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Stability of UV Curable Inks Applied in Three Layers on Papers Containing Straw Pulp After Artificial Ageing

Ivana Plazonić[1], Irena Bates[1], Maja Rudolf[1]
[1] University of Zagreb,Faculty of Graphic Arts, Zagreb, Croatia

Introduction

In order for prints to be considered high quality, regardless of the type of printing substrate, they must retain the initial optical quality achieved during printing and years after the printed product has been used or stored. The rate at which print quality deteriorates over time depends on several factors. The composition of the printing substrate, the composition of the printing ink, the technique of applying the ink to the substrate, and the interaction between the ink and the substrate have the greatest influence on the initial quality. In addition to the listed influences on the durability of the print quality, the conditions under which the print was used or stored, such as humidity, temperature, microorganisms, and air quality, also have an effect. Paper is the most commonly used printing substrate, and considering the favourable ecological components of this material, it will be used more and more in the future. The need for alternative raw materials to wood in its production will also become more pronounced. Precisely because of the cellulose fibres that make up its basis, paper is subject to many degradation changes.

Problem Description

In this paper, the optical stability of UV prints obtained by two printing techniques (gravure and screen printing) where UV curable inks were applied in three layers was studied. Accelerated ageing was performed as a simulation of natural ageing to determine the multicolour print quality deteriorates over time to evaluate the long-term behaviour of prints on papers with cereal pulp under the expected conditions of use. It is known that the conditions under which the prints were used or stored, such as humidity, temperature, microorganisms, pollutants and air quality, have a significant effect on the surface of printed products as well as a paper as a cellulose based porous printing substrate.

Methods

This research is divided into the following steps: laboratory production of straw pulp containing papers; gravure and screen printing with UV curing inks; accelerated ageing of multicolour prints and evaluation of the stability of prints upon ageing.
In Table 1 the data of the composition of papers used in this research are summarized.

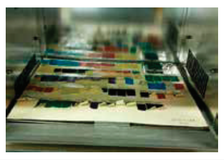
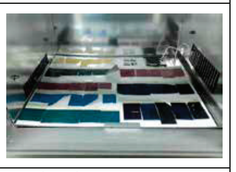
Table 1
Abbreviations used for marking laboratory-made papers

Abbreviation	Pulp composition	Paper production	Paper grammage, g/m²
K	100% recycled wood pulp	commercial	42.5
100N	100% recycled wood pulp	laboratory	42.5 ± 2.6
70N30W, 70N30B, 70N30TR	70% recycled wood pulp + 30% straw pulp	laboratory	
* W = wheat pulp; B = barley pulp; TR = triticale pulp			

To achieve multicolour prints on produced laboratory paper substrates, printing was performed with yellow, cyan and magenta UV inks applied in layers in specific order regarding the printing technique used. The prints were made using the laboratory equipment KPP Gravure System for gravure prints and a Shenzhen Juisun semi-automatic machine for screen prints.

Artificial ageing was performed in a Suntest XLS+ test chamber according to parameters listed in Table 2.

Table 2
Accelerated ageing procedure

Accelerated ageing procedure	Screen prints	Gravure prints
Samples in test chamber		
Equipment	Suntest XLS+ test chamber	
Standard	ASTM D 6789-02	
Wavelength (nm)	300 - 800	
Irradiance (W/m²)	765 ± 50	
Filter	daylight	
Relative humidity (%)	47	48
Temperature of ambient (°C)	21.2	21.5
Total duration of process (h)	96 (2 cycles of 48 h)	

The stability of UV curable inks applied in three layers on papers containing straw pulp after artificial ageing was evaluated based on optical stability by measuring spectrophotometric values of each print and by the colour difference (ΔE_{00}*) calculation according to equation 1.

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_t \left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)} \quad (1)$$

In graphic arts and printing industry, for most demanding products, the maximum acceptable ΔE_{00}* colour difference is 1.5.

Results and discussion

From the results of the Euclidean colour difference (Figures 1 and 2), it is visible that the multicolour brown prints show different optical stability regarding the used paper substrate and technique of applying UV curable inks. If we look at the composition of the paper as a printing substrate, the greater stability of the prints was noticed in paper without the addition of cereal straw pulp. With the addition of cereal straw to paper pulp, the colorimetric stability of the multicolour prints on such printing substrates after exposing to conditions of accelerated ageing decreases. It has been noticed that the prints obtained by the screen printing technique (Figure 1) show far greater optical stability of multicolour brown prints compared to prints obtained by gravure printing (Figure 2).

