https://doi.org/10.24867/GRID-2024-p77 Original scientific paper

THE IMPACT OF PAPER MADE FROM RECYCLED AND NON-WOODY PLANTS ON THE EFFECT OF FLUORESCENT PRINTS

Maja Strižić Jakovljević, Tereza Puhalović, Agata Radman,
Tamara Tomašegović, Sanja Mahović Poljaček
University of Zagreb, Faculty of Graphic Arts, Zagreb, Croatia

Abstract: *Fluorescent printing inks are often used for design elements in printing, signage, highlighted segments on packaging, and similar applications. In this research, commercially available papers made from recycled and non-woody fibers, such as hemp and cotton, will be used as substrates for printing with fluorescent inks. Paper printing substrate made entirely from virgin fibers will serve as a reference paper. The aim of this study is to determine the influence of paper made from recycled and non-woody plants on the effect of printed fluorescent inks. These paper printing substrates will be examined for their structural, surface, and optical properties, as well as screen-printed with fluorescent inks. The characteristic fluorescent effect of the printed ink will be evaluated using spectrophotometric method on all printing substrates. The difference between papers made from non-woody plants and recycled fibers compared to the reference paper made from virgin fibers will be determined, as well as their impact on the optical effect of fluorescent inks, printed elements, and line width. Additionally, a survey will be conducted to identify the most acceptable paper substrate for designs printed with fluorescent inks.*

Key words: recycled paper, non-woody plant paper, fluorescent printing inks, spectroscopy

1. INTRODUCTION

In the field of graphic technology and design, there is potential for replacing papers made from primary fibers with those made from recycled and non-woody materials. These materials, including papers produced from agricultural residues, align with the principles of a circular economy and support all three pillars of sustainability. Their selection can reduce environmental impact by lowering reliance on wood fibers and addressing the raw material crisis in the paper industry (Teacă, 2023; Cassel et al., 2023). Non-wood materials, such as agro-waste, have been found to exhibit comparable properties to traditional wood fibers, making them suitable for paper production (Kumar, 2022; Jaishwal et al., 2024; Clift et al., 2022). Using alternative materials can improve the physical properties of paper products, providing a sustainable and cost-effective solution to reducing wood pulp consumption and mitigating deforestation and CO_2 emissions (Cassel et al., 2023; Kurek et al., 2022). Additionally, papers made from recycled fibers and non-woody plants show potential for various printing techniques, including digital UV inkjet and flexography (Cassel et al., 2023; Rudolf et al., 2024) The print quality on these papers is comparable to that of papers made exclusively from recycled wood fibers (Rudolf et al., 2024). However, challenges such as increased ink penetration into the substrate need to be considered (Tamboli et al., 2022).
Fluorescent printing inks interact well with various substrates, offering excellent fluorescent effects and anti-fake properties. This broadens their application range, ensuring durable prints with enhanced visual appeal. (Dongjun, 2016). Fluorescent printing inks are classified as special effect inks, possess the ability to absorb UV radiation and re-emit photons at different wavelengths, a phenomenon known as luminescence (Jameson, 2014; Becidyan, 1995). This unique property enables them to be utilized across various applications, including decorative and packaging industries, for markings, signaling, orientation purposes, and document security (Bodenstein et al., 2019; Yook & Lee, 2013). In printing processes, fluorescent printing inks can be applied as varnishes in flexography, offset, and relief printing (Bozhkova et al., 2017; Talebnia et al., 2014), and in screen printing, they are often used by mixing the pigments with a transparent base (Becidyan, 1995).
Given the growing trend towards using alternative source printing substrates, their application in industries such as packaging is highly promising for the future. Additionally, these substrates are likely to be combined with various printing inks, including those with special effects such as fluorescent inks. This study aims to assess how paper substrates made from recycled and non-woody plants influence the performance of printed fluorescent inks. The investigation will focus on the structural, surface, and optical properties of these paper types, which will be screen-printed with fluorescent inks. To evaluate the distinctive fluorescent effects of the inks, spectrophotometric analysis will be employed across all paper substrates.

The study will compare the performance of non-woody and recycled fiber papers against a reference paper made from virgin fibers, analyzing their effects on the optical properties of fluorescent inks, printed elements, and line widths. Additionally, a survey will be conducted to identify the most favorable paper substrate for designs utilizing fluorescent inks.

