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TISKARSTVA, DIZAJNA I GRAFIČKIH KOMUNIKACIJA

ZBORNIK RADOVA
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Senj, 11. - 14. rujna 2019. godine, Hrvatska
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ZNANSTVENI RADOVI
SCIENTIFIC PAPERS

THE PENETRATION PROFILES OF INKJET INKS INTO LABORATORY SUBSTRATES WITH BARLEY PULP

PROFILI PENETRACIJE INKJET BOJA U LABORATORIJSKIM LISTOVIMA S PULPOM JEČMA

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SAŽETAK

Povećana svjetska ekološka svijest dovela je do znatnog porasta upotrebe recikliranog papira , ali i novih alternativnih izvora celulozne sirovineza proizvodnju papira u zamjenu za drvnu. Kako reciklirana drvna vlakna ne pružaju istu razinu kvalitete papira kao primarna vlakanca, neprestano se traže i istražuju alternativni izvori celuloznih vlakanaca.
U ovom radu promatrani su profili penetracije UV inkjet boja unutar laboratorijskih listova formiranih dodavanjem pulpe ječma u različitim omjerima u pulpu recikliranog papira. Svi dobiveni rezultati uspoređeni su s kontrolnim uzorkom, odnosno laboratorijskim listom, proizvedenim samo od reciklirane papirne pulpe.
Profili penetracije izrađeni su promatranjem i analizom snimljenih mikroskopskih slika presjeka uzorka, koji su prethodno kalupirani u epoksidnoj smoli. Cilj ovog rada je ispitati utjecaj nedrvnih vlakanaca na kvalitetu otiska te predložiti koji je udio takvih vlakanaca najprihvatljiviji za proizvodnju papira.

Ključne riječi: profili penetracije, pulpa ječma, laboratorijski listovi, UV inkjet boje

ABSTRACT

Increased worldwide environmental awareness has led to a substantial increase in the use of recycled papers and new alternative sources of cellulose fibres to manufacture new paper. As recovered wood fibres do not provide the same level of paper quality as the virgin ones, alternative sources of cellulose fibers are continuously sought and researched.

In this paper, the penetration profiles of UV inkjet inks within laboratory substrates formed with the addition of barley pulp in different weight proportions into pulp from recycled paper were observed. All the results have been compared to the control sample, respectively laboratory substrate produced only from recycled paper pulp.

Penetration profiles were performed by observing and analyzing the microscopic images captured in the region of interest from a cross section of a pre-molded specimen into an epoxy resin. The aim of this paper is to examine whether the proportion of non-wood fibres effects

the print quality, and to propose which fiber ratio is the most acceptable for paper production.

Key words: penetration profile, barley pulp, laboratory substrate, UV inkjet inks

Introduction

In this paper, the penetration profiles of UV inkjet inks into printing substrates made of barley pulp and a control sample made entirely of recycled wood pulp were compared.

The absorption of ink into the printing substrate depends on the physical and chemical properties of the printing substrate as well as the ink properties, but also on the interactions of the substrate and the ink.

Ink penetration can occur as surface dispersion of cellulose fibres or diffusion through cellulose fibres in the composition of the paper. Papers consisting of cellulose fibres network with several additives form heterogeneous printing substrates, and laboratory made papers are even more inhomogeneous in structure than commercial papers with very open surface which leads to a deep ink penetration into the paper structure. The movement of the ink within the porous structure of the printing substrate may influence the quality of the prints [1, 2, 3].

In the paper industry, wood is still the most commonly used raw material, but the use of non-wood sources of fibres has been on the rise in recent years [4]. In this study the barley straw as an agricultural residue was selected due to renewability, availability and cost-effectiveness for obtaining pulp [5]. In the laboratory, paper substrates were created by mixing barley pulp with recycled wood pulp.

To achieve high quality prints it is necessary to know the characteristics of the substrate and the possibilities of each printing techniques. Traditional technologies are still main printing techniques, while digital printing process is getting more and more popular, due to its ability to provide the required quality of the prints on a wide variety of substrates. Ink jet is one of the most common digital printing technologies, where the ink is ejected directly onto a substrate from a jet unit driven by an electronic signal and printing is performed without printing plates [6,7]. In ink jet technology, a finite amount of liquid is transferred directly onto a printing substrate [8].

