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The Influence of Anilox Roller Lines on the Ink Impression on Different Polymer Substrates in Flexo Printing

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Abstract: Flexo printing or flexography is the most common letterpress printing technique today. Compared to other printing techniques, the advantages of flexographic printing are higher printing speed, low material losses, the possibility of using water-based colors, high color consistency on the print itself. The appearance of the final product largely depends on the selection of the anilox roller, i.e. its line and volume, and on the substrate. The research carried out in this paper determined the influence of the anilox roller when printing on different polymer substrates, and colorimetric differences in color deviation were determined in prints that included four different manufacturers of solvent-based paints on five different polymer substrates (transparent BOPP, white LDPE, black and white recycled LDPE, blue LDPE and green LDPE) with anilox rollers of different lines (lpi) and volume (BCM). In the paper there were used three different anilox rollers with 100 lpi, 165 lpi and 220 lpi.

Keywords: color; flexo printing; line art; polymer substrates

1 INTRODUCTION

Flexographic printing or flexography is a fast-growing technique of direct relief printing. It enables printing in high speed using the roller-based principle. The printing forms in flexo printing are pliable so that they can be placed onto the rollers before the printing process; natural or synthetic rubber used to be the materials used in manufacturing, but today they are most often made of photopolymer.

In the printing process, the ink is applied to elevated (printing) elements and transferred onto the plate of the desired material. In flexo printing, rare low viscosity inks are used. In practice, three types of ink are used for the production of packaging: organic solvent based, water-based, and UV inks. Depending on the choice of the material (substrate) we want to print on, the printing ink can be chosen.

Printing can be done on various absorbent and non-absorbent materials that can be rugged, smooth, soft and hard. The most often used materials are foils, films, paper, and cardboard [1-5]. The flexography substrates are different, depending on the final purpose of the material. There is almost no material that couldn't be printed on using flexo printing process - from paper, through various plastics, to metal foils. Consequently, their surface characteristics are different and greatly affect the quality of the print itself. They can be absorbent and non-absorbent. The choice of substrate directly influences the choice of ink and its composition. A great challenge in the flexoprinting process is being familiar with the substrate material that is being printed, since each one has its own special requirements.

The following are most often used in the production of substrates for printing purposes: polyethylene (PE, LDPE, HDPE, MDPE), polypropylene (CPP, OPP, MOPP, BOPP, metallized films), polyamide (PA), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), and polyethylene terephthalate (PET) [6-10]. Nowadays, in order to protect the environment, efforts are being made to reduce packaging waste by replacing plastic films with biodegradable polymer-based films. The most important biodegradable polymers are: polylactide (PLA), cellulose, and starch-based products. Their physical, physicochemical, chemical, and mechanical properties can be compared with conventional plastics [11].

The packaging industry uses ecologically acceptable printing substrates such as recycled (and uncoated) paper, cellophane, PLA, PCL and other polymer materials [12-17]. The reason for using those materials are good properties such as low cost, light weight, content tolerance (especially food), adequate barrier, mechanical and optical properties, as well as suitability for processing using printing and packaging machines [18].

This technique has an advantage because printing can be done on different substrates, which has led to growth and various implementations of this printing technique [19-22].

Rosenholm showed in his paper that coated glossy or matte papers absorb the ink with more difficulty than the uncoated ones since they are less porous, and less permeable [23]. Tomerlin et al. show in the paper that the texture of the printing surface or the treatment of the PET film surface, used to reduce the surface tension, directly affect good adhesion of the ink onto the printing substrate [24]. Mariappan et al. researched in their paper the dynamics of liquid transfer between nanoporous stamps and solid substrates [25]. The research by Valdec et al. comprises the comparison of the most important quality parameters of graphic reproduction in accordance with the ISO 12647-6 standard for three types of printing substrates: uncoated and coated paper and OPP film [26], as well as the influence of printing substrate on quality of line screen and text reproduction in flexography [27, 28]. Zhang et al. determined by an analysis that the ink penetration depth into the substrate can theoretically predict the quality of printed material [29].

