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THE INFLUENCE OF SELF-ADHESIVE SUBSTRATES ON THE REALIZATION OF ACHROMATIC LABEL CREATED BY UV INKJET

UTJECAJ SAMOLJEPLJIVIH PODLOGA NA REALIZACIJU AKROMATSKE ETIKETE NASTALE UV INKJETOM

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Abstract

Compared with commercial printing products, current trends in label production are very optimistic. New self-adhesive materials (printing substrates) can be used in various industrial areas. When printing labels with UV Inkjet inks, they enable high-quality printing and are becoming a more and more common option. In this paper, the reproduction quality of achromatic tones for three characteristic self-adhesive products was examined (wine label, polypropylene label, and label with thermosensitive coating intended for additional printing in thermal printers). The high-performance UV Inkjet machine Durst Tau 330 RSC, which uses a special black-ink TAU RSC UV, was used for experimental printing. All obtained samples will be compared with reference values (FOGRA 39) where Fogra Media Wedge was measured. The measuring device used an x-rite Exact colorimeter which gave CIE LAB values were precisely determined and the colorimetric differences ΔE, ΔL, and ΔC were calculated. Additionally, image analysis was performed, as well as quality analysis of the printing system resolution (resolution profile size 8 x 5 mm). For this PIAS-II system will be used. Based on the obtained results, Polypropylene self-adhesive printing substrate proved to be the best and Avery the worst. The realized difference between Polypropylene and Avery was large ΔEPP-Avery = 4.62.

***Keywords**: label printing, UV Inkjet, CIE LAB DE, resolution profile, micro text readability.*

Sažetak

U odnosu na komercijalni tisak, trenutni trendovi u proizvodnji etiketa su vrlo optimistični. Tome pridonose novi samoljepljivi materijali (tiskovne podloge) čija je primjena moguća u raznim industrijskim područjima. Pri njihovom otiskivanju sve češće su UV Inkjet boje koja omogućavaju visokokvalitetni tisak. U ovom radu ispitana je kvaliteta reprodukcije akromatskih tonova za tri karakteristična samoljepljiva proizvoda: vinska etiketa, polipropilenska etiketa i etiketa sa sadržajem termoosjetljivog premaza namjenjenog za dodatno otiskivanje u termalnim pisačima. Za eksperimentalno otiskivanje primjenjen je visokoproduktivan UV Inkjet stroj Durst Tau 330 RSC koji koristi specijalnu crnu boju TAU RSC UV. Svi dobiveni uzorci bit će uspoređeni s referentnim vrijednostima (FOGRA 39) pri čemu je mjeren Fogra Media Wedge strip. Korišteni mjerni uređaj bio je kolorimetar x-rite Exact s kojim su precizno određene CIE LAB vrijednosti te izračunate kolorimetrijske razlike ΔE, ΔL i ΔC. Dodatno je izvršena slikovna kvalitete rezolucije tiskarskog sustava (rezolucijski profil veličine 8 x 5 mm). Pritom će se koristiti sistem PIAS-II. Na osnovi dobivenih rezultata Polipropilenska samoljepljiva tiskovna podloga se pokazala najbolja a Avery najlošija. Ostvarena razlika između Polipropilena i Averya iznosila je velikih ΔEPP-Avery = 4,62.

***Ključne riječi:** tisak etiketa, UV Inkjet, CIE LAB DE, rezolucijski profil, čitljivost mikro teksta*

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1. Introduction

Labels are a piece of paper, polymer film, metal, or fabric that is attached to a product. [1] The label thus contains information about that product such as price, quantity, origin, type, content, destination, etc. The main purpose of the label may be different, so it can contain a warning but also an additional source of information. However, the purpose of today's labels is becoming more and more decorative, having to attract attention within a multitude of similar products. An exact selection of materials is made depending on the type of product to which the labels are applied. The materials used can be cardboard, various laminates, metal foils, papers, textiles, polymers, and other synthetic substrates.

Labels can be divided into adhesive and non-adhesive. In addition to this main classification, there is a whole range of subcategories of labels. Thus, we can further distinguish: coated, uncoated, pressure-sensitive, and heat-sensitive, with conventional glue and with glue containing particles for easier manipulation. Of all types of labels, the world market is dominated by non-adhesive paper labels that are applied with liquid glue immediately before packaging.