2. METHODS

2.1 Materials

In this research, five types of uncoated papers are used, including high-quality uncoated offset paper based on virgin fibers serving as a reference, marked as MN. Paper printing substrates RW and NC are specified as uncoated recycled papers suitable for all common printers and printing processes. While both are made from recycled fibers, NC is produced entirely from post-consumer waste (PCW). PC and MH are specified as uncoated papers with rough surface, suitable for offset, UV offset, letterpress, and screen printing. PC is produced entirely from cotton fibers and has an uncoated surface. MR is produced from 30% hemp, 30% PCW, and 40% virgin fibers. Here, hemp is used as a fast-growing plant for raw material in paper production, with a significant share of virgin fibers, to gain a high whiteness grade.

Table 1: Paper-printing substrates used in the research

Paper-printing substrate	Grammage (g/m^2)	Paper composition - fibres
MN	120	Virgin
RW	80	Recycled
NC	80	Recycled
PC	120	100% cotton
MR	118	30% hemp, 30% PCW, 40% virgin

Daylight – visible fluorescent printing ink (Sebastar neon pink 103.466, Sebek Inks, Belgium) was used for printing full tone, letters and line elements on all printing substrates. The ink was screen printed on all selected paper substrates in 43 l/cm mesh for a full tone print, and 100 l/cm mesh for motif used in the research survey. The prints were made in a controlled laboratory conditions, and air-dried 72h before further tests.

2.2 Methods

Images of the paper surfaces and print lines on selected substrates were taken using an Olympus BX51 microscope (Olympus Corporation, Tokyo, Japan) at a magnification of 100× and 50×. The thickness (caliper) of the papers was measured with the DGTB001 thickness gauge (Enrico Toniolo, Milan, Italy), according to ISO 534:2011 (ISO: Geneva, Switzerland, 2011). Smoothness of the paper printing substrates was measured using PTI line Bekk Tester (PTI Austria GmbH, Laakirchen, Austria) on 10 samples for each substrate (5 on the felt side and 5 on the wire side of the paper), according to ISO 5627:1995 (ISO: Geneva, Switzerland, 1995).

The Cobb test is performed to determine the water absorptiveness of the selected paper printing substrates, according to ISO 535:2023 (ISO: Geneva, Switzerland, 2023). This method is suitable for sized paper and board, under standard conditions (ISO 187:2022) (ISO: Geneva, Switzerland, 2022). The Cobb test is directly related to the sizing of the paper, as the sizing process plays an important role in achieving a certain degree of resistance to the absorption or penetration of liquids, especially water (Deshpande, 2011). The ISO 535:2023 [42] test procedure includes placing a dry sample under the metal ring, pouring 100 mL of distilled water and leaving it to stand for 60 s. At 10 ± 2 s before the expiration of the test period, the water is poured out of the ring, and the sample is then placed between standardized blotting papers and the excess water is removed with a roller. The sample is weighed before and after exposure to water, resulting in the paper absorptiveness value (g/m^2). The test, in this research, is performed on the smoother side of the paper, selected for printing.

Optical properties of the paper substrates were measured with X-Rite (Grand Rapids, MI, USA), D50/2°, M1. Whiteness was measured over the entire visible range of the spectrum, while brightness was measured at 457 nm.

Spectral reflectance of the fluorescent prints on all papers was measured using 50 mm wide integrating sphere (ISP-50-8-R-GT) on the fibre-based USB 2000+ spectrometer (Ocean Optics, USA), set to CIE illuminant D50/2°, with UV lamp used as a light source, so that the fluorescence effect could be measured. The purpose of these measurements was to determine the influence of different paper printing substrates on spectral reflectance of fluorescent prints.

The final step in this research was a survey conducted on 76 respondents, in order to identify the most acceptable paper substrate for designs printed with fluorescent inks and to evaluate the correlation between visual perception and measured results of fluorescent prints on different substrates.

3. RESULTS AND DISCUSSION

3.1 Properties of Paper Substrates

The results of the caliper (thickness), bulk (specific volume) and density of the papers are presented in Table 2. Before the measurements, the preparation of the samples was conducted in accordance with the ISO 187:2022 standard for conditioning paper samples at 23 ± 1◦C and 50 ± 2% relative humidity (ISO: Geneva, Switzerland, 2022). The grammage (Table 1) and caliper values of each individual sample were used to calculate the density of the paper using the Equation (1) (ISO: Geneva, Switzerland, 2011):

$$Y = x/d \times 1000\ (g/cm^3) \qquad (1)$$

Where: x is the basis weight (g/m^2); d is the caliper (mm).