The quality of flexographic printing on biodegradable polymers was researched [30], and the correlation between the properties of polymer foils and the quality of flexographic printing was observed [31].

One of the factors that influence high-quality printing in flexography is the controlled transfer of ink onto the substrate. In flexographic printing, the anilox roller is an essential component of the ink system [32] which transfers the right amount of ink film thickness onto the printing plate, and from there the ink is transferred to the substrate.

Deganello et al. analysed the production of conductive tracks on micro level using different anilox volumes [33]. Cherry investigated the ink release characteristics of anilox rollers [34]. By quantifying the physical volume of ink transferred onto the substrate, as well as the optical density, it was shown that deeper cells provide greater capacity but also prevent ink release. Morgan et al. assessed the effects of ink elasticity on print uniformity in their paper [35].

Bould et al. evaluated the effect of pressure changes on print quality for different anilox specifications and line screen rulings on the plate [36]. The geometrical characteristics of the cells and the ink-carrying volume of the cells of the anilox roller were shown to have the greatest influence on solid density and halftone dot formation. The rate of increase of halftone density was found to be reduced as pressure increased, which was attributed to the ink approaching its maximum capability for spreading on the substrate. Blagodir et al. analysed the ink transfer process during flexographic printing. They carried out a numerical simulation and estimated the influences of the anilox cell shape, ink viscosity and printing plate contact angles on the ink transfer ratio [37]. Savickas et al. did an evaluation study of the anilox roller cell wear in their paper [38].

The printing process, ink, characteristics of the substrate onto which the printing is done determine the quality of the print. This quality can be described by different parameters such as: dot gain, dot shape, range of color tones, sharpness, trapping, and so on. The optical density value depends on the type of ink, its pigment and concentration, printing substrate, and printing technique [39, 40].

Borbely et al. researched the influence of different types of inks, printing pressure, and substrate on the print quality [41]. In his paper, Lipiak determined the methodology for assessing key factors that affect the quality and efficiency of a flexographic printing process [42].

The quality of flexographic print reproduction is constantly increasing and is conditioned by defining the entire process [43], processing of photopolymer printing forms [44], pressure between the roller and the characteristics of the substrates [45].

By using the latest techniques, it is possible to print excellent quality reproductions, which put flexographic printing at the very top of the printing industry, along with flat and intaglio printing.

2 EXPERIMENTAL PART

The experimental part of this paper includes the creation of prints on various polymer materials (non-absorbent substrates) of different colors with anilox rollers of different line screens (lpi) and volumes (BCM). This is done in order to prove the coloration of different colored substrates using different line screens and volumes of anilox rollers without using white opaque color as the first layer.

The goal of this experiment is to prove how different anilox roller line screens and volumes affect changes in coloring in flexographic printing. Five different substrate (foil) colors were used for the experiment of different thicknesses - 60 microns (μ), white LDPE 80 microns, black- white recycled LDPE 100 microns, blue LDPE 120 microns and green LDPE 130 microns (Tab. 1). The values of each color on an individual substrate were compared in relation to the used anilox roller.

Transparent BOPP foil, white LDPE foil, recycled black and white LPDE foil with a black color in its inner layer, blue LDPE foil and green LDPE foil were used as substrates. Additionally, a print was made on blue and green foil in order to show the differences between the colors on each color of foil without any opaque white paint coating. Sometimes, in order to obtain the color required for printing on colored or transparent foil, it is necessary to apply two layers of opaque white color.

Table 1 Overview of the used foil colors in the measurements

transp. BOPP 60 μ	White LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
*L** 94.51	*L** 90.04	*L** 84.95	*L** 65.50	*L** 65.24
*a** –0.59	*a** –71.56	*a** –2.26	*a** –19.60	*a** –42.56
*b** 0.78	*b** –54.42	*b** –4.07	*b** –41.96	*b** 59.88

The RK Print K-LOX Proofer was used to apply the ink and imitate the print, with test anilox rollers line screen (lpi) and volume (CBM) 100/18, 165/8.0 and 220/6.4. It is used to apply flexographic printing ink on various printing substrates, which can be used to simulate the imprint very faithfully. X-Rite SpectroExe was used for the measurements.