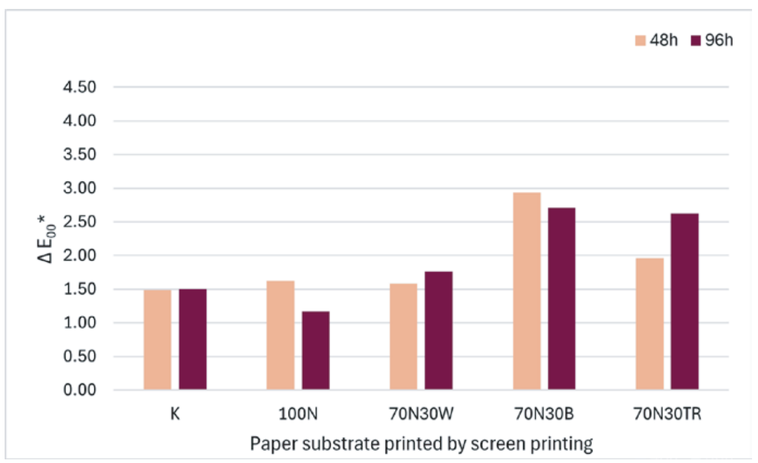


Figure 1
The Euclidean colour difference of UV curable inks applied by screen printing on paper substrates after artificial ageing

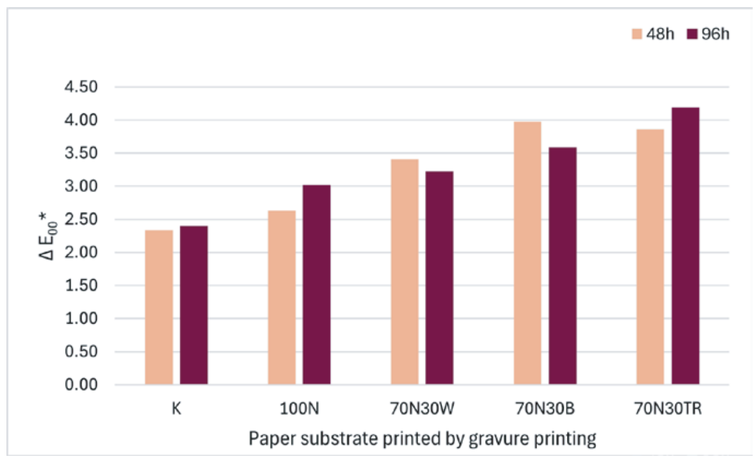


Figure 2
The Euclidean colour difference of UV curable inks applied by gravure printing on paper substrates after artificial ageing

The difference in the stability of gravure and screen multicolour prints achieved with three layers of inks applied one over the other is interesting as the results of previous study (Bates and al., 2023) showed that monocolour prints made with the gravure and screen printing processes after accelerated ageing of 48 hours reach a colorimetric difference of up to ΔE_{00}* ≤ 2. In that study it was noticed that from all analysed monocolour prints gained by gravure and screen printing technique, the most colour difference was in cyan prints. As the cyan ink is the last printed ink brown prints printed made by gravure printing and in screen printing the last applied ink was magenta that could be the reason for lower optical stability of gravure print. It was also observed that for both printing techniques of applying UV curable inks, regardless of the composition of the paper printing substrate, the most significant colour degradation occurs in the first 48 hours of accelerated ageing, while further prolonging the exposure time of the prints irradiance through the daylight filter does not show any significant continuation of the colour degradation.

Conclusion

The colour changes that occur on printed paper containing straw pulp upon ageing were analysed. As the colour stability of brown prints in which UV curable inks were applied in three layers on laboratory paper substrates by screen and gravure printing techniques was monitored in parallel, it was determined that screen prints have better colorimetric stability compared to gravure prints regardless of the composition of paper substrate. Of all the cereal straw pulps, the addition of wheat pulp to the recycled pulp provides the paper substrates for obtaining the most stable prints after ageing. The conclusion is that when choosing a printing substrate, it is very important to consider the desired lifetime of the graphic product and choose a paper substrate on this basis.

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