The density of the paper sheet represents the mass of one cubic centimeter of the tested sample. It is influenced by various additives used in paper production, such as fillers, sizing agents, and dyes, and the fiber type, separation, and mechanical treatments like refining, drying, and calendering. This parameter significantly affects the paper's optical and mechanical properties, including its structure, porosity, and compactness. In addition, the paper density is an indicator of the relative air content in the paper (Holik, 2013). The results presented in Table 2 show the highest density of 0.83 g/cm^3 for reference sample MN, followed by RW (0.81 g/cm^3), NC (0.80 g/cm^3), MR (0.69 g/cm^3), and PC (0.61 g/cm^3). This property of paper varies inversely with bulk (specific volume), which is calculated using the Equation (2) (ISO: Geneva, Switzerland, 2011):

$$1/Y = d/x \times 1000\ (cm^3/g) \qquad (2)$$

The specific volume of paper (bulk) is the volume per mass unit of paper (cm^3/g). A lower specific volume typically indicates denser paper. This property is important in the printing industry as it affects ink absorption, air permeability, and the final appearance of the printed material. The paper's specific volume is closely related to ink absorbency in printing processes. The ink absorption capacity of paper can be influenced by parameters such as the type of pulp used, basis weight, sizing agent, and beating degree (Ataeefard, 2015). The results indicate that PC has the highest bulk of 1.64 cm^3/g, followed by MR of 1.45 cm^3/g; NC of 1.25 cm^3/g; RW of 1.24 cm^3/g; and reference paper MN, having the lowest bulk of 1.21 cm^3/g (Table 2). This means that the reference paper MN has the highest density, lowest relative air content, and is more compact than the rest of the samples, which are more porose. Previous studies have shown that low density values were found to be more common in the recycled paper and paper made from non-woody plants than in paper made from virgin fibers, which is due to the larger voids and gaps between the fibers in the recycled paper and non-woody papers (Tampichai et al., 2019; González et al., 2014).

Table 2: The results of measured basic and structural properties of selected papers

Paper-printing substrate	Caliper (µm)	Density (g/cm^3)	Bulk (cm^3/g)
MN	0.145	0.83	1.21
RW	0.099	0.81	1.24
NC	0.1	0.80	1.25
PC	0.197	0.61	1.64
MR	0.171	0.69	1.45

The results of the paper smoothness using the Bekk method are shown in Figure 1 and represent the mean values of five (5) measurements for each individual type of paper tested on wire and felt side (marked as A and B). The surface properties of the paper have a significant effect on the print reproduction and quality. Uncoated papers exhibit a different surface smoothness on the wire and felt side, which is a result of the paper manufacturing process. Since high-quality printing and reproduction requires a high degree of smoothness, it is recommended to print on the smoother side of uncoated paper whenever possible. The results in Figure 1 show the highest degree of smoothness was measured for the RW B sample, with a value of 30.98 s. The smoothness of NC A is 30.54 s, followed by MN A (17.58 s), MR B (7.76 s), and PC B (1.98 s). The smoother side of each paper was selected for printing (marked pink in Figure 1) and analyzed in further tests.

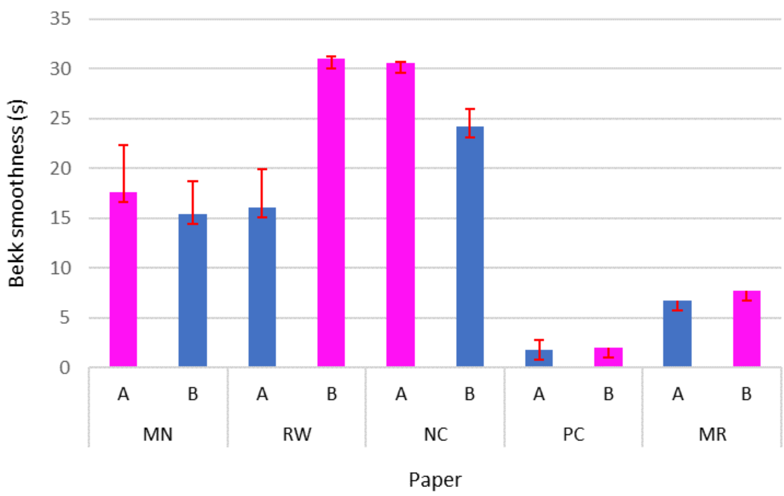


Figure 1: The results of Bekk smoothness of the papers

Figure 2 shows the results of water absorptiveness of the paper used in this research, according to the Cobb method. The results show the highest water absorptiveness, of 100 g/m^2, was found for MR. For hard-sized papers intended, for example, for offset printing, the Cobb value usually does not exceed 100 g/m^2 (TAPPI: Atlanta, GA, USA, 2013). Paper MR could be categorized between the class of hard-sized (Cobb value < 100 g/m^2) and soft-sized papers (Cobb value > 100 g/m^2). Soft-sized (or weak-sized) papers tend to absorb more water and have a more open structure (such as newsprint paper). They are suitable for printing techniques that require greater ink absorption. The water absorptiveness of papers made from recycled fibers, RW (78.8 g/m^2) and NC (36.4 g/m^2), showed different absorptiveness values compared to the reference sample MN (66 g/m^2), which are most likely due to different additives in paper production, such as fillers and sizing agents, which reduce the water absorption capacity. The water absorptiveness of PC is the lowest of all samples, resulting in 25.9 g/m^2. These results are also influenced by the paper composition, fiber type, and surface roughness.

