THE RUB RESISTANCE ASSESSMENT OF OFFSET UV PRINTS ON SUBSTRATE CONTAINING TRITICALE PULP

PROCJENA OTPORNOSTI NA OTIRANJE OFSETNIH UV OTISAKA NAČINJENIH NA PODLOZI KOJA SADRŽI TRITIKALNU PULPU

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Abstract

In terms of volume, wood is the most available natural resource of cellulose fibres on earth. Although almost 2000 years ago the Chinese used other raw materials to make paper (bast, bark, hemp, rags and rice grass), today wood is still the most important raw material for pulp and paper production. As the forest area decreases daily, there are fewer trees as raw materials for cellulose fibres, the production of paper and paper products has significantly focused on the usability of alternative non-wood raw materials. The usage of these alternative cellulose fibres for paper production is the most cost-effective and environmental solution that aims to reduce the consumption of virgin wood pulp in paper production by replacing it with alternative plant biomass. The goal of this work was to assess the quality of offset prints on a substrate where wood fibres have been partially replaced by alternative fibres from triticale straw. For that purpose, laboratory-made printing substrate containing 30% triticale pulp was printed with UV low migration offset inks used for printing labels and non-food packaging. The assessment of the print quality on such substrates was based on the rub resistance according to the standard BS 3110:1959.

Keywords: *triticale, offset printing, paper, rub resistance, usability*

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1. INTRODUCTION

The first mentioned material which was used for making paper was a papyrus plant that grew in Africa around 2600 BC [1]. Thin strips of papyrus plant obtained by cutting the inner side of the plant were laid side by side, pressed, beaten and smoothed to form a sheet of paper. The production of paper from plant fibres such as fibres derivated from bamboo, rice grass or hemp dates back to around 105 AD. The invention of paper is associated with the Chinese Tsai Lun who greatly improved the old methods of papermaking and introduced new materials such as tree bark, hemp, rags, fish nets, etc. [2]. The production of paper from plant fibres began in Europe around 1150 in Spain, in 1276 in Italy, and in 1338 in France. Today, wood is the most important raw material in the production of paper, although the Egyptians and Chinese used papyrus, bast, bark, hemp, rags and grass as the main raw materials for paper production more than 2000 years ago [3]. As forest area decreases daily due to urban sprawl and greater usage, there are fewer and fewer trees as raw material for cellulose fibres, therefore paper and paper products manufacturers are significantly focused on the utilization of alternative non-wood raw materials. Based on several studies, it is proven that the use of these alternative cellulose fibres for paper production is a more cost-effective, sustainable issues and environmentally friendly solution aimed at reducing the consumption of virgin wood pulp in paper production by replacing it with alternative fibres from natural growing plants. Alternative sources of fibrous materials have been analyzed and used worldwide, depending on the region in which they can be collected in large quantities [4]. Today, a very small proportion of graphic paper is produced with non-wood fibres, also called tree-free fiber sources, and can be divided into two major groups: agricultural residues and primary crops [5].

The most common fibre sources analyzed by numerous researchers were straw, sugar cane bagasse, bamboo, kenaf, hemp, sisal, abaca, cotton linter and reeds, as well as some exotic raw materials such as aquatic plants, tea waste, palm leaves and banana stems [6-10].

As the characteritics of the paper substrate are one of the factors that undoubtedly affects the overall quality of prints on packaging or publication, in this research attention is directed to the printing of laboratory-made paper substrates with pulp of virgin fibres obtained from triticale straw [11].

The aim of this study was to investigate and confirm the stability of the printed substrate with the addition of 30% triticale pulp. The assessment of print stability was observed by determining the colour change of the prints after the rub resistance test was performed. Print stability or colour degradation was estimated by the Euclidean colour difference (ΔE_{00}*) calculated from the measured colorimetric values (L*, a*, b*) of the prints. For this study, the observed printing substrates were printed with UV low migrating offset inks printed under laboratory conditions.

2. EXPERIMENTAL PART

The experimental part of this research was performed in four steps: 1. converting triticale straw into pulp; 2. forming laboratory paper substrates; 3. printing of paper substrates and 4. rub resistance assessment of prints.

