An Evaluation of Lines and Text Quality for Paper-based Packaging Using UV Wide-format Inkjet Printer

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Keywords: digital packaging, lines and text quality, folding carton, corrugated board

Abstract

Printed packaging is used to provide the consumer with details about the contents and use of a particular product. Some of this information is legally required, such as weight, vendor details, information about composition, description of contents and presence of allergens and nutritional details, etc. Customers are utilizing digital printing technology to meet compliance with changing global regulations quickly and effectively, by taking advantage of the high-resolution barcodes, QR codes, and data matrices on offer. The ability of a printing system to reproduce a sharp image with clear details is of crucial importance for high-quality reproduction. The main purpose of this experimental study is to evaluate lines and text quality for paperboard and corrugated board using UV Wide-format Inkjet Printer. A Roland VersaUV LEJ-640 UV LED printer with Eco UV-curable inks will be employed in this study. The test target is monochrome containing text and line resolution target. The text was printed in Times New Roman in 2, 4, 6, 8, 10, and 12 pt. The line dimensions are specified in points (72 points per inch) in a range from 0.01 points to 1 point. The positive version of the target used dark colors for the lines and text elements on a light background, and the negative versions of the target used light colors for the lines and text elements on a dark background. The test target also includes elements such as barcode, QR code, intelligent mail barcode, and nutrition facts as visual assessment. The results of this research have shown that printed packaging with information such as barcode, QR code, intelligent mail barcode, and nutrition facts are readable and/or scannable. Positive font size can be as small as 4 pt on the corrugated board and 2 pt on the paperboard. Positive line elements can be as small as 0.01 point while negative line elements can be as small as 0.40 point. Excessive edge noise of fine elements affects the clarity and visibility of the elements as well as the shape fidelity and legibility of the text.

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Introduction

Digital print technology is dramatically changing the packaging/prototyping market. Digital packaging offers advantages in terms of customization, shorter print runs, variable data printing, and quicker turnaround times, as well as sustainability. Allied Market Research (AMR) estimated that the global digital printing packaging market size was $20.6 billion in 2021, and is projected to reach $49.9 billion by 2031, with a compound annual growth rate of 9.1% from 2022 to 2031. According to Exactitude Consultancy, the digital printing packaging market will be increasing due to the increased demand for sustainable packaging, integration of QR codes and augmented reality, which will result in the market growth of being around 46.82 billion US dollars[1-2]. Personalized packaging allows brands to engage customers on a more meaningful way and boost marketing power through attractive specialty packaging. It has also elevated packaging's role as the first physical touch point between the consumers and brands. With the integration of variable data printing, QR codes, augmented reality and other technologies, personalized packaging will expand the market for many consumer products and generate new business opportunities.

The ability to print on a range of substrates, especially paperboard and corrugated material for the packaging market, makes the UV ink-jet digital printing technology attractive to package printers. Printing directly on a substrate gives the user a more accurate representation of the final package[3, 4, 5]. While converters are leveraging digital platforms with UV-curable inks to explore new opportunities with other media, paper-based packaging materials such as paperboard and corrugated board are widely used all over the world and are the leading material for packaging (about 40%). They are found at the point of sale, in storage and for distribution. Paper-based packaging materials have several important advantages including biodegradability, recyclability, and renewability. Approximately 20% of all paper and paperboard consumption used for packaging and over 50% of the paper and paperboard used for packaging is used by the food industry, while corrugated board is often used in the food and beverage industry[6]. Shorter product cycles, just-in-time deliveries and e-commerce are driving the demand for digital printing directly onto corrugated packaging[7].

Printed packaging is used to provide information to the final consumer and plays an important role in the presentation and advertising. It is essential that Paper-based packaging for graphical applications should provide excellent print quality[8]. Some of this information is legally required, such as weight, vendor details, information about composition, description of contents and presence of allergens and nutritional details, etc[6]. The on-demand nature of digital printing means that unique content updates - such as changes to allergen warnings and ingredients - can happen almost immediately, help ensure product safety.