In recent years, the market has increasingly shifted towards self-adhesive pressure-sensitive labels. Newer methods of labeling such as shrink sleeves, in-mold, and heat mapping have already been accepted in the market. The entire U.S. market for self-adhesive pressure-sensitive labels from webs is growing by 10-15% per year, with some printing companies and market sectors growing by 20% or more. The two main markets showing above-average growth are EDP (Electronic Data Processing) labels made with small handheld devices, and labels that feature the entire product design. [2]

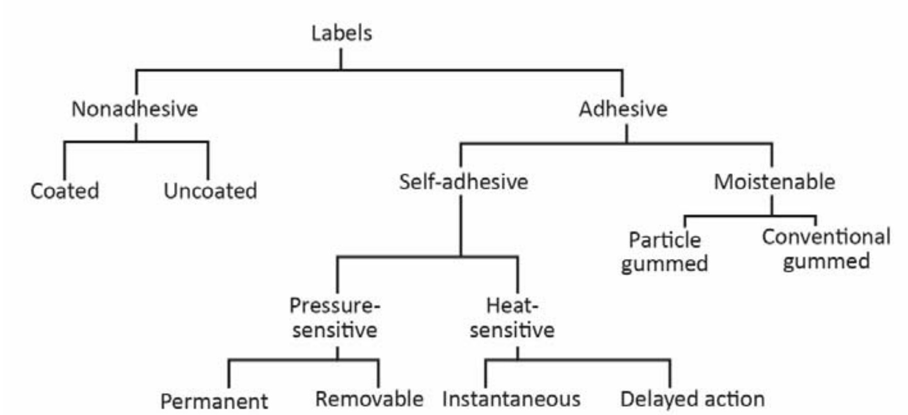


Fig. 1. The main division of labels depends on the materials from which they are derived [Kit L. Yam, The Wiley Encyclopedia of Packaging Technology, 2009]

2. Theoretical part

In addition to choosing the correct material for the functionality of the label, its application process is important as well. Therefore, we distinguish between the 6 main types of labels, which are: regular paper labels, moisture-activated labels, self-adhesive labels, heat-sensitive labels, in-mold labels, and shrink sleeve labels. Another important parameter in label selection is their composition, and the method used to print on them. In printing labels, the most commonly used methods are flexo press, letterpress, gravure printing, offset printing, screen printing, and foil printing. [3] However, digital printing techniques such as Inkjet and electrophotographic printing techniques have also been used recently, especially for small-series printing. It is these printing techniques that are achieving rapid growth in the production of modern labels. [4]

1.1. Self-adhesive labels

Self-adhesive labels are used due to their ability to be easily and quickly applied to various substrates. Structurally these are very complex materials that have 3 layers in their simplest form. For more complex labels, the number of layers can grow up to 5, enabling protection and safe use. In other words, each self-adhesive label (Figure 2) must contain a liner, functional adhesive, and a cover layer (printable top layer).

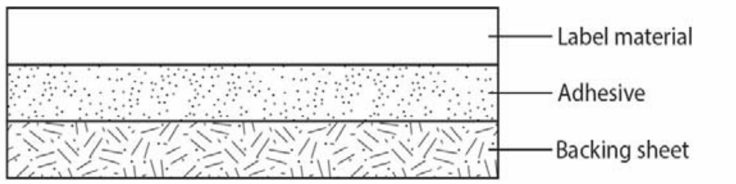


Fig. 2. Basic layers of self-adhesive label
[Kit L. Yam, The Wiley Encyclopedia of Packaging Technology, 2009.]

The liner is a thin lower layer on a self-adhesive label material that prevents uncontrolled adhesion of the functional part of the label. The liner also prevents premature peeling of the label, protects the adhesive from dust or some other damage, and slows down decay due to atmospheric conditions. It also serves to support the cover top layer in printing and allows cutting or other converting. Liners can be made of paper or polymer, with the paper ones coated with a layer of silicone facilitating the separation of the adhesive layer from the liner, while polymer liners are used in transparent labels. The most important characteristics of frequently used liners along with ratings are presented in Table 1 [5]

Tab. 1: Tab. 1: Comparison of frequently used liners
https://barcode-labels.com/getting-started/labels/liners

	Roll kraft paper form	Glassine paper	Poly coated kraft paper	Sheet form kraft paper	PET
Thickness (Avg.)	63.5-116. µm	55.9-78.7 µm	76.2-203.2 µm	116.8-304.8 µm	25.4-101.6 µm
Smoothness	Good	Very good	Very good	Very good	Superior
Strengt	Good	Very good	Very good	Very good	Superior
Die cutting	Good	Very good	Very good	Good	Superior
Dispersing	Good	Very good	Very good	N/A	Superior
Layflat	Fair	Fair	Good	Very good	Ecellent
Sheeting	N/A	Poor	Good	Very good	Ecellent
Backprinting	Very good	Varies	Varies	Varies	Fair
Cost	Low	Low	Medium	Medium	High

The choice of the adhesive type directly affects properties such as the initial tack, final adhesion strength, and shear resistance. Initial tack describes the strength of the adhesion between the label and the base immediately after contact has been made. Final adhesion strength defines the maximum adhesion that the label achieves in contact with the surface to which it is applied.