EXPERIMENTAL PART

Laboratory substrates of approx. 42.5 g/m2, formed by Rapid-Köthen sheet former (FRANK-PTI), were made entirely of recycled wood pulp or from mixture of recycled wood and barley pulp (Table 1.). Semi chemical barley pulp was obtained from crop residue leftover on fields after harvesting which was collected, manually cut and processed by soda pulping method [9,10].

On laboratory substrates full-tone areas of cyan, magenta and yellow inks were printed by digital EFI Rastek H652 UV curable inkjet printer with the resolution of 600 × 600 dots per inch (dpi) (respectively with high quality mode 8 pass) and printing speed of 12.10 m2/ hr.

Table 1: Laboratory substrates composition and marks

Laboratory substrates		
Mark	Composition	
	Barley pulp (B), %	Recycled pulp (N), %
N	0	100
1NB	10	90
2NB	20	80
3NB	30	70

Prints were cut to 10 mm × 30 mm strips which were inserted into an epoxy resin, a mixture of Epofix resin (contains bisphenol-a-diglycidylether) and Epofix hardener (contains triethylenetetramine). The specimens (Figure 1.) were dried at room temperature for 12 hours prior to grinding and polishing which were performed using a Buehler Grinder Machine and Struers DAP-V Polishing Machine.

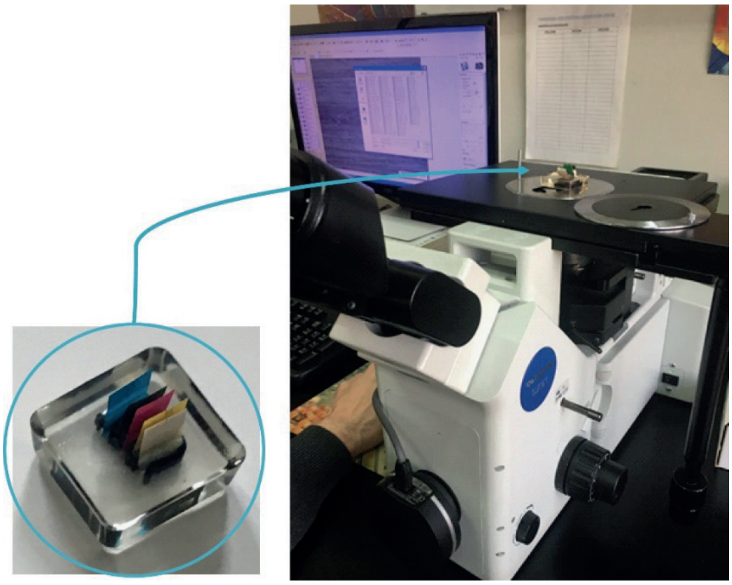

Figure 1. The specimen inserted into an epoxy resin and light microscope Olympus GX 51 analysis of the cross section of samples

The cross section of samples was observed at 200× magnification using a light microscope Olympus GX 51 with an Analysis software and captured images in region of interest were further analysed by ImageJ software to examine penetration length of inkjet inks into laboratory substrates with barley pulp. Microscopic images captured, in region of interest, from a cross section of a pre-moulded specimen into an epoxy resin (laboratory substrates N and 3NB printed with cyan, magenta and yellow ink) are presented at Figure 2. The ink penetration was calculated from the 50 sections obtained from the microscopic images. The thickness of laboratory substrates was also determined on microscopic images from the cross section of samples.

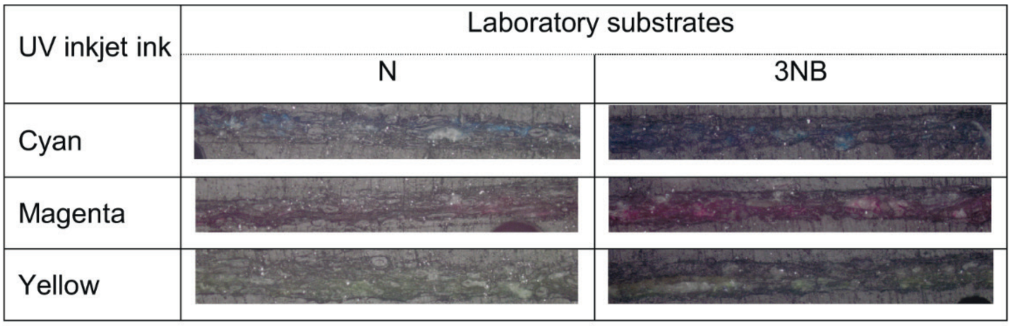

Figure 2. Cross section of laboratory substrates N and 3NB printed with cyan, magenta and yellow ink

RESULTS AND DISCUSSION

Thickness as a base structural property of printing substrate is summarized in Table 2 in order to get a better insight into the interactions of the substrate and the ink.