Experimental Methodology

The experimental program evaluated lines and text quality for paperboard and corrugated board using UV Wide-format Inkjet Printer a Roland VersaUV LEJ-640 UV LED printer. The test target is monochrome, and all evaluated elements of the testing image have a solid tone, that is, 100% surface coverage. The test target contained text and line resolution target. The text was printed in Times New Roman in 2, 4, 6, 8, 10, and 12 pt. The line dimensions are specified in points (72 points per inch) in a range from 0.01 points to 1 point. The test target also includes elements such as barcode, QR code, intelligent mail barcode, and nutrition facts for visual assessment.

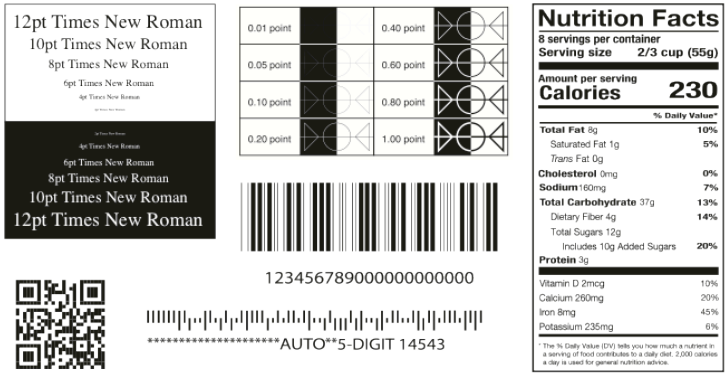


Figure 1: *Test target for analysis of line and text print quality in positive and negative shape.*

Printing trials were conducted on 12-pt solid bleached sulphate boards (SBS) paperboard of 236 g/m^2 and E-flute corrugated boards.

The test chart was printed on the selected boards using the following print settings:

- Artistic: 1440*1440 dpi
- High Quality: 720*1440 dpi
- Standard: 720*1080 dpi
- High Speed: 540*720 dpi

Microscopic images of line elements and text in positive and negative were captured by using a digital microscope for visual assessment. Samples for the analysis are captured with 150x magnification.

Results and Discussion

Test target printed results for the E-flute corrugated board and 12-pt SBS paperboard are displayed in Figure 2 and Figure 3, respectively. Overall, barcode, QR code, and intelligent mail barcode are readable and/or scannable. The nutrition facts are generally readable. Positive font size can be as small as 4 pt, while negative font size of 4 pt is barely readable. Positive line elements can be as small as 0.01 point.

However, negative line elements are unduly filled in for the fine lines such as 0.01 point, 0.05 point, and 0.10 point. Fine line of 0.20 point can be seen by naked eyes on 12-pt SBS paperboard. Paperboard tends to have sharper/clearer line and text reproduction, compared to corrugated board.