The time needed for a label to reach its final adhesion strength depends on the rigidity of the glue, the roughness of the surface, and the ambient temperature, while shear resistance is a measure of the internal strength of cohesion forces in glue. [6] By their chemical composition, the adhesives used in self-adhesive labels are generally divided into acrylic and rubber-based adhesives. However, there are also subgroups such as modified acrylic adhesives, silicone adhesives, emulsion adhesives, solvent-based adhesives, and hot-melt glues. Table 2 presents the comparison of the most commonly used label adhesives. [7]

Tab. 2: Comparison of common adhesives types used for label manufacturing [https://www.mddionline.com/news/fundamentals-selecting-pressure-sensitive-adhesives]

Characteristic	Rubber-based	Acrylic	Modifield Acrylic	Silicone
Cost	Lowest	Medium/high	Medium/high	Very high
Tack	Medium/high	Medium/low	High	Low
Temperature resistance	Low	High	Low/moderate	Very high
Adhesion	Medium/high	Moderate/high	High	Medium/low
Shear	Medium/high	Moderate/high	Low	moderate
Solvent resistance	Poor	Good	Low/moderate	Excellent
Ultraviolet resistance	Poor	Ecellent	Poor	Excellent
Plasticizer resistance	Poor	Moderate/good	Poor/moderate	Excellent
Low-surface-enegy materials	Excellent	Poor/moderte	Excellent	Poor
High-surface-energy materials	Excellent	Excellent	Excellent	moderate

3. Experimental part

In this paper, three types of label substrates printed on a calibrated Durst Tau 330 RSC UV Inkjet machine are compared. The Inkjet machine used applied CMYK Fuji Samba inkjet modular heads (distribution 8 x 4) with a maximum print resolution of 1200 x 1200 dpi (2 pl drop) with a print speed of 52 m/min. Place of printing was demo center Durst (Brigstenen, Italy) with controlled working conditions (black Inkjet UV ink 28° C). Data corresponding to the Fogra 39 standard was taken as reference values for the prints. Experimental prints were also made with FUJI Samba Inkjet head varying three self-adhesive materials: OPP TC white gloss 60 (polypropylene material), ScandTherm TSC (thermosensitive material), and Verge Creme FSC (wine label). For visual evaluation of black prints, Fogra 39 achromatic tones were also printed on EFI offset proof paper 9200 Semimatt (200 g/m2) using an Epson SC-P5000 Inkjet proof printer. The same pattern (Ugra/Fogra Media Wedge CMYK 3.0 printing form) containing a standard color bar for measuring prints on digital machines is printed on all substrates. The color bar consists of 72 fields arranged in 3 rows. [12]

The first row contains the most important primary fields in which black coverage is controlled in the range of 10%, 20%, 40%, 60%, 80%, and 100% TV. Using the Xrite eXact premium spectrophotometer/colorimeter, the CIE L* a* b* values of each field were measured, analyzing only the achromatic part. [13] To determine which self-adhesive substrate is the most similar to the Fogra 39 standard, CIE LAB DE2000 color changes have been calculated. For image analysis and visual comparison of the resolution profile, the PIAS-II digital microscope with an integrated Image Analysis program was used. Each printed image is compared with the reference PDF [14]. A schematic representation of the experiment is shown in Figure 3.