Four different manufacturers of solvent-based inks used in flexographic printing were applied. Measurements were made under the same conditions, i.e. under the same pressure on K-LOX Proofer on Coca-Cola red paint by the manufacturer Donetsk, blue paint P 300 by the manufacturer Siegwerk, on orange P 151 by the manufacturer Huber, and on yellow paint P 115 manufactured by Sun Chemical. Prior to doing the measurements, the kinetic viscosity of the flexo printing ink used in the experiment was tested. Test prints were then made on transparent, white, recycled white-black, blue, and green foil with three different anilox line screens and volumes, without applying an opaque white color before a certain color was applied on an individual substrate. Kinetic viscosity was measured using a DIN cup and a stopwatch to obtain the viscosity using the unit of time how many seconds it takes for the ink to flow out of the DIN cup. The measured viscosity was 20 m^2/s, which is also an ideal value that is, additionally, extremely important for achieving high quality in flexographic printing.

To calculate colorimetric differences (ΔE) in printing the following formula was used [46]:

$$\Delta E^*_{ab} = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{0.5} \quad (1)$$

It was used to calculate the colorimetric difference between the value of the reference sample and the value of the measured sample made using a different anilox roller on a different substrate.

The tables (Tab. 2 to Tab. 13) show the results of colorimetric difference (ΔE) between the values of the reference sample (L_2*, a_2*, b_2*), and the values of the measured sample (L_1*, a_1*, b_1*) for each color made using a different anilox roller on different substrates.

Table 2 Overview of COKE RED color measurement on all the substrates using anilox roller 100 lpi

DONECK - COKE RED color - anilox 100 lpi					
COKE RED References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2* 43.90	L_1* 41.59 ΔL* (–2.31)	L_1* 42.28 ΔL* (–1.60)	L_1* 43.27 ΔL* (–0.61)	L_1* 25.93 ΔL* (–17.95)	L_1* 24.81 ΔL* (–-19.07)
a_2* 71.40	a_1* 66.57 Δa* (–4.83)	a_1* 68.37 Δa* (–3.0)	a_1* 58.46 Δa* (–12.91)	a_1* 38.72 Δa* (–32.65)	a_1* 33.31 Δa* (–38.06)
b_2* 53.20	b_1* 43.67 Δb* (–9.53)	b_1* 47.10 Δb* (–6.10)	b_1* 28.20 Δb* (–25.00)	b_1* 22.29 Δb* (–30.91)	b_1* 22.76 Δb* (–30.44)
ΔE	10.93	7.00	28.15	48.43	52.36

Table 3 Overview of COKE RED color measurement on all the substrates using anilox roller 165 lpi

DONECK - COKE RED color - anilox 165 lpi					
COKE RED References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2* 43.90	L_1* 49.65 ΔL* (5.77)	L_1* 47.24 ΔL* (3.36)	L_1* 42.07 ΔL* (-1.81)	L_1* 29.51 ΔL* (–14.37)	L_1* 27.44 ΔL* (–16.44)
a_2* 71.40	a_1* 65.22 Δa* (–6.15)	a_1* 68.83 Δa* (–2.54)	a_1* 58.68 Δa* (–12.69)	a$_1$* 37.60 Δa* (–33.77)	a_1* 33.03 Δa* (–38.34)
b_2* 53.20	b_1* 19.87 Δb* (–33.33)	b_1* 37.62 Δb* (–15.58)	b_1* 30.16 Δb* (–23.04)	b_1* 8.47 Δb* (–44.73)	b_1* 24.58 Δb* (–28.62)
ΔE	34.38	16.13	26.38	57.88	50.61

Table 4 Overview of COKE RED color measurement on all the substrates using anilox roller 220 lpi