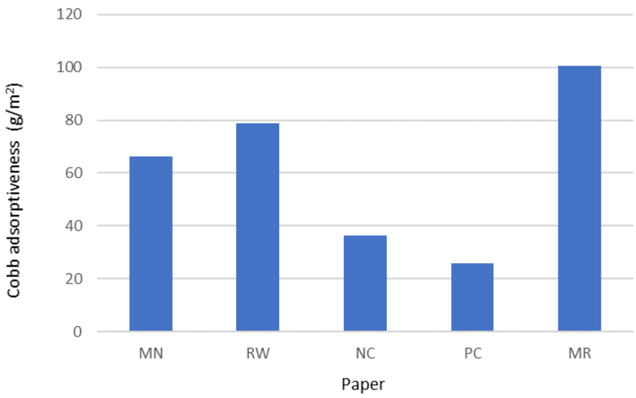
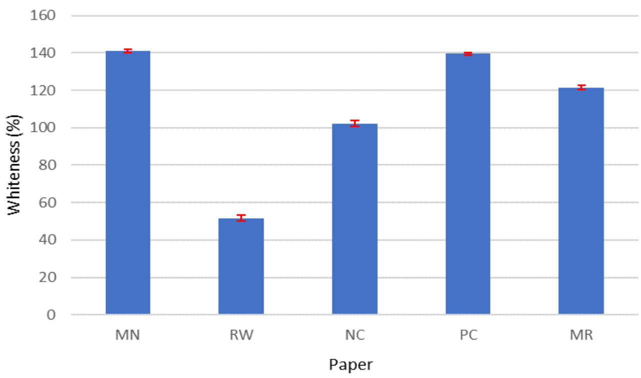
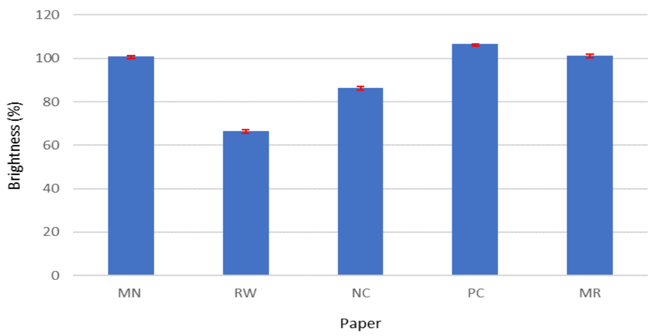


Figure 2: The results of Cobb absorptiveness (t = 60 s) of the papers

Optical properties of measured printing substates show the highest whiteness grade for the reference MN (141.2%) and PC (139.6%), followed by MR (121.4%), and recycled papers NC (101.9%) and RW (51.3%) (Figure 3a). Brightness measurements resulted in the highest degree for PC (106.5%) and PC (106.5%), which is almost equaled with the reference MN (101.0%) (Figure 3b). Recycled paper substrates NC and RW have the lowest brightness degree of 86.3% and 66.6%, consistent with the paper composition which implies the residual printing ink particles and secondary fibers. Additionally, such paper composition can result in higher degree of yellowness, especially if no OBA (Optical Brightening Agents) or dyes are used. This is most likely for the paper RW, since measured yellowness has a positive value of 7.9% (Figure 3c). Base-paper composition and additives have a crucial role in optical properties of the paper, which greatly affect the characteristics of the print. The result of optical measurements for reference paper MN shows the presence of OBAs, since whiteness exceeds 100%, with the lowest yellowness rate of -17.5%. The results of optical measurements confirm high properties of papers made of non-woody plants (PC and MR), consistent with visual impression.