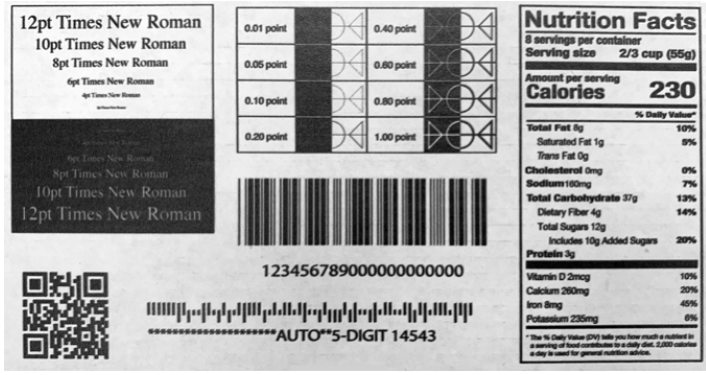


Figure 2: *Printed Test Target on E-flute Corrugated Board.*

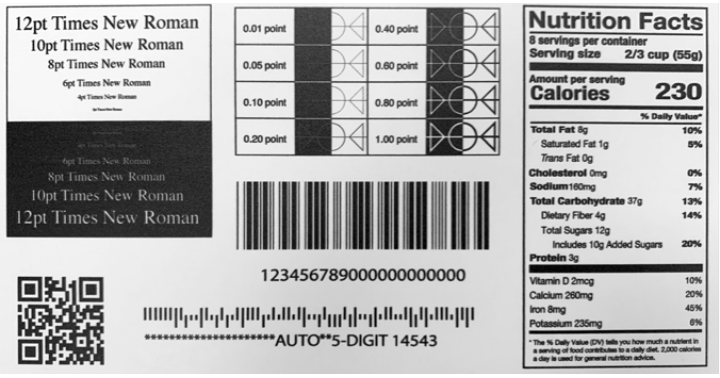


Figure 3: *Printed Test Target on 12-pt SBS Paperboard.*

Line Quality on the E-flute Corrugated Board

The line resolution target is used to evaluate the ability of the UV Ink-jet printer to handle positive and negative line elements. Line raggedness is an important factor in the visual readability of small text fonts and the technical readability of barcodes. The higher line raggedness characteristics can be related to the absorbency of the printing substrate, as well as print settings. Figures 4 - 7 compare the quality reproduction of lines in positive and negative shapes on the E-flute corrugated board. The line with least edge noise is a line printed with Standard print setting. High speed print setting resulted in double lines and had jaggedness edges. Significantly bigger edge raggedness with High-Speed print setting can be easily noticed, visually. High Quality and Artistic print settings tend to reproduce smoother lines.

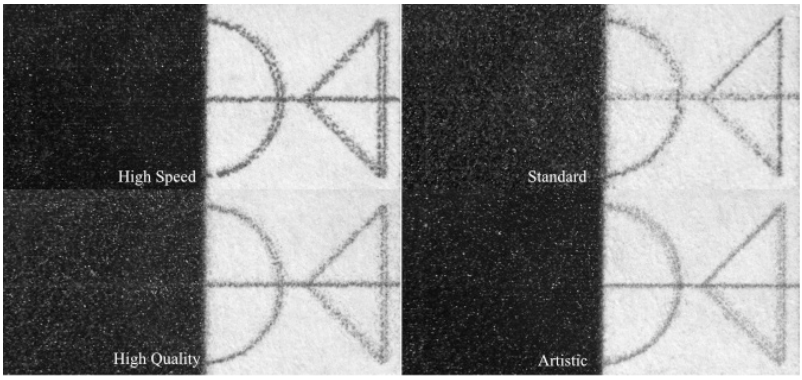


Figure 4: *Visual comparison of line reproduction (0.01 pt) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

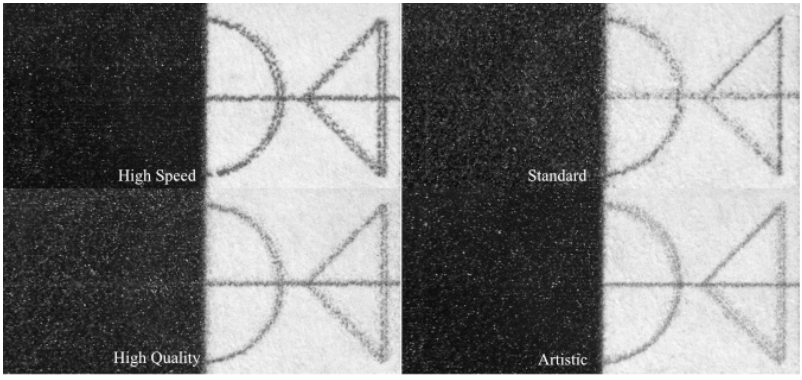


Figure 5: *Visual comparison of line reproduction (0.05 pt) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