DONECK - COKE RED color - anilox 220 lpi					
COKE RED References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2* 43.90	L_1* 54.92 ΔL* (11.04)	L_1* 52.27 ΔL* (8.39)	L_1* 46.96 ΔL* (3.08)	L_1* 32.49 ΔL* –11.39)	L_1* 30.17 ΔL* (–13.71)
a_2* 71.40	a_1* 59.54 Δa* (–11.83)	a_1* 64.09 Δa* (–7.28)	a_1* 55.59 Δa* (–15.78)	a_1* 32.75 Δa* –38.62)	a_1* 28.78 Δa* (–42.59)
b_2* 53.20	b_1* 9.36 Δb* (–33.33)	b_1* 26.19 Δb* (–27.01)	b_1* 21.12 Δb* –32.08)	b_1* –2.53 Δb* (–55.73)	b_1* 26.51 Δb* (–26.69)
ΔE	46.73	29.20	35.89	68.77	52.12

It can be noticed from the measurements that the prints on the green and blue foil are unrecognizable and that it is impossible to make a correction. Therefore, this is solved by adding the already mentioned white paint as a base on the colored foil. Tab. 2, Tab. 3 and Tab. 4 show the influence of each anilox roller line screen on the print of COKE RED on five types of foil, from transparent to green. Only the print on the white LPDE film with 100 lpi anilox looks quite similar to the original COKE RED color, the difference ΔE is 7.0, while on other line screens a very big difference in coloring in prints can be seen.

Table 5 Overview of blue color P300 measurement on all the substrates with anilox roller 100 lpi

SIEGWERK - P 300 color - anilox 100 lpi					
P 300 References	Transp BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2^* 35.95	L_1^* 36.18 ΔL^* (0.23)	L_1^* 31.64 ΔL^* (–4.31)	L_1^* 31.45 ΔL^* (–4.51)	L_1^* 29.90 ΔL^* (–6.06)	L_1^* 21.12 ΔL^* (–14.84)
a_2^* –8.52	a_1^* –13.02 Δa^* (–4.51)	a_1^* –3.05 Δa^* (5.47)	a_1^* -3.33 Δa^* (5.19)	a_1^* 1.69 Δa^* (10.21)	a_1^* –27.02 Δa^* (–18.50)
b_2^* –63.35	b_1^* –60.99 Δb^* (2.35)	b_1^* –62.20 Δb^* (1.14)	b_1^* 59.42 Δb^* (3.93)	b_1^* –63.32 Δb^* (0.02)	b_1^* –7.16 Δb^* (56.18)
ΔE	5.09	7.06	7.92	11.87	60.98

Table 6 Overview of blue color P300 measurement on all the substrates with anilox roller 165 lpi

SIEGWERK - P 300 color - anilox 165 lpi					
P 300 References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2^* 35.95	L_1^* 46.26 ΔL^* (10.31)	L_1^* 39.73 ΔL^* (3.78)	L_1^* 40.75 ΔL^* (4.79)	L_1^* 37.21 ΔL^* (1.26)	L_1^* 29.42 ΔL^* (–6.53)
a_2^* –8.52	a_1^* –31.20 Δa^* (–22.68)	a_1^* –18.26 Δa^* (–9.75)	a_1^* –18.22 Δa^* (–9.70)	a_1^* –9.52 Δa^* (–1.00)	a_1^* –46.82 Δa^* (–38.31)
b_2^* –63.35	b_1^* –53.83 Δb^* (9.51)	b_1^* 57.01 Δb^* (6.33)	b_1^* –56.44 Δb^* (6.90)	b_1^* –63.93 Δb^* (–0.59)	b_1^* 4.17 Δb^* (67.51)
ΔE	26.67	12.22	12.83	1.71	77.90

Table 7 Overview of blue color P300 measurement on all the substrates with anilox roller 220 lpi

