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Usability of straw for secondary packaging printed by offset and gravure printing techniques

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ABSTRACT

Packaging is the material with which the product is wrapped or inside which the product is placed. The main function of packaging is to protect the packaged product, identify it and place it on the market, and to ensure the original shape of the packaged goods. The trend today is to reduce the global amount of packaging waste by recycling the same waste or reusing other available waste materials, while maintaining the required quality of the packaging thus produced. Cereal grains which include wheat, rye, barley, oats, rice, corn, millet, sorghum, wheat, spelt and others, are staple foods for human and animal consumption. Each year, large quantities of stalks are left in the fields after harvesting, and after drying in the sun is mostly treated as waste. Given the high availability of cereals worldwide, cereal straw could be more usefully utilized as an alternative source of fiber for secondary packaging. Therefore, the printing paper substrates were formed from the straw pulp of three different cereal species (wheat, barley and triticale) and mixed with recycled wood pulp in a 3:7 ratio. Since offset and gravure printing are used globally to print absorbent packaging, in this study we analyzed the black prints made by these two printing techniques. The usability of the printed papers with straw pulp for secondary packaging was observed based on the penetration of the ink into the printing substrate. It was found that the composition of the paper substrate has no effect on the depth of ink penetration into the printing substrate, so that cereal straw can be used as waste material for the production of secondary packaging. In general, prints with gravure inks have lower ink penetration compared to offset inks.

Keywords:
gravure printing,
offset printing,
packaging,
ink penetration,
straw pulps

EXPERIMENTAL PART

The experimental part of this study was performed in several steps:
1) production of laboratory paper substrates with straw pulp; 2) printing of laboratory-produced papers; 3) print quality assessment: 3a) ink penetration depth analysis; 3b) analysis of integral optical ink density; 3c) analysis of spectrophotometric values and optical spectrum.

1) Straw of wheat (Triticum spp.), barley (Hordeum vulgare L.), and triticale (Triticale sp.), the most abundant crops in Croatia, was collected after harvest and manually cut into 3 cm long pieces . The cleaned straw was processed into semi-chemical pulp using the soda-pulp method. Laboratory-produced papers with a weight of about 42.5 g/m^2 consisted entirely of recycled wood pulp (marked as N) or a mixture of 70% recycled wood pulp and 30% unbleached wheat (marked as 3NW), barley (marked as 3NB) or triticale pulp (marked as 3NTR) were formed using a Rapid-Köthen sheet former (FRANK-PTI) according to the standard EN ISO 5269-2:2004. According to composition, three different laboratory-produced papers with straw pulp were compared with laboratory-produced paper consisted only of recycled wood pulp (N).

2) In this research, the main techniques (offset and gravure) for printing secondary packaging on absorbent substrates were used. Offset printing was performed in full tone using conventional black ink Express (manufactured by Sun Chemicals) with 5% red fluorescent pigment (Radion, Radglo PS-15) using a Prüfbau multipurpose testing machine at a temperature of 23 °C and a relative humidity of 50%. All samples were printed at a speed of 0.5 m/s and a pressure of 600 N. Gravure printing was performed with a laboratory KPP Gravure System using a printing cylinder with a mechanical hardness (HS) of 65 Shore and an engraved printing plate at an angle of 37° with a diamond needle at an angle of 130° with a screen of 100 lines/inch, or 40 lines/cm. Prints were made in full tone using Sunprop black ink (manufactured by Sun Chemicals) containing a 5% red fluorescent pigment (Radion, Radglo PS-15) at a speed of 20 m/min at a temperature of 23 °C and a relative humidity of 52 %.

3a) Ink penetration depth of black ink into the laboratory-produced papers was determined by mixing a red fluorescent pigment into a conventional black ink with which prints were then made. Samples measuring 10 mm x 30 mm were cut on a Microtom machine and then filled with EpoFik Kit epoxy compound (manufactured by Struers). A cross-section of the samples was taken using a Leica TCS SP8 X confocal laser scanning microscope with a fluorescence excitation channel of 560 nm (reflection) and processed with the Leica Microsystem program at a magnification of 63x, numerical aperture of 1.4 (immersion objective: HC PL APO CS2 63×/1.40) and additionally analyzed with the ImageJ program. The mean values and standard deviation of the ink penetration depth (Hp) were calculated from 50 sections obtained from the microscopic images using the Eq.1:

$$Hp = l / d \times 100 \qquad (1)$$

Where l is the maximum ink penetration value and d is the local thickness of the paper in the measured part.