2.1. Converting triticale straw into pulp

The agricultural residue of the triticale crop was harvested in the continental part of Croatia, hand-cut into 1 to 3 cm long pieces and turned into a semi-chemical pulp according to the Soda method [11]. Triticale straw was converted into pulp by the decomposition of lignin and hemicelluloses without depolymerization of cellulose fibres. The procedure of converting triticale straw into pulp is summarized in Table 1.

Tab. 1: The procedure of converting straw into pulp

Soda pulping – cooking in autoclave		Decantation and rinsing		Defibration in Holländer Valley mill	
Chemical $NaOH_{(aq)}$	16 %	Tap water	2 × 10 l	Tap water	23 l
Bath ratio straw:$NaOH_{(aq)}$	1:10			At 24 °C	40 min
At 120 °C and 170 kPa	60 min			pH	8.5 – 9.0

2.2. Forming laboratory paper substrates

Gained triticale pulp was mixed with the recycled wood pulp in a ratio of 3:7. The procedure for forming laboratory paper substrates in laboratory conditions is presented in Table 2. As a reference sample, laboratory paper substrate with only recycled wood pulp is formed at same conditions.

Tab. 2: Procedure for forming laboratory paper substrates

Disintegration		Homogenisation		Handsheet /paper substrate	
m (pulp)	80 g	V (H_2O)	10 l	weight	42.5 g/m^2
V (H_2O)	1.6 l	pH	7.5		
pH	8	T	45 °C	diameter	20 cm
T	45 °C	t	5 min		

2.3. Printing of paper substrates

Offset printing is one of the main printing techniques for publications and packaging that provides high print quality [12]. Offset printing is a very popular technique that is growing every year in the field of packaging, especially with the advent of UV curing systems [13]. Therefore, all paper substrates were printed in full tone by Prüfbau multipurpose printability testing machine with SunCure Starluxe low migration inks (manufacturer Sun Chemicals) at a temperature of 23 °C and relative humidity of 50%. In order to assess the rub resistance of monocolour and multicolour prints, the printing was performed with one layer of cyan, magenta, yellow or black ink, with two layers with cyan and yellow, magenta and yellow, cyan and magenta, and in three layers with cyan, magenta and yellow ink. All samples were printed at a speed of 0.5 m/s and a pressure of 600 N, after which the prints were dried with a continuous flow dryer Technigraf Aktiprint L 10-1 (output power of the UV lamp max. 120 W/cm). The obtained prints contain colorimetric values based on the recommendations of ISO 12674 standards [14]. Some basic characteristics of paper printed for this study are shown in the table below (Table 3), where paper marked as K is commercial paper produced from the recycled pulp (used as a control sample), N is a laboratory paper produced from the recycled pulp (used as a reference sample) and 3NT is a laboratory paper produced with 30% triticale pulp.

Tab. 3: Characteristics of paper substrates [11]

Paper substrates	Thickness (µm)	Ash (%)	R_a (µm)
K	63.20 ± 2.90	10.00 ± 0.04	2.57 ± 0.32
N	94.00 ± 2.79	4.73 ± 0.22	4.15 ± 0.34
3NT	99.40 ± 6.20	3.99 ± 0.15	4.40 ± 0.39

2.4. Rub resistance assessment of prints

High-quality reproductions and stability of prints depend on the requirements of the graphic product, and in order to achieve them it is necessary to be aware of the characteristics of the paper substrate and the possibilities of a particular printing technique. Durability or rubbing stability is the resistance of prints to colour fading during shipping, storage and handling or during usage by end-users. A high degree of stability to rubbing is especially required for large-gram packaging, with products that are used repeatedly. In this research, the aim was to assess and compare the rub resistance of samples printed in one, two, or three layers on paper substrates made with triticale pulp and made with recycled wood pulp (laboratory N or commercial K).

The rub resistance assessment of the prints was performed in accordance with the standard BS 3110:1959 [15] by the Rub and Abrasion tester (manufacturer Hanatek) at a constant speed of 60 rpm. During the test, the entire contact surface of the printed substrate with a diameter of 50 mm is evenly rubbed on the principle of circular motion (20, 40 and 60 revolutions) on the unprinted substrate with a diameter of 115 mm under constant pressure of 3.45 kPa which provides a block with a weight of 0.5psi (0.23 kg).