SIEGWERK - P 300 color - anilox 220 lpi					
P 300 References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2^* 35.95	L_1^* 44.97 ΔL^* (9.01)	L_1^* 47.21 ΔL^* (11.26)	L_1^* 44.97 ΔL^* (9.01)	L_1^* 39.81 ΔL^* (3.86)	L_1^* 32.75 ΔL^* (–3.20)
a_2^* –8.52	a_1^* –23.61 Δa^* (–15.09)	a_1^* –25.83 Δa^* (–17.31)	a_1^* –23.61 Δa^* (–15.09)	a_1^* –15.25 Δa^* (–6.73)	a_1^* 50.74 Δa^* (–42.22)
b_2^* –63.35	b_1^* –53.95 Δb^* (9.39)	b_1^* –56.04 Δb^* (7.30)	b_1^* –53.95 Δb^* (9.39)	b_1^* –61.36 Δb^* (1.98)	b_1^* 8.52 Δb^* (71.87)
ΔE	19.93	21.90	19.93	8.01	83.41

Tab. 5, Tab. 6 and Tab. 7 show the influence of all three line screens used on P300 color print on five types of foils. The best print was achieved using the 100 lpi line screen on white, and black and white recycled LDPE substrate, if the printing of blue color on blue substrate is ignored (print with anilox 165 lpi on blue foil) due to the rare ink and the same foil color and coloring, the result is satisfactory.

Table 8 Overview of measuring orange color P151 on all substrates using anilox roller 100 lpi

HUBER - P 151 color - anilox 100 lpi					
P 151 References	transp. BOPP 60 µ	white LDPE 80 µ	black and white LDPE 100 µ	blue LDPE 120 µ	green LDPE 130 µ
L_2^* 69.74	L_1^* 66.51 ΔL^* (–3.23)	L_1^* 64.77 ΔL^* (–4.97)	L_1^* 58.82 ΔL^* (–10.91)	L_1^* 39.34 ΔL^* (–30.40)	L_1^* 41.20 ΔL^* (–28.54)
a_2^* 47.38	a_1^* 46.30 Δa^* (–1.07)	a_1^* 57.13 Δa^* (9.75)	a_1^* 49.09 Δa^* (1.71)	a_1^* 29.90 Δa^* (–17.48)	a_1^* 23.73 Δa^* (–23.64)
b_2^* 77.05	b_1^* 71.47 Δb^* (–5.56)	b_1^* 81.01 Δb^* (3.98)	b_1^* 71.54 Δb^* (–5.49)	b_1^* 40.76 Δb^* (–36.27)	b_1^* 44.15 Δb^* (–32.87)
ΔE	6.51	11.65	12.34	50.44	49.54

Table 9 Overview of measuring orange color P151 on all substrates using anilox roller 165 lpi

HUBER - P 151 color - anilox 165 lpi					
P 151 References	transp. BOPP 60 μ	white LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
L_2^* 69.74	L_1^* 73.91 ΔL^* (4.17)	L_1^* 69.98 ΔL^* (0.25)	L_1^* 62.89 ΔL^* (–6.84)	L_1^* 46.20 ΔL^* (–23.54)	L_1^* 45.65 ΔL^* (–24.09)
a_2^* 47.38	a_1^* 32.50 Δa^* (–14.88)	a_1^* 47.16 Δa^* (–0.22)	a_1^* 40.10 Δa^* (–7.28)	a_1^* 10.19 Δa^* (–37.18)	a_1^* 11.17 Δa^* (–36.21)
b_2^* 77.05	b_1^* 55.45 Δb^* (–21.58)	b_1^* 74.08 Δb^* (–2.95)	b_1^* 63.70 Δb^* (–13.33)	b_1^* 17.31 Δb^* (–59.72)	b_1^* 50.50 Δb^* (–26.53)
ΔE	26.54	2.97	16.66	74.18	50.94

Table 10 Overview of measuring orange color P151 on all substrates using anilox roller 220 lpi