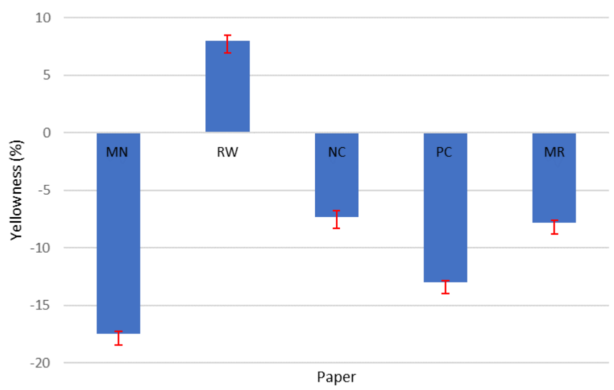


(a)



(b)

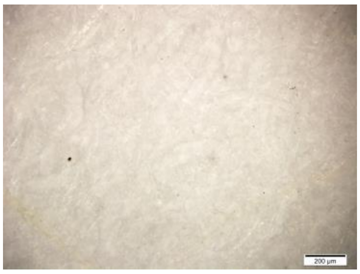
Figure 3 (part 1): The results of optical measurements of selected paper – printing substrates: a) whiteness; b) brightness



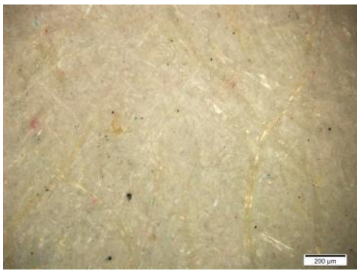
c)

Figure 3 (part 2): The results of optical measurements of selected paper – printing substrates: c) yellowness

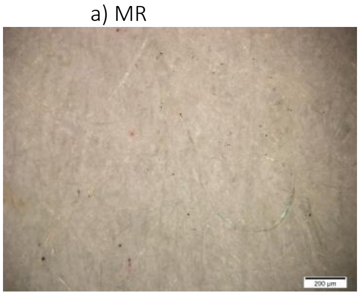
Figure 4 shows the microscopic images of the paper-printing substrate surface at magnification 100×. As can be seen in Figure 4a, the surface structure of the reference sample MN, a paper based on virgin fibers, is uniform and interspersed with well-interwoven fibers of different widths, with almost no impurities. The papers made from 100% recycled fibers (RW and NC) have a surface structure made of thin fibers interwoven in all directions in the surface structure (Figure 4b, Figure 4c). The particles of recycled material are visible in the RW sample. Sample PC (Figure 4d) has a surface structure that is the most irregular compared to all the observed samples. The fibers are of a uniform width, long and without visible breaks. Sample MR has an interwoven fiber structure consisting of 30% hemp, 30% PCW, and 40% virgin fibers (Figure 4e). The hemp fibers are narrow and interwoven between virgin fibers, which have a uniform shape without breaks.



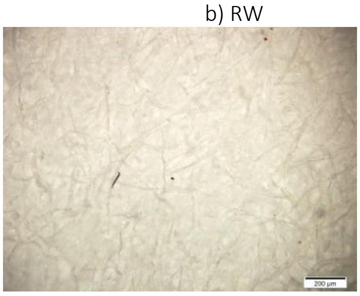
a) MR



b) RW



c) NC



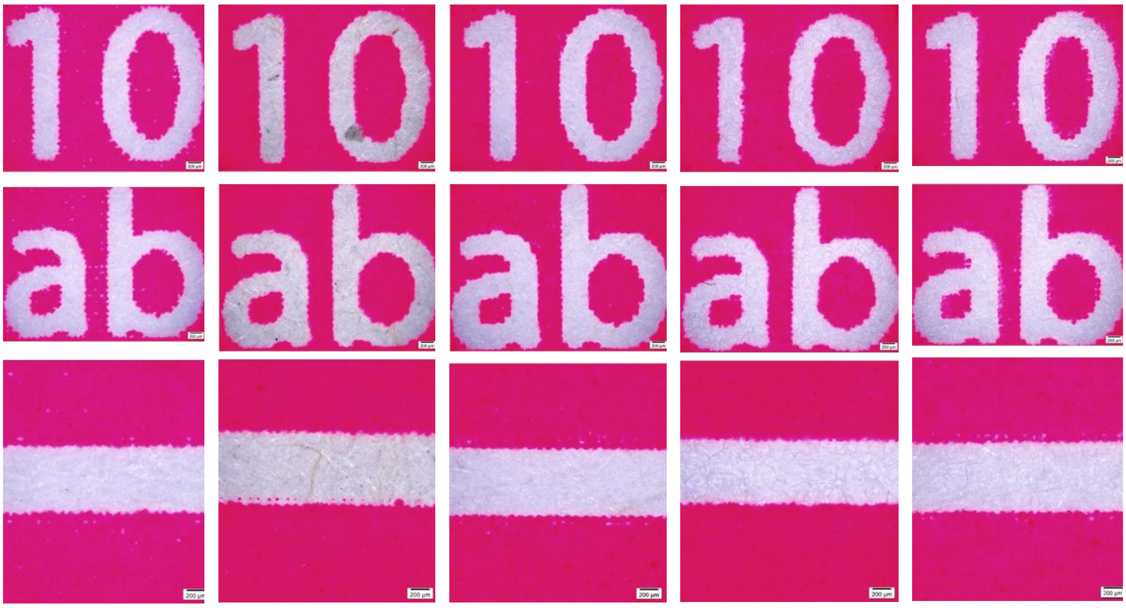
d) PC

e) MR

Figure 4: Microscopic images of the paper-printing substrate surface (100× magnification): a) MN; b) RW; c) NC; d) PC; e) MR