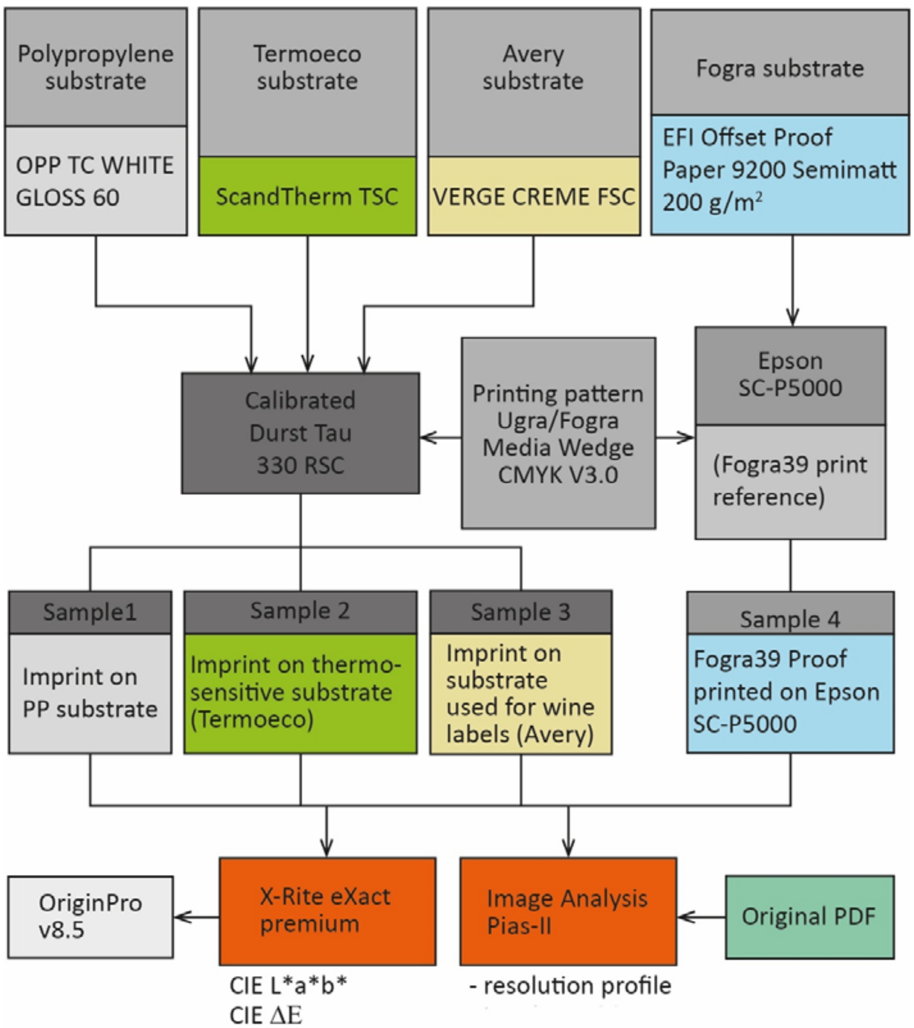


Fig. 3. Schematic representation of the experiment.

4. Results and discussion

For the purposes of standardization, it is necessary to use precisely defined printing substrates. The exact tolerance of printing substrates which can be considered as standard is defined by the ISO 12647 standard. This value shall not exceed the colorimetric difference of CIE LAB ΔE2000 = 3.0. Figure 4. shows a chart of the total colorimetric difference (ΔE2000) of the tested print substrates compared to Fogra 39.

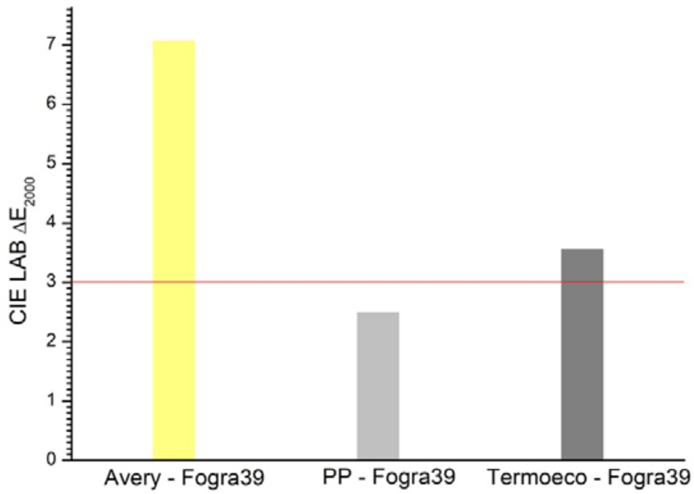


Fig. 4. The color difference of self-adhesive substrates Avery Verge vreme FSC, OPP TC White Gloss 60 and ScandStick ScandTherm TCS.

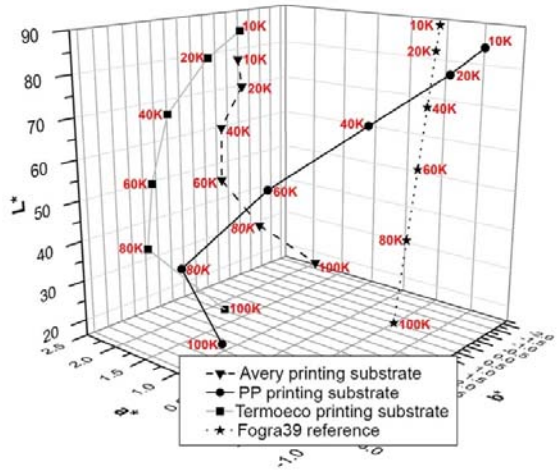
Figure 4 shows that the Avery Fasson Verge crème FSC printing substrate, which is intended for printing wine labels, has the greatest deviation from the standard Fogra39 substrate. The total colorimetric difference is very large, amounting to ΔEAvery-Fogra=7.06. This means that it exceeds Fogra's tolerance limit by ΔE =4.06. Such a substrate cannot be a standard printing substrate and not all tones defined by Fogra 39 can be achieved on it.