3b) The optical ink density parameter was used to determine the thickness of the ink film (black ink with red fluorescent pigment) on laboratory-produced paper substrates. Optical ink density (Di) was measured on all prints using a Techkon SpectroDens densitometer (manufacturer Techkon GmbH) through a 3 mm aperture (measurement conditions status E, illumination D50, standard observer 2°, no polarizing filter, calibrated to paper samples). A higher value of the optical ink density means a larger ink layer or a higher ink concentration and a higher optical contrast compared to the substrate.

*3c) The tristimulus values are the colorimetric value L*a*b*, which completely unambiguously describes the color, whereby the colorimetric value L* describes the lightness, the colorimetric value a* coordinates the green/red color and the colorimetric value b* coordinates the blue/yellow color in the CIE L*a*b* color space. In the graphic industry, color reproduction is controlled by measuring spectrophotometric values L*a*b* and the optical spectrum of samples with spectrophotometers.*

RESULTS AND DISCUSSION

In order to compare the usability of printed paper with straw pulp for secondary packaging, first the penetration depth of the printing ink into the substrate was determined and then the quality of the print was observed using three qualitative parameters

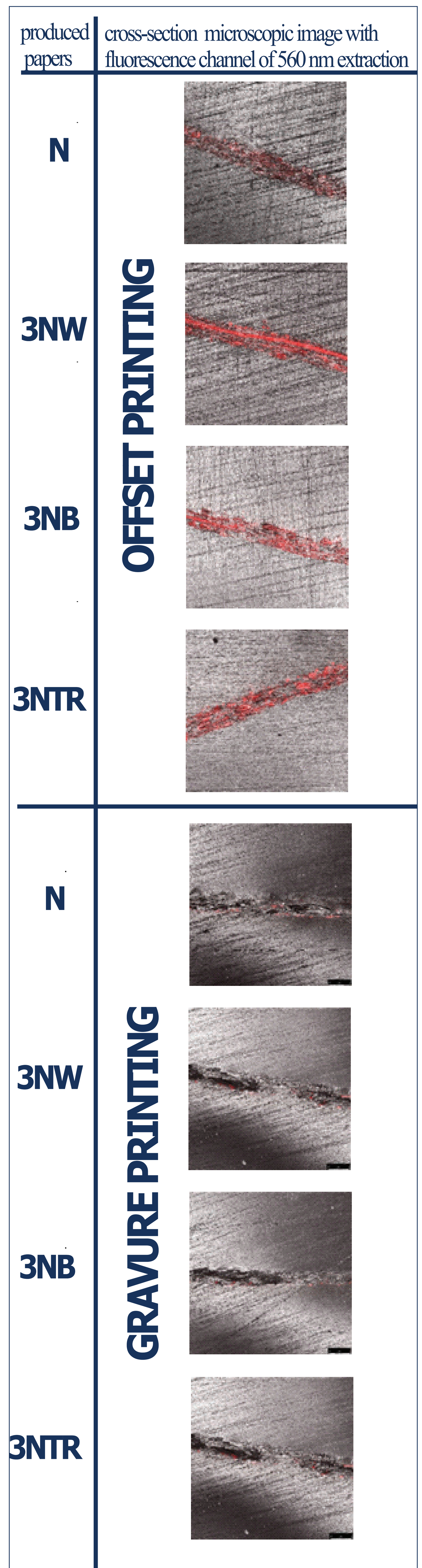

Fig. 4. Microscopic images of cross-section of printed laboratory-produced papers by offset and gravure technique

