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Comparison of Optical Stability of Papers Containing Wheat Pulp Printed with Digital and Flexographic Printing Technique after Accelerated Ageing

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Abstract

Flexographic and digital printing are currently the fastest growing branches in the printing industry. The selection of printing substrates for these printing techniques is large, but paper substrates are the most widely used. Paper manufacturing is based mainly on the use of renewable fibers, and the dominant fiber resource for the pulp and paper industry is wood which is accounting for 90% of the world's fiber utilization. As woods consumption for paper production is still high, there are various possibilities to reduce it. One way is by reducing the proportion of wood pulp in paper by adding straw pulp of various cereals such as wheat. Wheat straw has numerous advantages and can be used in pulp form as a source of primary fibers for paper production. As paper as a multi-component material, besides fibers composed of cellulose, hemicellulose and lignin also includes additives, minerals and synthetic polymers. Due to its complex nature it is prone to deterioration when exposed to elevated temperature, humidity and light. Paper ageing is irreversible change and is the best indicator of paper optical permanence. Objective of this study was to determine the optical stability of prints after undergoing aging treatment with elevated temperature and UV light for 48 and 96 hours. Laboratory papers containing wheat pulp were printed by two printing techniques with cyan and yellow inks to compare better optical stability: UV inkjet and flexographic technique. The optical stability of all prints was observed based on the difference in the reflection spectra (ΔR). The results indicated that all laboratory papers printed with cyan ink with flexographic technique show better optical stability than the ones printed with digital technique. Laboratory papers printed with yellow ink by both techniques show good optical stability.

Key words

Accelerated ageing, Digital, Flexographic, Optical stability, Prints, Wheat pulp

1. INTRODUCTION

Flexography printing is a method of direct printing, that uses resilient relief image plates of rubber or photopolymer material. The plates are inked by a cell-structured, ink-metering „anilox" roll carrying a fast-drying fluid ink to plates which achieve high quality printed reproduction of text and images on any substrate, absorbent or nonabsorbent. Flexographic printing is an efficient, cost-effective and versatile printing method. Flexography printing uses low-viscosity inks which dry very quickly between the printing units of a printing machine. Solvent-based, water-based and ultraviolet-curable inks are used in flexographic printing and the appropriate ink for each substrate must be very careful chosen. Adhesion, block resistance, rub resistance, heat resistance and lightfastness can be satisfactory on one substrate but terrible on another. Different ink systems require different control and different conditions [1]. Recently developed digital printing technique differs from traditional, analog printing methods because digital printing machines do not require any printing plates. Instead of using printing plates to transfer a printing image, digital printing machines print the ink directly onto the printing substrate. Ink jet printing is a technique where inkjet heads deposit droplets of ink on the paper as the printing substrate and the image is produced by means of a dot matrix that creates the letter or graphic image [2]. Digital production print technology is evolving quickly, and its output quality is improving continuously [3]. It is predicted that digital printing technique will grow dramatically as press become cheaper with improvements in the print quality [2]. Flexographic and digital printing, both with their advantages and disadvantages can print on all kinds of substrates from paper, board, polymer materials (foil and film) to thick cardstock, heavyweight papers, folding cartons and fabric. [1,3]. Since paper is the most widely used printing substrate all over the world and wood is currently dominant raw material for paper manufacture, it would be sensible and commercially viable to replace it as much as possible with other plant biomasses by utilization of non-wood fiber materials to produce cellulose pulps [4,5]. The non-wood fibers have some features that are superior to those of wood fiber and others that represent clear disadvantages, such as fiber storage issues. Nonetheless, it is possible to manufacture high-quality paper from these fibers. The cellulose content of wheat straw is very similar to that of wood. The hemicellulose content tends to be higher, but the lignin content is considerably lower. The lower lignin content is an advantage in papermaking [4]. Several studies have shown that straw fibers from certain cereals like wheat show suitable characteristics required for pulp and paper production.

The quality and appearance of graphic product are crucial when end users consider buying products [6]. Therefore, optical stability is amongst most important factors when it comes to product appearance. Paper is constantly exposed to numerous endogenous and exogenous factors that affect its stability. Due to factors such as heat, light and moisture, paper ageing processes cause change in chemical and mechanical properties of paper elements and ink components during the ageing process [7]. Artificial ageing speeds the natural ageing process of paper by subjecting it to extreme conditions for certain period of time and is used to determine the lifespan or permanence of paper or even to predict the long-term effects of conservation treatments [8]. In researches several methods of simulation of the natural ageing process are used, since the process of natural ageing is impractical because of the involved period of time [9]. In this research, the optical stability of flexography and digital prints made on substrates with wheat pulp will be observed trough difference in reflectance spectra where deterioration will be visible after accelerated ageing process.

2. MATERIALS AND METHODS

2.1. Laboratory Papers

Wheat straw was converted into semi-chemical pulp according to soda method [10]. Pulping conditions are presented in Table 1.