Polypropylene printing substrate Arconvert OPP OPP TC White Gloss 60 is the only substrate that can be classified as standard. Its colorimetric difference is ΔEPP-Fogra=2.49 and is below Fogra's limit of ΔE=3.0. Such a substrate is high-quality and can be recommended for printing labels according to the Fogra 39 standard for its printing characteristics.

The ScandStick ScandTherm TCS base, which is intended for additional printing in thermal printers and can be classified as a marginal substrate because it has a colorimetric difference of ΔETermoeco-Fogra=3.55. Therefore, it surpasses it by ΔE=0.55 which, unlike Avery, is very close to Fogra's limit of ΔE=3.0. The prints on this substrate are likely to be satisfactory and most tones will be reproduced with minimal deviation within the printing system (coloring unit).

In addition to the print substrate, the black UV Inkjet ink used plays an important role. The most demanding black and white labels are thus printed multitone, with highly pigmented ink used to meet food and pharmaceutical industry standards. Colorimetric differences of black colour separation printed on the Avery Verge FSC, OPP TC White Gloss 60, and ScandStick ScandTherm TCS substrates are shown in Figure 5.

With standard achromatic black we have a linear curve. The Avery, Polypropylene, and Termoeco substrates do not follow this ideal curve and it has a shift that is more pronounced in chromaticity. In medium tones, Termoeco and Avery have a slight deviation in the yellow direction, returning towards reference values in the higher tones. Polypropylene increases linearly towards yellowish tones with increased surface coverage. However, at the full tone, it decreases sharply.



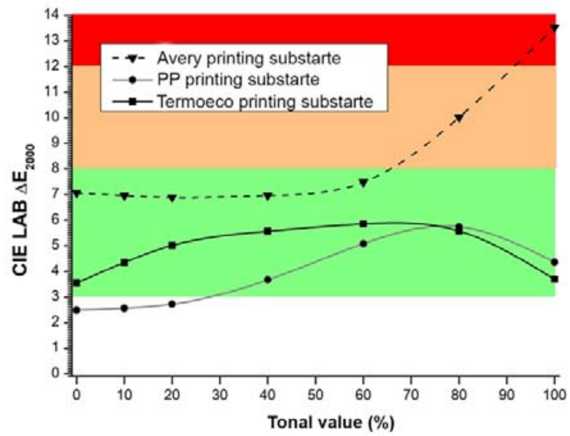


Fig. 5. Deviation of black prints on self-adhesive materials Avery, Polypropylene and Termoeco created on the Durst Tau 330 RSC printing machine: a) 3D playback curve, b) CIE LAB ΔE

Looking at the total black colour difference in Figure 5b, we note that no substrate is within the permissible deviation. The exception is Polypropylene, in which only lighter tones (10%, 20% TV) are within the limit of permissible deviation. The black colour difference of Polypropylene increases at higher tones, with the maximum occurring at 80% of the tonal value ($\Delta E_{PP\text{-}Fogra(80\%TV)}$=5.74). At the solid tone, it decreases to $\Delta E_{PP\text{-}Fogra(100\%TV)}$=4.36. Thermoco stays within the limits of medium deviation at all black tone values. The deviation is nearly constant, equaling ΔE=5.74 on average. At full tone, the color difference of the thermoeco label decreases to $\Delta E_{Termoeco\text{-}Fogra(100\%RTV)}$=3.7, which is the best reproduction of the full black tone. At lower to medium black tones, the Avery label is constant and follows the upper limit of the medium deviation (mean $\Delta E_{Avery\text{-}Fogra(10\%\text{-}60\%TV)}$=7.08). In higher black tones (over 60% of the tonal value) it grows to $\Delta E_{Avery\text{-}Fogra(80\%TV)}$=10.01 (area of greater deviation), after which the trend of deviation growth continues in full tone and reaches the value of $\Delta E_{Avery\text{-}Fogra(100\%TV)}$=13.53, falling within the area of unacceptable colour deviation.

For the resolution test, a wedge which is a segment of Fogra's PDF that serves to analyze test prints and test the condition of digital printing machines was analyzed. The resolution test is performed by reproducing an 8x5 mm BW wedge. The wedge is then photographed with a digital microscope with 2.5 μm corresponding to 1 pixel in the photograph. The wedge contains 4 square-shaped fields with elements sized 1x1, 2x2, 3x3, and 4x4 pixels. At the top of the wedge, there is a control surface, a square grid with 50% TV. Figure 6 shows reflectance curves and a photo of the reproduced wedge for the tested substrates. Visual analysis of the black photograph of the wedge on the Avery substrate printed with the Durst Tau 330 RSC UV Inkjet machine shows the two lowest-sized fields (1x1 px and 2x2 px) cannot be achieved. The first field in which clearer square shapes appear is the third field that is defined by elements of 3x3 px in size. In the last field, in which the elements are 4x4 px in size, it is seen that the square elements are clearer and white fields are increasingly noticeable. Therefore, this segment has a more pronounced noise. The greater the noise means the greater the precision of the printing system.