3.2 Properties of Printed Samples

Figure 5 shows microscopic images of the fluorescent printed edge elements and lines on selected printing substrates at 50× magnification. The edge elements and lines of the prints show irregularities in sample RW, while paper PC for example show greater smoothness. The selection of different paper substrates resulted in width of the printed lines screen-printed in negative (Figure 5, Table 3), which is the widest for MR, 738 µm with some irregularities, and narrowest for PC, 678 µm, where the line seems straighter and more precise (the nominal line width is 600 µm). Recycled RW and NC show a similar line width, but fluorescent prints result in a smoother line on NC substrate. This result could be related to possible fillers in NC paper composition, which contributes to more closed paper surface and better printability. The lines in the negative are wider on papers with higher absorptiveness (MR, RW); however, there was no significant growth of printed elements due to ink spreading or soaking on the paper surface.



a) MN b) RW c) NC d) PC e) MR

Figure 5: Microscopic images of the fluorescent printed edge elements and lines (negative) on selected printing substrates (50× magnification): a) MN; b) RW; c) NC; d) PC; e) MR

Table 3: The results of measured line width printed on selected substrates

Paper-printing substrate	Printed line width (µm)
MN	702
RW	757
NC	725
PC	678
MR	738

The results of measured spectral reflectance of the fluorescent prints on selected printing substrates (Figure 6) show similar trend for all samples, with curve peaking at two regions inside visible spectra, one at 440 nm and the other at 610 nm. A smaller peak at 440 nm results in spectral reflection between 32 and 50%. Spectral reflectance of fluorescent prints at 610 nm shows similar differences in the degree of spectral reflectance for all samples, with the highest peak resulting in 163 % for MR paper, followed by PC at 160 %, MN at 152 %, NC at 147 % and RW at 135%. These results are related to optical properties of the paper substrates, as well as their composition. A higher degree of whiteness and brightness results in higher spectral reflectance compared to recycled paper. Structural and surface properties of paper also affect the spectral reflection of fluorescent prints. The highest spectral reflectance of PC and MR can be linked to their lowest Bekk smoothness and highest bulk values of all measured samples. PC also resulted in high optical properties, which also contributed to high spectral reflection of fluorescence prints.

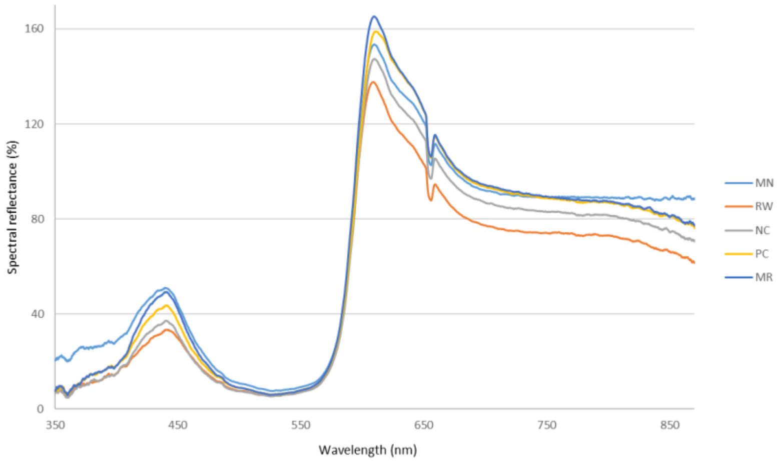


Figure 6: Spectral reflectance of the fluorescent prints on selected printing substrates

The survey was conducted to identify the most acceptable paper substrate for designs printed with fluorescent inks. Along with samples of motifs printed on all paper-printing substrates, respondents were asked to evaluate on which substrate does the printed element seem most noticeable (Figure 7a), on which substrate the printed element seems least noticeable (Figure 7b), and which solution of the printed element would they recommend (Figure 7c). The results correlate with the results of spectral reflectance of the prints, which is the highest for MR and PC, evaluated as the substates with most noticeable fluorescent prints (MR – 41.8% and PC – 31.3%). Even 70.1% evaluated sample RW as the least noticeable, which also confirms the lowest spectral reflection of this sample. 58.2% of the respondents would suggest PC paper as the solution for the printed element. These results are consistent with the results of spectral reflection, edge elements and printed lines conducted in this research.

