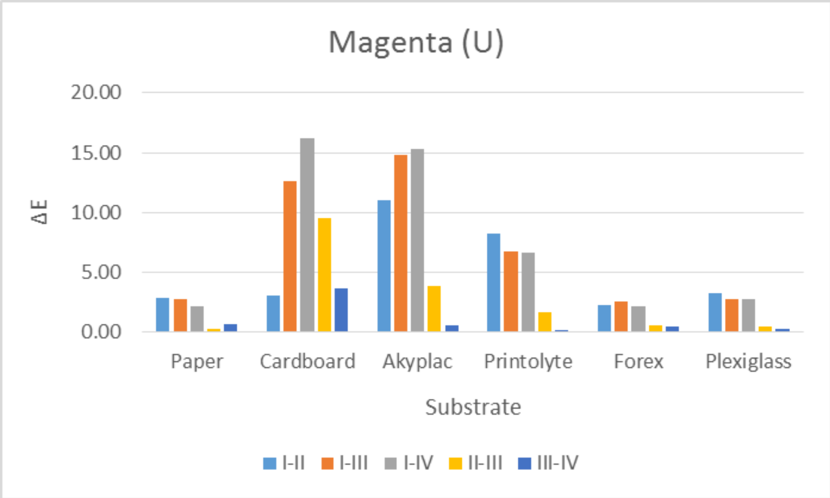

Figure 8: Graphic representation of the colour difference values for the Magenta process colour of the U samples

Figure 9 gives a graphic representation of the colour difference values for the Yellow process colour of the U samples. When compared to the initial values, the values measured after each rubbing cycle are greater than 5, which means that there is a massive visual difference between the cycles. The measured values compared to the previous rubbing cycle vary from the imperceptible to massive differences. The graphic shows that the lowest colour difference values are measured on the U5 sample.

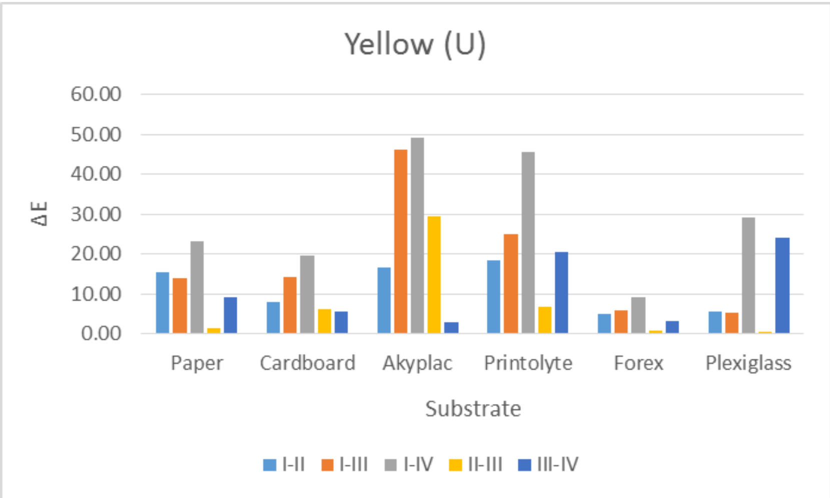

Figure 9: Graphic representation of the colour difference values for the Yellow process colour of the U samples

Obtained results lead to the conclusion that, when printed using HP HDR230 Scitex inks (P samples), the lowest colour difference values are measured for the cyan process colour, where specimens P1 and P2 showed particularly good results. The most significant colour difference values were measured for the black process colour, particularly for specimens P2 and P4. On the other hand, when printed using HP HDR250 Scitex inks (U samples), the lowest colour difference values are measured for the magenta process colour, where specimens U1, U5 and U6 showed particularly good results. The most significant colour difference values were measured for the black process colour on all specimens.

4. CONCLUSIONS

Trending substrates for digital printing used for both indoor and outdoor applications are often exposed to various types of influences. All tested materials had different characteristics as well as the applied colours. According to expectations, the results led to the conclusion that on different substrates, HP HDR250 Scitex inks (U samples) shown better results. However, paper and cardboard substrates shown better results when printed with the HP HDR230 Scitex inks. The analysis also confirmed that fastness properties very much depend on the type of pigment in ink, since black colour which is believed to have large pigment particles showed the poorest rubbing properties.
Future research could include a more detailed analysis of the chemical composition of the ink to investigate whether any component other than pigments affects the rubbing fastness and to what extent. Besides, a uniformed number of strokes within one rubbing cycle for all substrates could be considered.

5. ACKNOWLEDGMENTS

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