Table 2. The thickness of laboratory substrates determinate on microscopic images of the cross section of samples

Unprinted laboratory substrate		**Thickness (µm)**	
		Average	Stdev.
N		81.58	2.39
1NB		68.03	3.33
2NB		84.45	7.38
3NB		83.44	5.55
Printed laboratory substrate	**UV inkjet ink**	**Thickness (µm)**	
		Average	Stdev.
N	Cyan	103.15	6.27
	Magenta	94.98	4.76
	Yellow	108.43	5.50
1NB	Cyan	103.15	6.27
	Magenta	99.78	3.92
	Yellow	91.54	5.56
2NB	Cyan	80.57	4.80
	Magenta	82.90	5.76
	Yellow	85.58	5.40
3NB	Cyan	86.09	8.92
	Magenta	83.02	6.06
	Yellow	96.63	4.54

Thickness of an unprinted laboratory substrates is approximately equal for all analysed samples (~83 µm), except for substrate made with addition of 10% barley pulp (1NB) which was lower (68.03 µm). As expected, the thickness of all specimens increases after printing regardless of the used ink. It is interesting that the greatest increase in thickness was measured for papers without the addition of barley pulp (26% for substrate N printed with cyan ink, 16% for substrate N printed with magenta ink and 33% for substrate N printed with yellow ink) and for papers with 10% barley pulp (51% for substrate 1NB printed with cyan ink, 47% for substrate 1NB printed with magenta ink and 35% for substrate 1NB printed with yellow ink). The increase in thickness was insignificant for papers with a high content of barley pulp.

Table 3. Penetration length values of cyan, magenta and yellow UV inkjet inks into laboratory substrates

Laboratory substrate	UV inkjet ink	Penetration depth (µm)		
		Average	StDev.	Range
N	Cyan	38.11	13.68	15.0 - 60.4
	Magenta	37.57	14.30	22.0 – 91.0
	Yellow	49.43	12.92	27.4 - 92.0
1NB	Cyan	52.77	15.89	21.0 – 93.8
	Magenta	50.23	13.18	17.8 - 89.4
	Yellow	43.59	12.19	26.4 - 70.8
2NB	Cyan	72.12	6.43	60.3 – 86.8
	Magenta	77.18	11.43	53.5 – 93.3
	Yellow	42.84	14.65	15.8 – 81.0
3NB	Cyan	44.42	13.62	19.0 – 69.4
	Magenta	45.51	13.38	24.2 – 80.0
	Yellow	53.79	12.07	26.4 – 88.4

From penetration length values, listed in Table 3, it is evident that the lowest penetration of all UV inkjet inks (yellow, cyan and magenta) were obtained on laboratory substrate made only from wood pulp (N). Addition of barley pulp into wood pulp formed laboratory substrates (1NB, 2NB and 3NB) shows higher penetration length values for all analysed UV inkjet inks. Standard deviations for all laboratory substrates are relatively high (approximately 13 µm), that indicates a strong inhomogeneity of the substrate. A wide range of results of penetration length also presents inhomogeneity (minimum value of 15.0 µm was measured for cyan ink into substrate N and the maximum value of 93.8 µm was for cyan ink into substrate 1NB).

Total ink penetration length was about ~1/3 of the thickness of the laboratory substrates without barley pulp (N), while for substrates with barley pulp it was about 1/2 of their thickness while for substrate 2NB penetration reaches value of 90% for cyan ink and 93% for magenta ink.