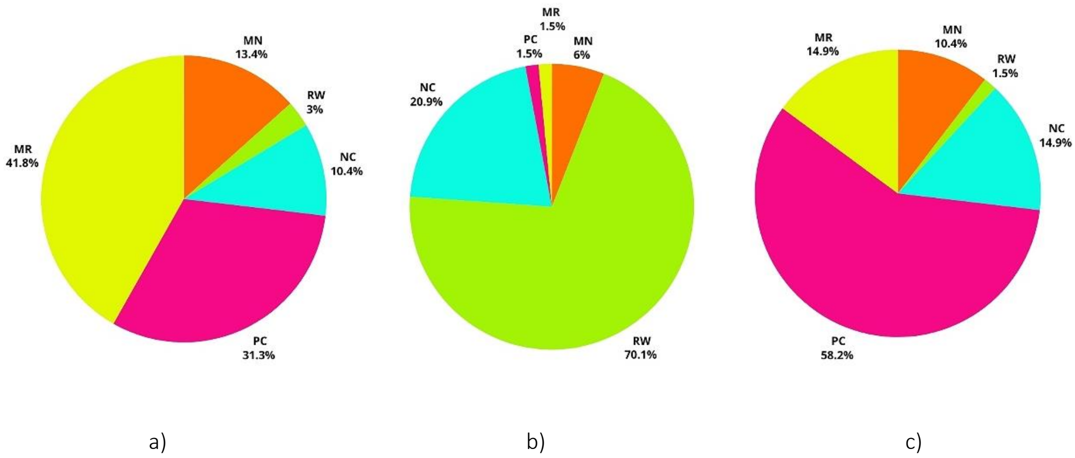


Figure 7: The results of the research survey: a) the printing surface on which the printed element appears most noticeable; b) the printing surface on which the printed element appears to be the least noticeable: c) the solution of the printed element proposed by the respondents

4. CONCLUSIONS

This study determines the impact of different uncoated paper substrates made from recycled and non-woody plant fibers on the optical performance of fluorescent prints. Papers from non-woody plants, made of cotton and hemp (MR, PC), demonstrated high optical properties, including whiteness and brightness, which enhanced the spectral reflectance of fluorescent prints. These substrates also provided smoother surfaces and better print quality compared to recycled papers (NC, RW).

Fluorescent inks performed best on cotton (PC) and hemp-based papers (MR), with the highest spectral reflectance values and improved line sharpness. Survey results supported these findings, showing a clear preference for non-woody plant-based substrates for visual appeal. Overall, cotton and hemp papers represent a promising, sustainable alternative to traditional fibers for high-quality fluorescent printing applications, with potential in packaging, signage, and security printing.
The result of this study suggests that further research into these fibers could yield even better results across more printing techniques.

5. REFERENCES

Ataeefard, M. (2015) The influence of paper whiteness, roughness and gloss on the optical density of colour digital printing. *Pigment & Resin Technology.* 44(4), 232-238. Available from: doi: 10.1108/PRT-11-2014-0108

Becidyan, A. N. (1995) Luminescent pigments in security applications, colorresearch & application. *Color Research and Application.* 20, 124–130. Available from: doi: 10.1002/col.5080200208

Bodenstein, C., Sauer, M. H., Hirmer, K., Dorsam, E. (2019) Printing process and characterization of fully padprinted electroluminescent panels on curved surfaces. *Journal Of Coatings Technology and Research.* 16, 1673–1681. Available from: doi: 10.1007/s11998-019-00243-0

Bozhkova, T., Spiridonov, I. & Shterev, K. (2017) Overview of security printing typesand trends in its future development. *Bulgarian Chemical Communications.* 49, 195-201. Available from: http://bcc.bas.bg/BCC_Volumes/Volume_49_Special_L_2017/195-201-Bojkova-31.pdf

Cassel, N., Chalancon, J., Pisaroni, H., Plazonić, I., Seleš, V. R. & Bates, I. (2023) Utilization of Laboratory Papers with Non-Wood Fibres as Printing Substrates Observed Through the Maximum Ink Penetration Depth. *Tehnički Glasnik.* 17, 32–37. Available from: doi: 10.31803/tg-20220213172821

Clift, M. J. D., Lucia, L., Vrabič-Brodnjak, U., Možina, K. (2022) Invasive Alien Plant Species for Use in Paper and Packaging Materials. *Fibers.* 10, 94. Available from: doi: 10.3390/fib10110094

Deshpande, M. S. (2011) Printing papers: Sizing and its role. *J. Eng. Res. Stud.* 2, 17–21.