Optical colour changes were determined using the Euclidean colour difference (ΔE_{00}*) calculated from the colorimetric values measured before and after the test. Measurements of colorimetric values on printed substrates were performed using a spectrophotometer SpectroEye (manufacturer X-Rite) under measuring conditions of status E, standard illumination D50 and 2° observers. The Euclidean colour difference (ΔE_{00}*) of all analyzed prints was calculated according to the following equation 1 [16,17].

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

Where:

ΔE_{00}*– the total colour difference, the Euclidean colour difference

$\Delta L'$ – the lightness difference between print before and after rub resistance test

$\Delta C'$ – the chroma difference between print before and after rub resistance test

$\Delta H'$ – the hue difference between print before and after rub resistance test

R_T – the rotation function

K_L, K_C, K_H – the parametric factors for variation in the experimental conditions

S_L, S_C, S_H – the weighting functions

3. RESULTS AND DISCUSSION

To examine the durability of prints in packaging and the image within publications, the rub stability analysis was performed on monocolour and multicolour prints in order to observe whether the number of ink layers affects the reduction of rub resistance.

Figure 1 shows that colour degradation is rising with the number of rotations on all printed papers. A substrate with the addition of triticale pulp printed with cyan ink shows lower stability after the rub resistance test than commercial paper (K) and reference laboratory paper (N), while all substrates printed with magenta ink show very similar colour stability. It is visible that yellow prints are the most stable considering that the Euclidean difference is the lowest on all samples. The highest colour difference caused by rubbing movements is visible on a substrate with 30% triticale pulp printed with black ink after 60 rotations where the Euclidean colour difference is above the reference line of ΔE_{00}*=2 (ΔE_{00}*=3.09). All other printed substrates show very good rub stability and are below the recommended value of ΔE_{00}*=2, where the human eye can barely see the difference in colour.