Table 1. Pulping conditions

Type of straw	Pulping method	Extraction conditions
Wheat	Soda pulping	Temperature of 120°C, alkali level of 16% for 60 min, and a 10:1 liquid biomass ratio

Obtained unbleached wheat pulp was mixed with recycled wood pulp in different weight ratios, 10%, 20% and 30%. A laboratory paper containing only recycled wood pulp was used as a reference paper in the process of comparing quality of optical properties of laboratory papers containing wheat pulp. Laboratory papers weighed approximately 42.5 gm^{-2} were formed by a Rapid Köthen sheet former ((FRANK- PTI GmbH, Birkenau Germany) according to EN ISO 526 9-2:2001 standard [11]. In total, 4 types of laboratory papers were formed. Abbreviations used in marking all samples are listed in Table 2.

Table 2. Abbreviations used in marking samples

100R	laboratory paper with 100 % recycled pulp (reference)
90R10W	laboratory paper with 90% recycled pulp and 10% wheat pulp
80R20W	laboratory paper with 80% recycled pulp and 20% wheat pulp
70R30W	laboratory paper with 70% recycled pulp and 30% wheat pulp
48h	accelerated aged for 48 hours
96h	accelerated aged for 96 hours

2.2. Printing of Laboratory Papers by Flexographic Technique

All laboratory papers were printed in full tone with cyan and yellow ink by flexographic laboratory device Esiproof RK Printcoat Instruments with water based flexographic inks. Printing was performed with anilox roll with total volume of 39.1 cm3/m-2 and engraved with line screen of 40 lincm-1 at a temperature of 23° C and a relative humidity of 50%. An engraving angle for anilox roll was 60 degree angle, respectively the hexagonal cell that offers higher quantity of cells that indicates increasing in the ink transfer, as well as homogeneity.

2.3. Printing of Laboratory papers by Digital Technique

Each laboratory paper was also printed in full tone with cyan and yellow ink by digital EFI Rastek H652 UV curable inkjet printer with the resolution of 600 x 600 dots per inch (dpi) (respectively with high quality mode 8 pass) and printing speed of 12.10 m^2/hr.

2.4. Accelerated Ageing

Laboratory papers printed with both techniques were exposed to accelerated ageing treatment in the test equipment SunTEST XSL+ according to standard ASTM D 6789-02 [12] under conditions summarized in Table 3.

Table 3. Conditions used during artificial ageing

Conditions	
Wavelength (nm)	290 - 800
Irradiance (Wm^{-2})	765 ± 50
Test equipment	SunTEST XSL+, Id.No. 196 Rotronic Hygrolog, Id.No. 180/2
Duration process (h)	48 96
Ambient condition	24.8°C 54.7 % RH
Filter	daylight

2.5. Optical Properties

For assessment the quality and permanence of the prints obtained on laboratory papers with added wheat pulp after artificial ageing, optical stability was observed trough color degradation. Color degradation was estimated through the difference in reflectance spectra between unaged and aged prints (ΔR), calculated according to the equation 1. Prints reflectance spectra measurements were processed using X-rite spectrophotometer with standard illuminate D50 and 2° observer, in the interval of the wavelengths from 400 nm to 700 nm for every 10 nm. Reflectance values (R) were measured for all printed paper samples before and after ageing. Optical measurements were repeated 25 times on each sample.

$$\Delta \mathrm{R} = \mathrm{R}_{unaged} - \mathrm{R}_{aged} \quad (1)$$

3. RESULTS AND DISCUSSION

Figures 1-4 present the experimental results of reflectance measurements presented as ΔR, before and after accelerated ageing in the visible part of electromagnetic spectrum for all analyzed papers printed with digital and flexographic technique.

Following graph in Figure 1 shows the difference in reflectance values on laboratory papers printed by flexographic printing technique with cyan water based printing ink. The highest reflectance difference is visible on paper made from 100% recycled pulp after 48 hours of artificial ageing. It also shows the highest difference after 96 hours of accelerated ageing compared to other papers printed with cyan flexographic ink. The highest optical stability is visible on laboratory paper made with the addition of 10% wood pulp after 48 hours of accelerated ageing.

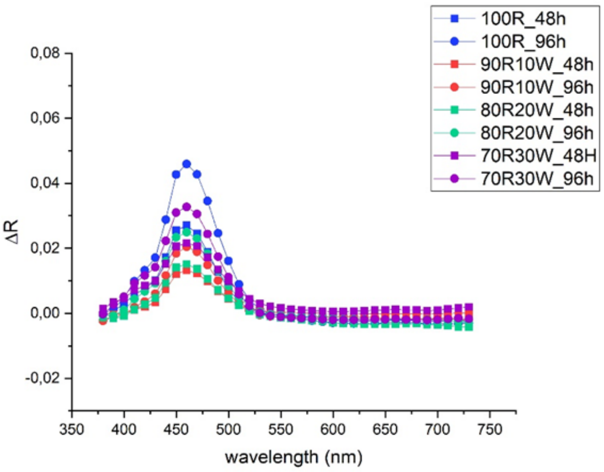

Figure 1. The influence of ageing time on reflectance spectra of cyan prints made by flexographicprinting technique on laboratory papers without (100R) and with wheat pulp (90R10W, 80R20W, 70R30W)

Figure 2 shows the difference in reflectance values between unaged and aged laboratory papers printed by flexographic printing technique with yellow water based printing ink. It is visible that the highest degradation occurs on paper made from 100% recycled pulp after the first 48 hours of accelerated ageing. The best optical stability of prints provides papers made with addition of wheat pulp of 20% and 30%.