HUBER - P 151 color - anilox 220 lpi					
P 151 References	transp. BOPP 60 μ	white LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
L_2^* 69.74	L_1^* 77.75 ΔL^* (8.01)	L_1^* 71.74 ΔL^* (2.00)	L_1^* 66.72 ΔL^* (–3.01)	L_1^* 43.96 ΔL^* (–25.77)	L_1^* 49.03 ΔL^* (–20.70)
a_2^* 47.38	a_1^* 25.33 Δa^* (–22.05)	a_1^* 43.60 Δa^* (–3.78)	a_1^* 44.85 Δa^* (–2.53)	a_1^* 14.47 Δa^* (–32.90)	a_1^* 0.27 Δa^* (–47.11)
b_2^* 77.05	b_1^* 43.59 Δb^* (33.44)	b_1^* 69.82 Δb^* (–7.21)	b_1^* 71.87 Δb^* (–5.16)	b_1^* 26.78 Δb^* (–50.25)	b_1^* 54.80 Δb^* (–22.22)
ΔE	40.85	8.38	6.49	65.36	56.05

Tab. 8, Tab. 9 and Tab. 10 show prints of P 151 color with three different anilox line screens on all foils. The best prints were obtained on white LPDE foil with 100 lpi and 220 lpi anilox, and on recycled white LPDE foil using anilox 220 lpi. All differences up to ΔE = 10 could be corrected to make the difference as small as possible.

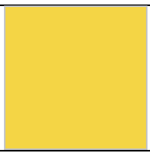
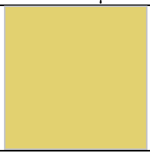
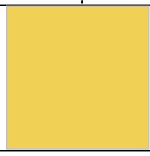
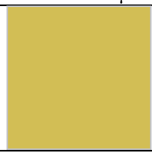
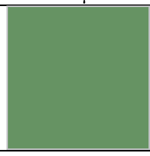
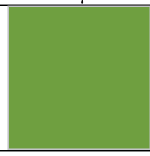
Table 11 Overview of yellow color P115 measurement on all substrates using anilox roller 100 lpi

SUN CHEMICAL - color P 115 - anilox 100 lpi					
P 115 References	transp. BOPP 60 μ	white LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
L_2^* 88.27	L_1^* 81.69 ΔL^* (–6.58)	L_1^* 80.84 ΔL^* (–7.43)	L_1^* 77.64 ΔL^* (–10.63)	L_1^* 52.80 ΔL^* (–35.47)	L_1^* 57.44 ΔL^* (–30.83)
a_2^* 1.62	a_1^* 4.30 Δa^* (2.68)	a_1^* 14.21 Δa^* (12.59)	a_1^* 12.55 Δa^* (10.93)	a_1^* –20.28 Δa^* (–21.90)	a_1^* –24.16 Δa^* (–25.79)
b_2^* 80.24	b_1^* 91.50 Δb^* (11.26)	b_1^* 94.95 Δb^* (14.71)	b_1^* 91.69 Δb^* (11.45)	b_1^* 51.79 Δb^* (–28.45)	b_1^* 69.16 Δb^* (–11.08)
ΔE	13.32	20.74	19.07	50.47	41.69

Table 12 Overview of yellow color P115 measurement on all substrates using anilox roller 165 lpi

SUN CHEMICAL - color P 115 - anilox 165 lpi					
P 115 References	transp. BOPP 60 μ	white LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
L_2^* 88.27	L_1^* 86.52 ΔL^* (–1.75)	L_1^* 86.02 ΔL^* (–2.26)	L_1^* 77.20 ΔL^* (–11.07)	L_1^* 56.24 ΔL^* (–32.03)	L_1^* 59.93 ΔL^* (–28.34)
a_2^* 1.62	a_1^* –2.98 Δa^* (–4.61)	a_1^* 5.58 Δa^* (3.95)	a_1^* 1.47 Δa^* (–0.15)	a_1^* –28.81 Δa^* (–30.43)	a_1^* –30.45 Δa^* (–32.07)
b_2^* 80.24	b_1^* 63.80 Δb^* (–16.44)	b_1^* 79.61 Δb^* (–0.63)	b_1^* 70.28 Δb^* (–9.96)	b_1^* 35.83 Δb^* (–44.41)	b_1^* 69.51 Δb^* (–10.73)
ΔE	17.16	4.60	14.89	62.64	44.12