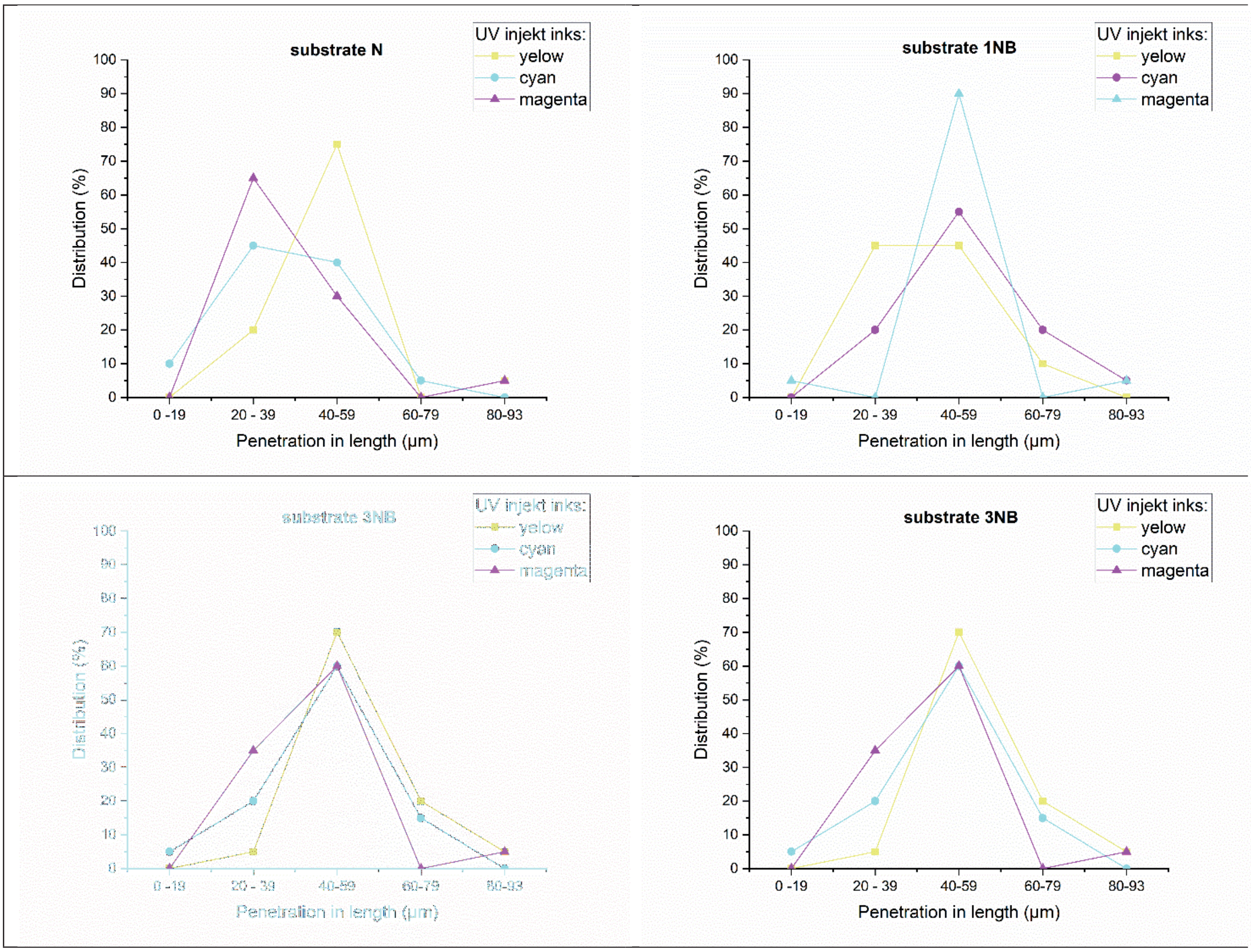

Figure 3. Penetration results distributions of UV inkjet inks into laboratory substrates

Penetration distributions of UV ink jet inks into laboratory substrates without (N) and with barley pulp (1NB, 2NB and 3NB) are presented at Figure 3. It is visible that over 75 % of penetration values for yellow ink into substrate N are measured in length range from 40 to 59 μm, while for cyan and magenta ink the length rage from 20 to 39 μm is more dominant one (over 65% of measurements for cyan and approximately 45% for magenta). However, 95% of all measurements of penetration for yellow, cyan and magenta inks are in range from 20 to 59 μm into substrate N. Addition of barley pulp for all inks has the similar influence. Namely, for substrates with barley pulp penetration values move into the range of higher penetration values. The most penetration values were measured in a range from 40 to 59 μm for all three inks into papers with barely pulp, while for cyan and magenta inks the most penetration values were measured in the range from 60 to 79 μm.