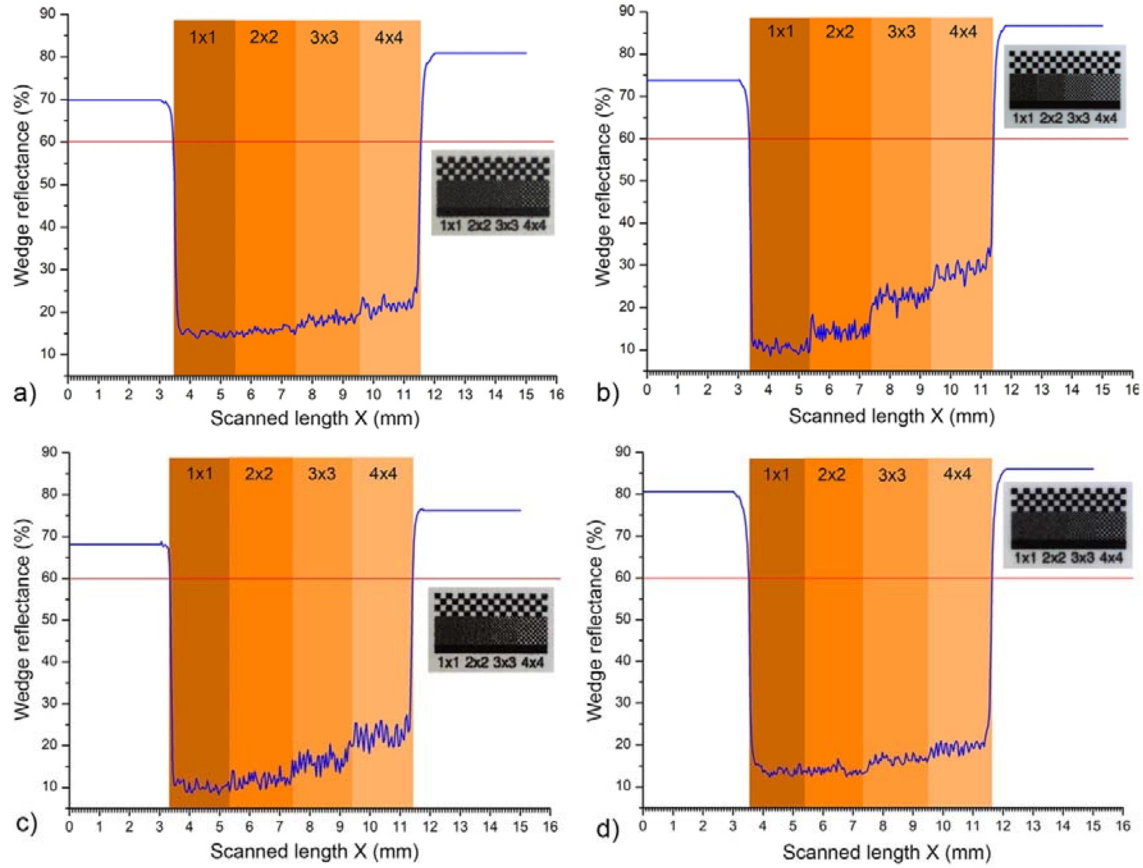


Fig. 6. Reflective curves and wedge photographs in the resolution test on the press background: a) Avery; Polypropylene; c) Termoeco; d) EFI Offset Proof paper 9200 semimatt.

In addition to visual analysis, the wedge can be analyzed using the reflectance curves obtained by image analysis. Thus, it is seen that the first field (1x1 px) located at a length of ≈ 3.5 mm to ≈ 5.5 mm does not contain clear peaks that correspond to the white and black square elements. All values range between $R_{Avery(1x1)\_min}$=13.94% and $R_{Avery(1x1)\_max.}$ =16.37%, with the mean of the curve equalling $R_{Avery(1x1)\_mean.}$=15.02%.

The second field with dimensions of 2x2 px (an area from ≈ 5.5 mm to 7.5 mm,) also has no pronounced peaks and retains values almost identical to the first field. The mean of the curve is $R_{Avery(2x2)\_mean.}$ =15.64% with peak values between $R_{Avery(2x2)\_min.}$=14.15% and $R_{Avery(2x2)\_max}$.=17.11%.