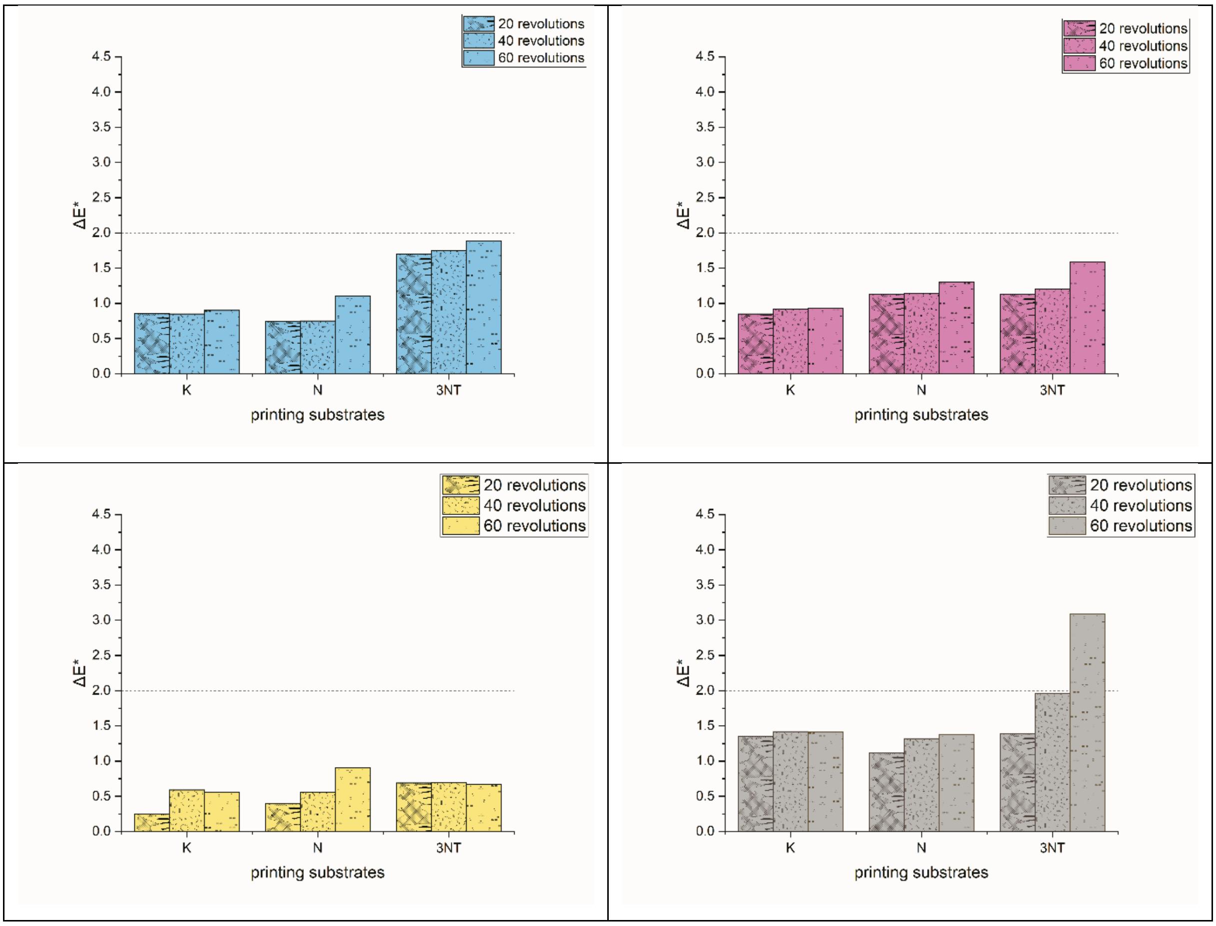

Fig. 1: Colour difference (ΔE_{00}*) of the monocolour prints made with cyan, magenta, yellow and black ink, after rub resistance testing with 20, 40 and 60 revolutions

As in previous graphs, it is also visible in Figure 2 that the Euclidean colour difference values rise with the higher number of rotations on all printed substrates. Commercial paper (K) printed in two layers with magenta and yellow ink (M+Y) exhibits the highest colour difference after 60 rotations where its value reached 2.2, which is slightly above the reference line. Reference laboratory paper (N) and paper with 30% triticale pulp (3NT) printed in two layers with cyan and yellow ink (C+Y) show increased ΔE_{00}* values that are above the reference lines. Namely, printed reference laboratory paper N after 40 and 60 rotations exceeding of negligible ΔE_{00}*=2.1 and 3NT after 60 rotations where ΔE_{00}*=2.52. Of all substrates printed in two layers with cyan and magenta ink (C+M), the reference laboratory paper (N) has the highest colour degradation after 60 rotations (ΔE_{00}*=4.05), while the substrate with 30% triticale pulp shows overrun above the reference line after 40 and 60 rotations. Laboratory paper with 30% triticale pulp printed in three layers of inks with cyan, magenta, and yellow ink (C+M+Y) shows good rub resistance after 20 and 40 rotations, while other substrates values are above the reference line.