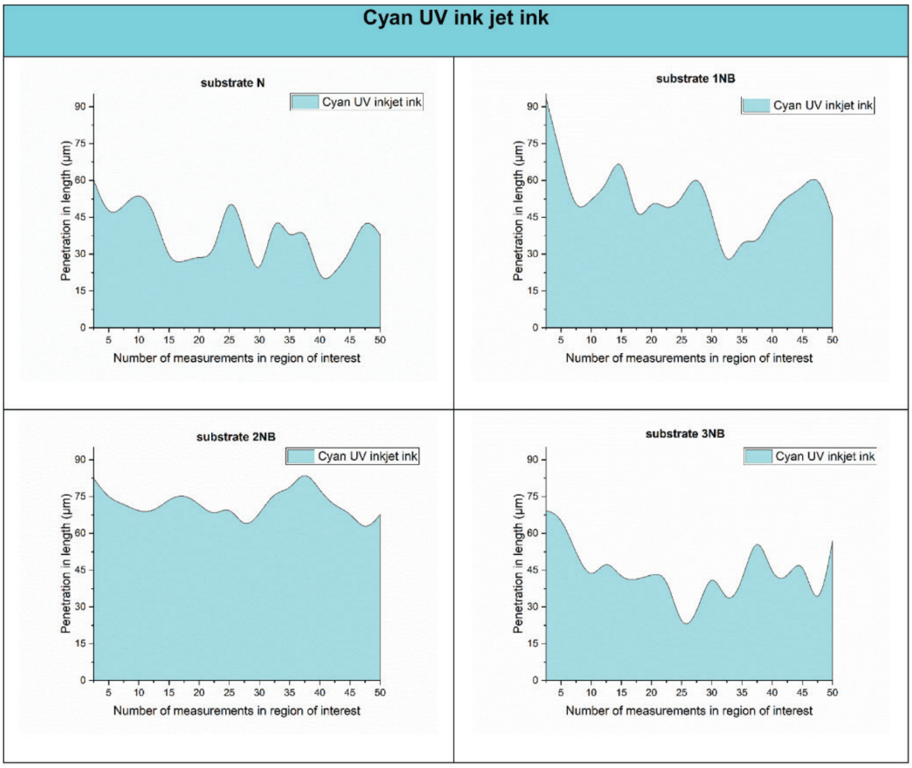

Figure 4. Penetration profile of cyan ink into laboratory substrates

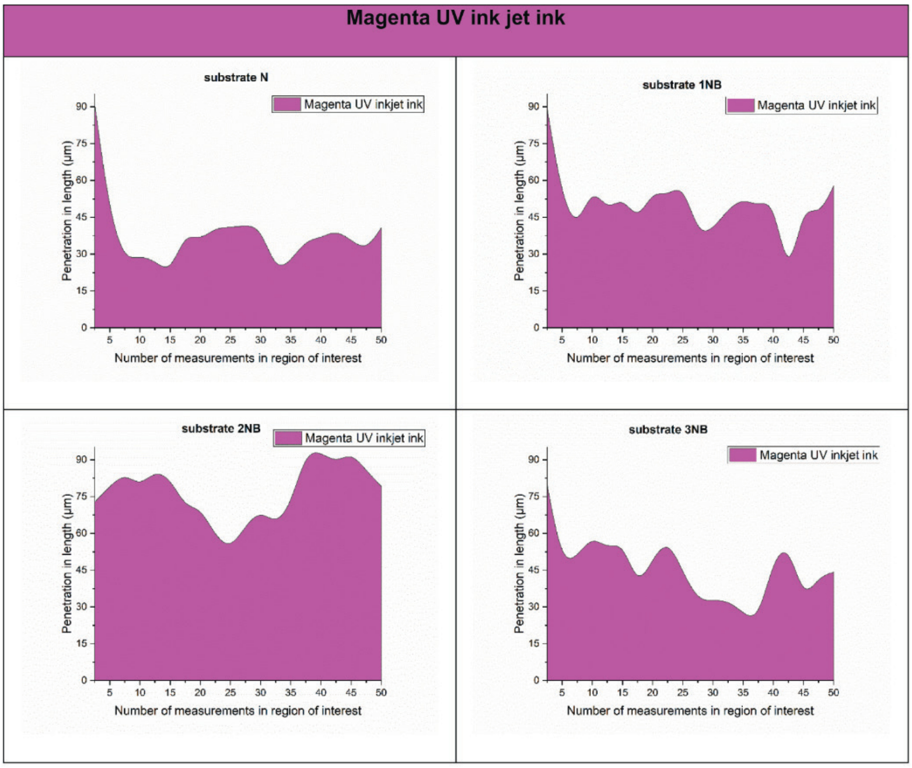

Figure 5. Penetration profile of magenta ink into laboratory substrates

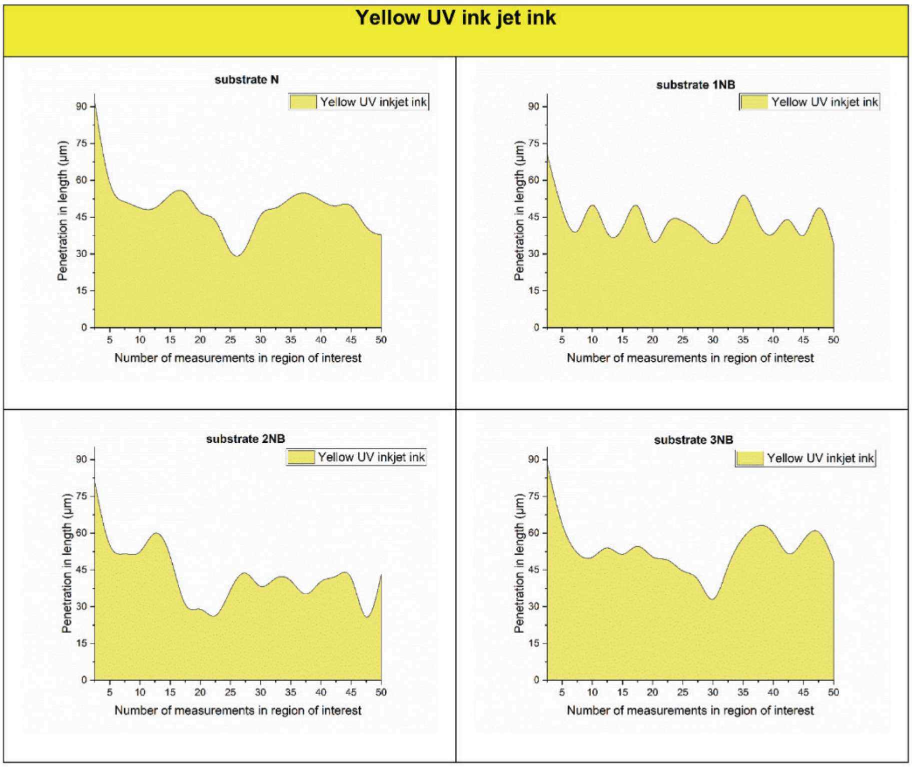

Figure 6. Penetration profile of yellow ink into laboratory substrates

In order to illustrate the penetration of ink into the laboratory substrate more clearly, the penetration profiles made from 50 measurements are shown in the figures 4-6. From the figures, penetration profiles of the cyan and magenta inks shown that laboratory substrates made only from recycled wood pulp and those with the addition of 30% barley pulp have very similar penetration of the ink. The highest penetration lengths of cyan and magenta inks into the substrate are observed in laboratory substrates with 20% barley pulp. Penetration profiles of yellow ink into laboratory substrates made only from recycled wood pulp and with the addition of 30% barley pulp are also look similar, but they are higher than for laboratory substrates made with the addition of 10 and 20% barley pulp.

CONCLUSION

From penetration profiles it is visible that all substrates have nonuniform penetration values indicating a very high inhomogeneity of laboratory made substrates. It is clear that the addition of barley pulp increases the penetration of all inks into the substrate by about 10% compared to the substrates without barley pulp. Generally, into laboratory substrates with barely pulp all inks penetrate more than half of the substrates thickness while for laboratory substrates without barely pulp penetration length is slightly higher than one third of the substrate thickness.

Keeping in mind that virgin fibres provide papers that absorb better than recycled papers and that this research has been done on laboratory made paper that have not gone through the final stages of surface treatment, the obtained ink penetration results are promising for the usage of barley pulp in the manufacture of printing paper.

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