In the third field (an area of ≈ 7.5 mm to 9.5 mm), the first differences between black and white fields are visible and the peaks of the reflectance curve are clearer. The mean of the curve is $R_{Avery(3x3)\_mean}$.=18.17%. The minimum value is $R_{Avery(3x3)\_min.}$=16.5% while the maximum is $R_{Avery(3x3)\_max.}$=20.64%.

The fourth field (4x4 px), in which the dimensions of the elements are largest, is located in the area of ≈ 9.5 mm to 10.5 mm. It is also the best reproduced and has satisfactory noise. The peaks of the curve are noticeable and the difference between the black and white elements is more visible. The mean of the reflectance value is $R_{Avery(4x4)\_mean.}$ =21.65%, while the highest reflectance in this area is $R_{Avery(4x4)\_max.}$ =25.8% and the lowest $R_{Avery(4x4)\_min.}$ =18.28%.

The polypropylene substrate also proved to be an ideal substrate for the resolution test, being able to reproduce the smallest graphical elements. From visual analysis, it is seen that the first field (1x1 px) has a poorer reproduction of the elements, (white square elements are hardly visible and little noise occurs). The second field (2x2 px) has visible black and white elements. The third (3x3 px) and fourth fields (4x4 px) have almost ideally printed elements and white fields can be counted with the naked eye.

The results from the visual assessment can be quantified by image analysis. Thus, in the first field of 1x1 px (an area from ≈ 3.5 mm to 5.5 mm), the reflective curve contains small peaks, which means that the printing elements are not reproduced well and could not be accurately detected. The mean of the curve is thus $R_{PP(1x1)\_mean.}$=10.61%, with a minimum value of $R_{PP(1x1)\_min.}$=8.51% and a maximum value of $R_{PP(1x1)\_max.}$=12.9%.

The second 2x2 px field in the area from ≈ 5.5 mm to 7.5 mm has clear reflectance peaks representing white and black square elements. The minimum value of the curve is $R_{PP(2x2)\_min.}$=11.87% while the maximum is $R_{PP(2x2)\_max.}$=19.12%. The mean is $R_{PP(2x2)\_mean.}$ =14.5%.

The third field of 3x3 px ranging from ≈ 7.5 mm to 9.5 mm is the first field for which the resolution test can be said to be ideal. It has the biggest difference so far between black and white square elements. The peaks are clear with a maximum reflectance peak of $R_{PP(3x3)\_max.}$ =25.73% and minimum $R_{PP(3x3)\_min}$. =17.5%.

The fourth field of 4x4 px in the area from ≈ 9.5 mm to 11.5 mm is the first field on this base where the reflectance curve can be compared with the PDF. Therefore, the curve contains six visible peaks corresponding to the realistic image of the wedge, which contains 6 white square elements in each row. The highest reflectance is $R_{PP(4x4)\_max.}$=34.21% and the lowest $R_{PP(4x4)\_min.}$=24.2%, the mean of the curve is $R_{PP(4x4)\_mean.}$=28.9%.

Thermal label Termoeco, like Polypropylene, is also suitable for the reproduction of smaller graphical elements. However, the smallest elements (1x1 px and 2x2 px) cannot be reproduced sharply. Thus, the first field (1x1 px) is not well-realized, and the print is similar to that on Polypropylene. In the second field (2x2 px) some white elements begin to appear but visually it is not at the level of Polypropylene. The third field (3x3 px) has visible elements that are not yet completely clear, in contrast to Polypropylene. The fourth field (4x4 px) is good and has clear elements that can also be counted with the naked eye. It is, however, still not visually at the same level as polypropylene.

Termoeco's reflectance curve looks good. The first field 1x1 px (≈ 3.5 mm – 5.5 mm) is very similar to Polypropylene with small amounts of noticeable noise. Tiny peaks are visible, but visually there is still not much difference between the black and white elements. The highest reflectance is $R_{Term.(1x1)\_max.}$=12.21% while the lowest is $R_{Term.(1x1)\_min.}$=8.3%. The mean is $R_{Term.(1x1)\_mean}$.=10.14%.

The second field of 2x2 px elements (≈ 5.5 mm – 7.5 mm) has more noticeable tips but does not have a uniform repetition frequency like polypropylene. Therefore, its noise and curve values are somewhat worse than that of Polypropylene. The achieved mean reflectance is $R_{Term.(2x2)\_mean.}$=11.73%. The maximum reflectance achieved in this part of the wedge is $R_{Term.(2x2)\_max.}$=15.2% while the lowest is $R_{Term.(2x2)\_min.}$=9.42%.

In the third field (3x3 px) in the range of ≈ 7.5 mm to 9.5 mm, the first major differences in reflectance between black and white fields are noticeable. The peaks are clear and the noise is more intense. The differences between black and white elements are almost the same as polypropylene. However, the edges of the elements themselves are not sharp and serration or disturbances in the noise occur. The maximum measured reflectance is $R_{Term.(3x3)\_max.}$=21.17%, the minimum is $R_{Term.(3x3)\_min.}$=12.54% and the mean is $R_{Term.(3x3)\_mean.}$ =16.36%.