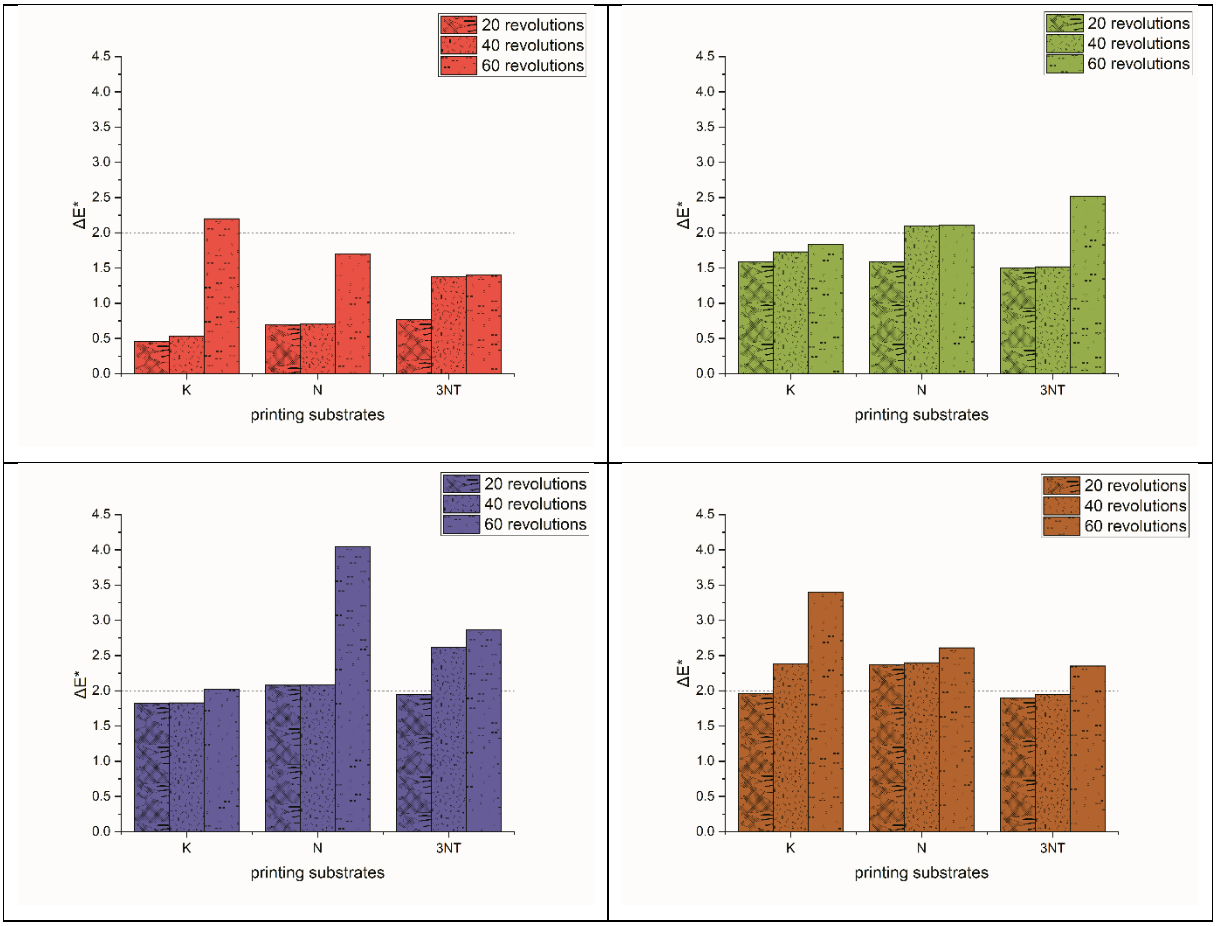

Fig. 2: Colour difference (ΔE_{00}*) of the multicolour prints made with magenta and yellow (M+Y), cyan and yellow (C+Y), cyan and magenta (C+M) and cyan, magenta, and yellow ink (C+M+Y), after rub resistance testing with 20, 40 and 60 revolutions

Observing the the rub resistance results of the all prints regarding the characteristics of the printing substrate, no significant difference in the stability of the prints was observed, and thus the use of paper with the addition of alternative pulp is possible. Moreover, our previous research has led to the conclusion that the addition of straw pulp up to 30% into laboratory-made paper substrates provide prints with acceptable resistance to rubbing [18,19].

4. CONCLUSION

From the measured data evaluating the rub resistance of printed laboratory papers with triticale pulp in relation to printed laboratory and commercially recycled wood paper, the following conclusions can be drawn:

- regardless of the type of paper, all analyzed monocolour prints show very good rub resistance even after treatment with 60 revolutions, except for prints made with black ink which shows optimal resistance only up to 40 revolutions.
- for multicolour prints made in two layers of the ink, there are larger changes in colour after the rub resistance testing, which are mainly around the reference line (ΔE_{00}*=2), except for the print made with cyan and magenta, where the deviations

in colour on the laboratory prints with and without added triticale pulp are more pronounced.

- the multicolour prints obtained in three layers of the ink proved to be the most unstable regardless of the composition and the production of the printing substrate.
- the rub resistance assessments of laboratory and commercial papers confirm that paper with the addition of triticale pulp does not show significant degradation in colour and can be used in the printing industry for printing packaging and publications with the aim of reducing the utilization of wood fibre resources.

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