González, I., Alcalà, M., Chinga-Carrasco, G., Vilaseca, F., Boufi, S., Mutjé, P. (2014) From paper to nanopaper: Evolution of mechanical and physical properties. *Cellulose.* 21, 2599–2609. Available from: doi: 10.1007/s10570-014-0341-0

Holik, H. (2013) Handbook of Paper and Board. 2nd ed. Wiley: Hoboken, NJ, USA.

ISO. (1995) ISO 5627. Paper and Board—Determination of Smoothness (Bekk Method). Geneva, Switzerland. Available from: https://www.iso.org/standard/20129.html [Accessed 5th March 2024].

ISO. (2011) ISO 534:2011. *Paper and Board—Determination of Thickness, Density and Specific Volume.* Geneva, Switzerland. Available from: https://cdn.standards.iteh.ai/samples/53060/5dca48d6975d42898e536cb86b96132e/ISO-534-2011.pdf [Accessed 5th March 2024].

ISO. (2022) ISO 187:2022. *Paper, Board and Pulps—Standard Atmosphere for Conditioning and Testing and Procedure for Monitoring the Atmosphere and Conditioning of Samples*. Geneva, Switzerland. Available from: https://cdn.standards.iteh.ai/ [Accessed 5th March 2024].

ISO. (2023) ISO 535:2023. *Paper and Board—Determination of Water Absorptiveness—Cobb Method*. Geneva, Switzerland. Available from: https://www.iso.org/standard/80320.html

Jaishwal, K. K., Izhar, A., Chhaya, S. (n. d.) Development of Reinforced Paper and Mitigation of the Challenges of Raw Material, Availability by Utilizing Areca Nut Leaf. Available from: https://imisrise.tappi.org/TAPPI/Products/22/SEP/22SEP469.aspx [Accessed 5th March 2024].

Jameson, D. M. (2014) Introduction to fluorescence. CRC press, Boca Raton. Available from: doi: 10.1201/b16502

Kumar, P. N. (2022) Use of Alternative Raw Materials and Pulp Blending Improves the Strength Properties of Pulp and Paper. *Techniques and Innovation in Engineering Research.* 6, 96–106. Available from: doi: 10.9734/bpi/taier/v6/4557E

Kurek, M., Bates, I., Plazonić, I., Rudolf, M., Seleš, V. R., Ga lić, K., Maretić, K. P. (2022) Effects of Non-Wood Fibres in Printed Paper Substrate on Barrier and Migration Properties. *Tehnički Glasnik.* 16, 299–305. Available from: doi: 10.31803/tg-20220203155555

Li, Dongjun. (2016) 8. Fluorescent printing ink. Publication of US2940937A (Patent).

Rudolf, M., Bates, I., Plazonić, I., Seleš, V. R., Maretić, K. P., Mendeš, M. M. (2022) Evaluation of the Line and Edge Quality of Printed Letters on Recycled Paper with Straw Pulp. Available from: https://www.grid.uns.ac.rs/symposium/download/2022/posteri/32.pdf

Talebnia, F., Nourmohammadian, F. & Bastani, S. (2014) Development of novelfluorescent offset ink based on coumarin dyes: Synthesis and properties. *Progress in Organic Coatings.* 77, 1351–1359. Available from: doi: 10.1016/j.porgcoat.2014.04.022

Tamboli, D. A., Doshi, S. T., Mule, S. D., Lamkane, K. E. & Patil, S. R. (2022) Design and Fabrication of Paper Recycling Unit. *International Journal of Mechanical Engineering and Technology.* 2, 17–20. Available from: doi: 10.48175/IJARSCT-5892

TAPPI (2013) TAPPI 441. *Water Absorptiveness of Sized (Non-Bibulous) Paper, Paperboard, and Corrugated Fiberboard (Cobb Test)*. Atlanta, GA, USA. Available from: https://www.tappi.org/content/tag/sarg/t441.pdf

Tanpichai, S., Witayakran, S., Srimarut, Y., Woraprayote, W., Malila, Y. (2019) Porosity, density and mechanical properties of the paper of steam exploded bamboo microfibers controlled by nanofibrillated cellulose. *Journal of Materials Research and Technology.* 8, 3612–3622. Available from: https://doi.org/10.1016/j.jmrt.2019.05.024

Teacă, C. A. (2023) Making Paper from Materials That Are Essential to Our Lives/Making Paper without Trees Is the New "Must". *BioResources.* 18, 4379–4382. Available from: doi: 10.15376/biores.18.3.4379-4382

Yook, K. S. & Lee, J. Y. (2013) Fabrication and luminance switching of flexibleorganic bistable light-emitting diodes on flexible substrate. *Journal of Luminescence.* 137, 105–108. Available from: doi: 10.1016/j.jlumin.2012.12.050