The fourth field with 4x4 px elements (≈ 9.5 mm – 11.5 mm) has clearly expressed reflectance peaks. However, due to the worse sharpness of the edges of the elements, minor errors occur in the reflectance curve. The mean reflectance is $R_{Term.(\ 4x4)\_mean.}$ =22.5%, the minimum reflectance is $R_{Term.(4x4)\_min.}$=18.2% and the maximum reflectance achieved is $R_{Term.(\ 4x4)_max.=}$27.35%.

The test printing papers for Inkjet printing are fully adapted for Inkjet ink. Therefore, they are expected to produce the best results. However, water-based ink will perform worse than UV-drying ink. Due to the ink used, the first two fields (1x1 px and 2x2 px) of the wedge are not reproduced successfully. In the first field, there is no realization of white square elements, while the differences in the second field are barely visible. The third field (3x3 px) is the first field with small indications of visible reproduction of that part of the wedge. The fourth field (4x4 px) has clear square elements in the field. This is due to micro-spillages of water-based dyes that failed to dry quickly enough.

The reflectance curve fully corresponds to the visual assessment. Thus, the first field with the smallest elements of 1x1 px size (≈ 3.5 mm – 5.5 mm) does not have the expected curve and does not have clear noise. The mean is $R_{EFI(1x1)\_mean}$.=13.81%. The maximum value of the curve is $R_{EFI(1x1)_max.=}$15.63% while the minimum is $R_{EFI(1x1)_min.=}$12.37%.

The second field (2x2 px in an area of ≈ 5.5 mm to 7.5 mm) has the same curve as the first field. Therefore, its values are similar. Thus, the minimum $R_{EFI(2x2)min.=}$12.54%, maximum $R_{EFI(2x2)max.}$=16.68% and the mean is $R_{EFI(2x2)\_mean.}$=13.94%.

The third field (the area from ≈ 7.5 mm to 9.5 mm) of 3x3 px size has the worst reflective curve when compared to the other tested printing surfaces. Such a curve contains visible peaks but the curve itself is full of errors and the noise is poorly visible. Curve values are marginally better than the first and second fields. The maximum reflectance achieved is $R_{EFI(3x3)max.}$=19.39%, the minimum reflectance is $R_{EFI(3x3)min.}$=15.09 % and the mean curve value is $R_{EFI(3x3)mean.}$=16.56%.

The fourth field, which is the field with the largest elements of 4x4 pixels (≈ 9.5 mm – 11.5 mm) has more pronounced peaks and more noise in the curve. The curve itself doesn't look bad but the difference between high and low reflectance values is not large. The maximum reflectance is a low $R_{EFI(4x4)max.}$=21%, the minimum is $R_{EFI(4x4)\_min.}$=16.9% and the mean is $R_{EFI(4x4)mean.}$=19.36%.

5. Conclusion

Based on colorimetric measurements of black ink, it is noticeable that the label material OPP TC White Gloss 60 (polypropylene) has similar values to the Fogra 39 standard. Therefore, this makes it the best label material for the realization of achromatic prints. The difference between Polypropylene and Avery is large and equal $\Delta E_{PP\text{-}Avery}$ = 4.62.

The label material of Avery Verge crème FSC (wine label) achieves a large colorimetric difference in black separation, which is high compared to the Fogra39. The image analysis shows that the polypropylene print substrate also has the best ability to print high resolutions and reproduce demanding illustrations. Polypropylene label material has the highest whiteness (the highest spectral reflectance) and the lowest ink absorption, therefore the black elements stand out more and there is no dye spillage on the printed surface. Therefore, it achieves the greatest difference between minimal and maximum reflectivity, and the noise was not created. The values are: $\Delta R_{PP(1x1)}$=4.4%, $\Delta R_{PP(2x2)}$=7.33%, $\Delta R_{PP(3x3)}$=8.23% and $\Delta R_{PP(4x4)}$=10.01% .

The Avery wine label is the worst performer in high-resolution printing. This is due to the excessive absorbance of the label material in addition to the low viscosity of black UV inkjet ink. The wine label is not a good choice for printing small details and extremely small fonts. The difference between maximum and minimum reflectance is small and amounts to $\Delta R_{Avery(1x1)}$=2.43%, $\Delta R_{Avery(2x2)}$=2.96%, $\Delta R_{Avery(3x3)}$=4.14%, and $\Delta R_{Avery(4x4)}$=7.32%. The last readable font size is 3 pt in positive (although much worse than ones on polypropylene) and 4 pt in negative.

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