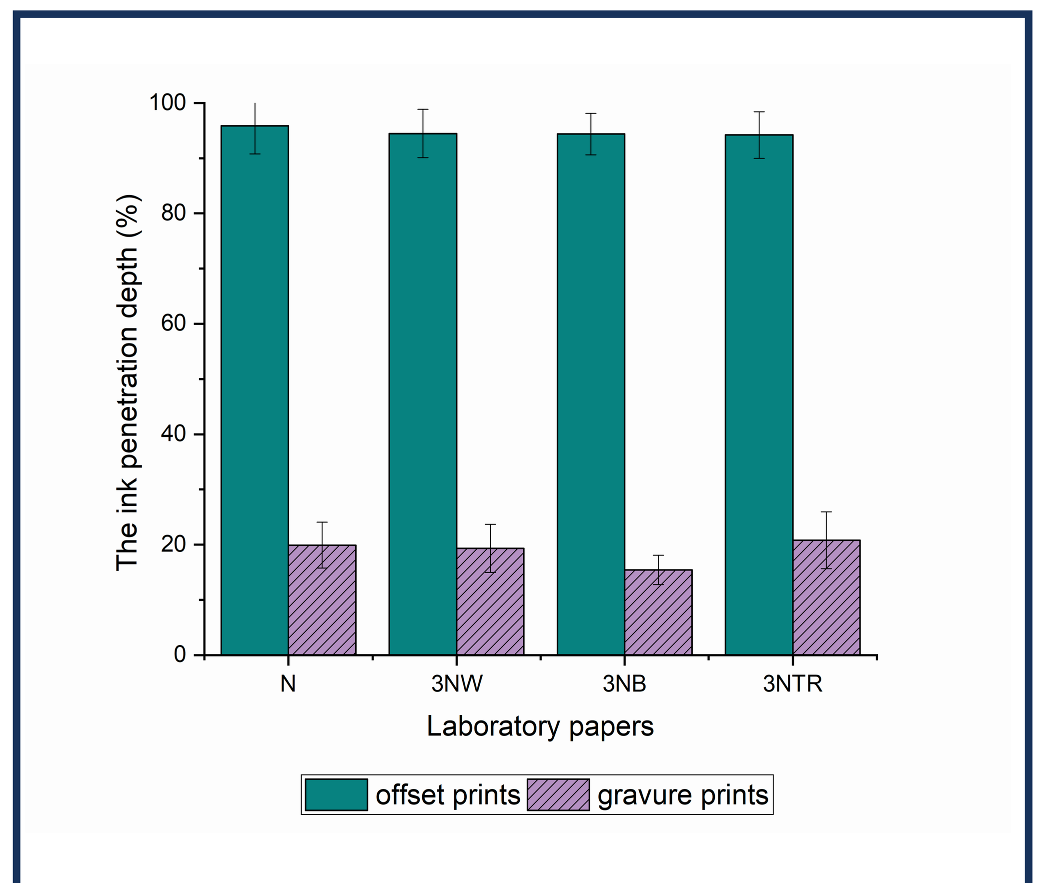

Fig. 1. The ink penetration depth of offset and gravure prints

Tab. 1 Optical ink density values on offset prints and gravure prints

	D_i	
	Offset prints	*Gravure prints*
N	1.22 ± 0.03	1.29 ± 0.01
3NW	1.27 ± 0.02	1.31 ± 0.41
3NB	1.26 ± 0.02	1.29 ± 0.28
3NTR	1.28 ± 0.40	1.30 ± 0.32