Table 13 Overview of yellow color P115 measurement on all substrates using anilox roller 220 lpi

SUN CHEMICAL - color P 115 - anilox 220 lpi					
P 115 References	transp. BOPP 60 μ	white LDPE 80 μ	black and white LDPE 100 μ	blue LDPE 120 μ	green LDPE 130 μ
					
L_2* 88.27	L_1* 85.62 ΔL* (–2.65)	L_1* 86.50 ΔL* (–1.77)	L_1* 78.72 ΔL* (–9.55)	L_1* 57.90 ΔL* (–30.37)	L_1* 61.09 ΔL* (–27.18)
a_2* 1.62	a_1* –3.52 Δa* (–5.14)	a_1* 2.63 Δa* (1.01)	a_1* –1.30 Δa* (–2.92)	a_1* –31.19 Δa* (–32.81)	a_1* –34.03 Δa* (–35.65)
b_2* 80.24	b_1* 55.08 Δb* (–25.16)	b_1* 71.12 Δb* (–9.12)	b_1* 61.16 Δb* (–19.08)	b_1* 26.80 Δb* (–53.44)	b_1* 68.81 Δb* (–11.43)
ΔE	25.81	9.34	21.53	69.68	46.27

Tab. 11, Tab. 12 and Tab. 13 show color samples on all foils using all three anilox rollers. The best coloration was obtained using 165 lpi anilox on a white LDPE substrate. It can also be noticed that the yellow color on blue and green LDPE foil looks unrecognizable, quite greenish.

If the results of Coca-Cola red are observed, taking into account the anilox rollers line screen and the selected substrate, the worst results are obtained. It is only on the 100 lpi anilox line screen on white LPDE 80 μ that looks quite similar to the original COKE RED (Doneck) color, while there is a very big difference in coloring on prints on other line screens.

Blue color P 300 and orange P 151 give the best results taking into account the anilox roller line screens and the selected substrates. Blue color P 300 (Siegwerk) in one substrate with anilox 100 lpi roller (transp. BOPP 60 μ) gives satisfactory results, and on Blue color P 300 with anilox 165 lpi roller on blue LDPE 120 μ gives best results. This is true for orange P 151 (Huber) on one substrate of white LDPE 80 μ using an anilox 165 lpi roller; also for yellow color (Sunchemical) on one substrate of white LDPE 80 μ using an aniolox 165 lpi roller the results are acceptable.

When looking at the anilox roller line screen, the best results, i.e. the smallest colorimetric differences, are obtained using anilox 165 lpi and with blue color P 300 on a blue LDPE 120 μ substrate, followed by HUBER P 151 on a white LDPE 80 μ substrate, and finally using SUN CHEMICAL P 115, also on white LDPE 80 μ substrate.

The biggest colorimetric differences were obtained in blue LDPE 120 μ and green LPDE 130 μ substrates with Coca-Cola red, orange P 151, and yellow P 115. On the other hand, with blue P 300, the biggest colorimetric difference was obtained on green LPDE 130 μ substrate.

3 CONCLUSION

Flexographic printing has nowadays become synonymous for quality printing. Flexographic printing is today used for numerous packaging that can be found in the retail shelving. A conclusion can be drawn from the experimental part that we cannot, and should not, ignore the coloring of the substrate as an important factor in the printing process. This is evident from the obtained results, and therefore it can be concluded that it is almost impossible to obtain the desired color without prior printing of the opaque white color before the desired color is printed. This is done in order to obtain an imitation of printing on a white background. It could also be said that the anilox roller is the "heart" of every flexographic machine because it greatly affects the reproduction. The results also lead to a conclusion that different anilox roller line screens and volume have a different effect on the print on the smooth surface of the film or foil, and that, in order to print full tones, anilox roller with a small line screen and a large volume is not always needed. Contrary to that, a satisfactory print can be achieved with higher line screen and volume anilox rollers.

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