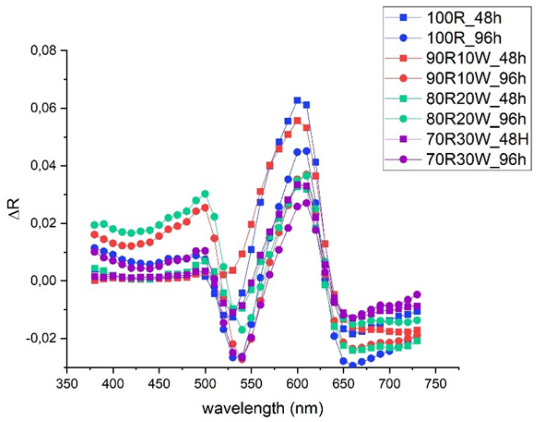

Figure 2. The influence of ageing time on reflectance spectra of yellow prints made by flexographic printing technique on laboratory papers without (100R) and with wheat pulp (90R10W, 80R20W, 70R30W)

In Figure 3, cyan prints on all laboratory papers obtained by digital printing technique present expected reflectance curves. The highest degradation of all cyan prints occurs after first 48 hours of accelerated ageing on laboratory paper 100R, paper without wheat pulp. After additional 48 hours of accelerated ageing, degradation is still visible but significantly lower. Others cyan prints obtained on laboratory papers with wheat pulp addition show similar behavior. However, cyan prints made on papers with 30% of wheat pulp exhibit the lowest reflectance differences, so they are the most stable ones. It is clearly visible that reflectance values of all cyan prints drop with addition of wheat pulp into papers.

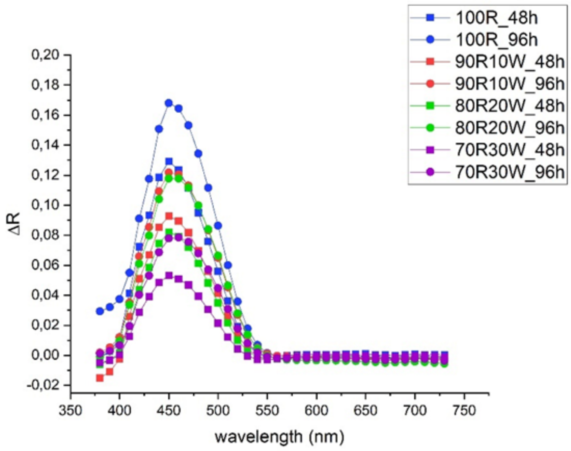

Figure 3. The influence of ageing time on reflectance spectra of cyan prints made by digital printing technique on laboratory papers without (100R) and with wheat pulp (90R10W, 80R20W, 70R30W)

Figure 4 represents the difference in reflectance values for laboratory papers printed by digital technique with yellow ink. The same trend is also visible here as on previous graph for cyan prints. The highest degradation occurs within the first 48 hours of accelerated ageing, and stability is better with each additional increase in shere of wheat pulp in printing substrate. The best optical stability was noticed on prints obtained on paper with addition of 30% wheat pulp. Yellow prints show better optical stability than cyan prints.

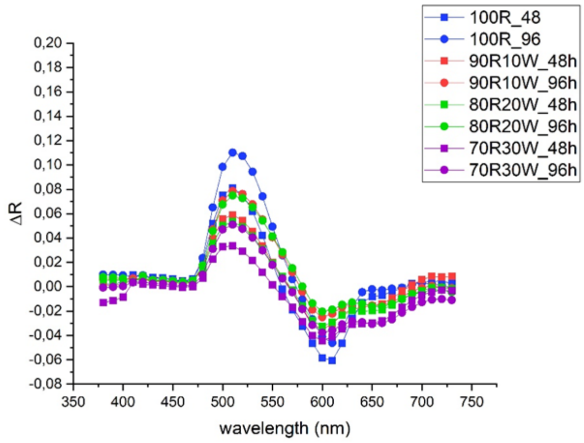

Figure 4. The influence of ageing time on reflectance spectra of yellow prints made by digital printing technique on laboratory papers without (100R) and with wheat pulp (90R10W, 80R20W, 70R30W)

4. CONCLUSION

The aim of this research was to point out the influence of printing technique and printing substrate with wheat pulp on optical stability of prints. Considering all obtained results, the following can be concluded:

- The highest color degradation of cyan and yellow prints occurs in the first 48 hours of accelerated ageing on all papers printed with both techniques,
- Cyan ink printed with flexographic printing technique provides better optical stability than the one printed with digital technique,
- Yellow ink provides prints with higher optical stability of prints on all printing substrates than cyan ink for both printing techniques,
- Addition of wheat pulp into paper substrate positively influences optical stability of all analyzed prints

The results in this research suggest that the optical stability of prints on papers formed with addition of wheat pulp is satisfactory and could be additionally improved if papers would be formed in industrial production.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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