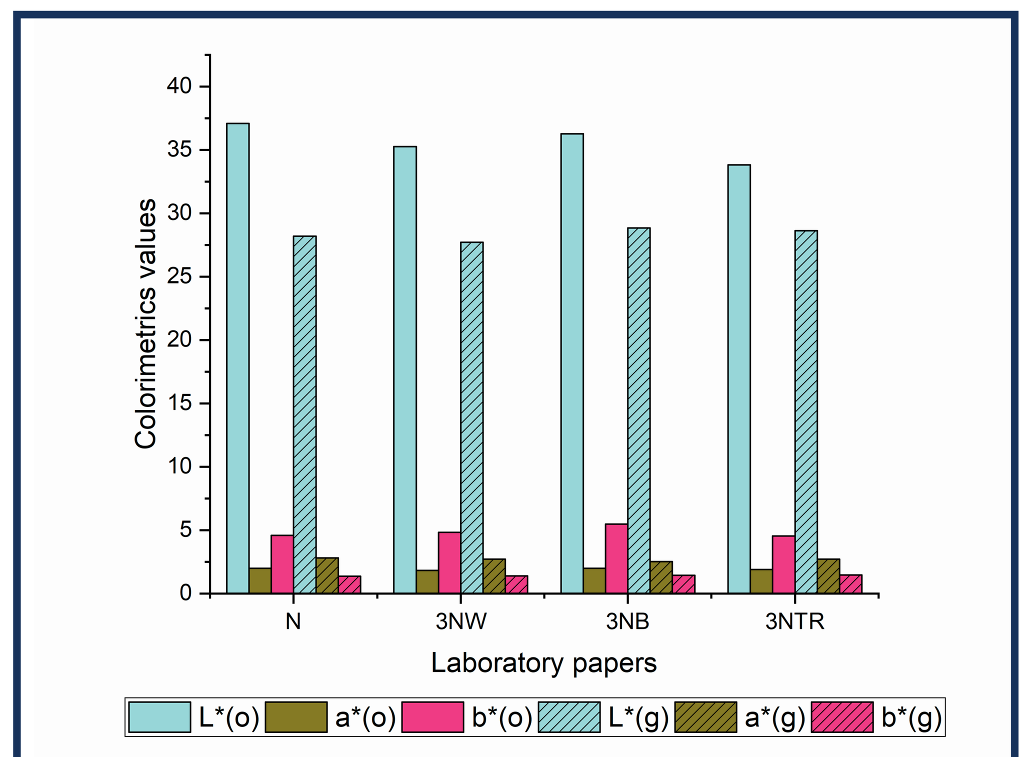

Fig. 2. Colorimetric values of offset prints (o) and gravure prints (g)

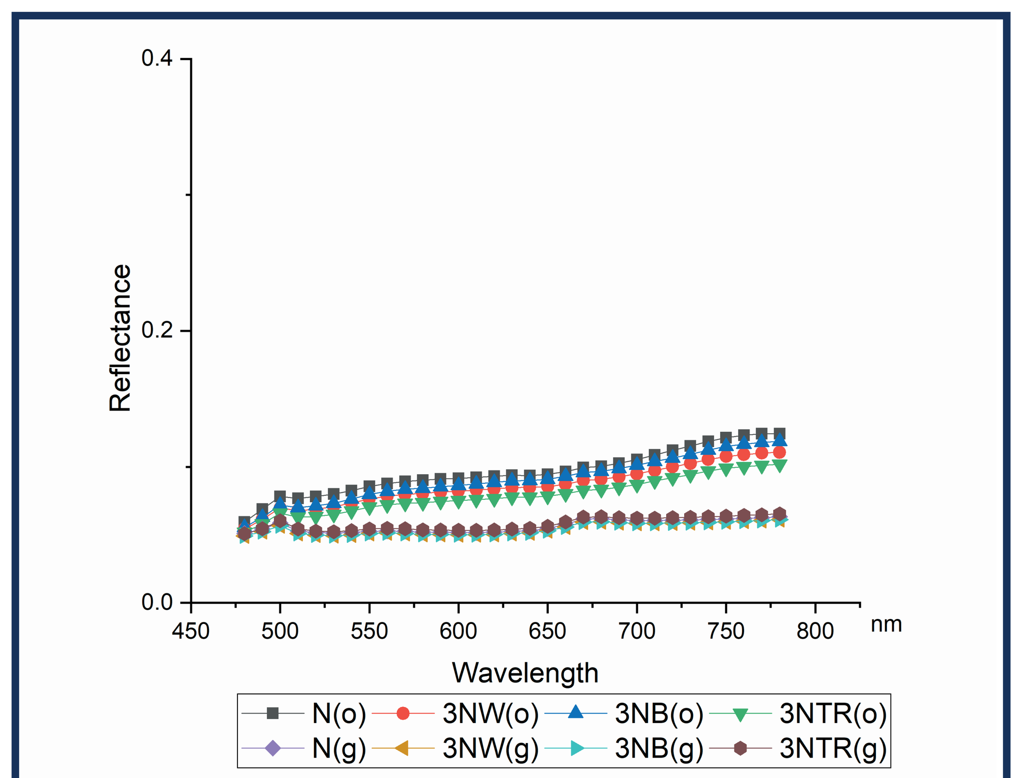

Fig. 3. Optical spectrum of black prints with fluorescent pigments obtained with offset printing (o) and gravure printing (g)

CONCLUSION

Based on the results of assessing the usability of wheat, barley and triticale straw for secondary packaging the following conclusions can be drawn:

- *Based on the value of integral optical density, spectrophotometric values and reflectance spectrum, it is not possible to determine the penetration depth of black ink into laboratory-produced papers.*
- *Substrates printed with gravure black ink have lower ink penetration compared to offset black ink, with lower reflectance values being achieved, which is characteristic of achromatic (black) color.*
- *The composition of the laboratory-produced paper substrate has no influence on the depth of ink penetration into the printing substrate, so cereal straw can be used as a waste material for the production of a substrate for printing secondary packaging.*

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This work has been supported in part by Croatian Science Foundation under the project "Printability, quality and utilization of substrates with non-wood fibers" (UIP-2017-05-2573).