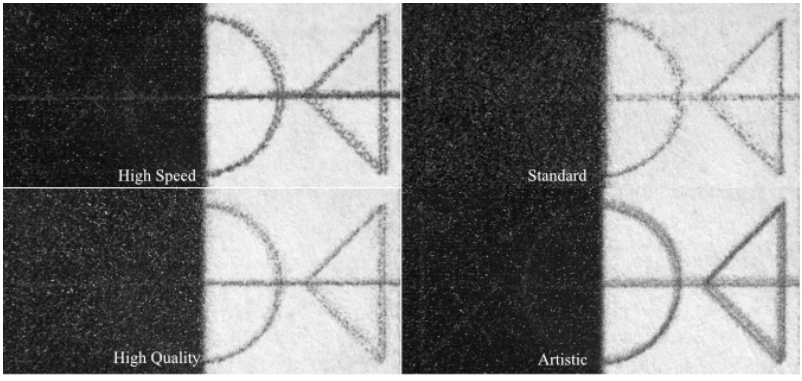


Figure 6: *Visual comparison of line reproduction (0.10 pt) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

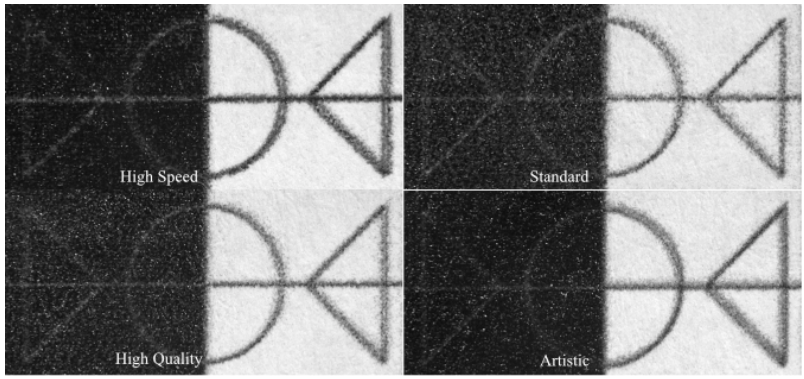
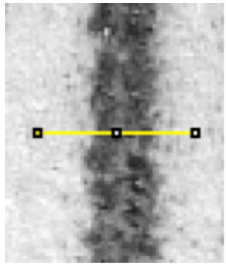
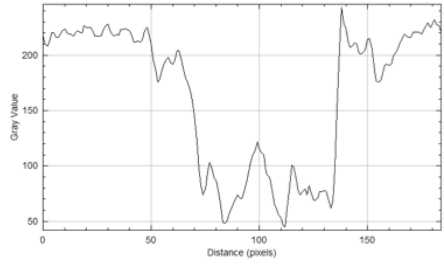


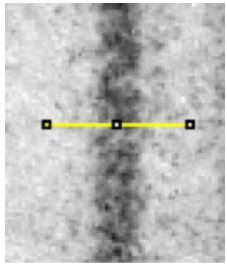
Figure 7: *Visual comparison of line reproduction (0.20 pt) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

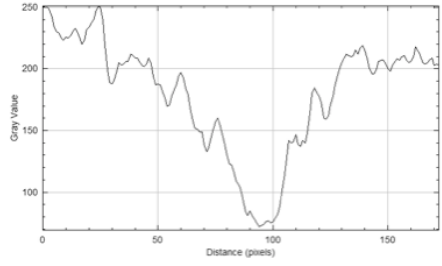
Edge sharpness is highly important for line elements, especially for reading line codes since they directly influence the reading speed. ImageJ software was employed as a plot profile tool to generate a 2D line profile based on microscopic images, which was used for the analysis of line edge sharpness. Figure 8 displays a two-dimensional graph of the intensities of pixels along a yellow line for a line of 0.20 pt on E-flute corrugated board for four print settings. First, a line is drawn perpendicular to the stroke to mark the area for the analysis (Figure 8, left images), and then a 2D line profile is created based on the color density (Figure 8, right images). The X-axis represents the distance along the line and the Y-axis is the Gray Value. Among four print settings, a line printed with High-Speed print setting tends to have a shaper edge, with sudden transition on both edges. A line printed with Standard and High-Quality print settings resulted in blurry, softer edges, where the transition from full line color to the color of the printing substrate is gradual.





High Speed





Standard

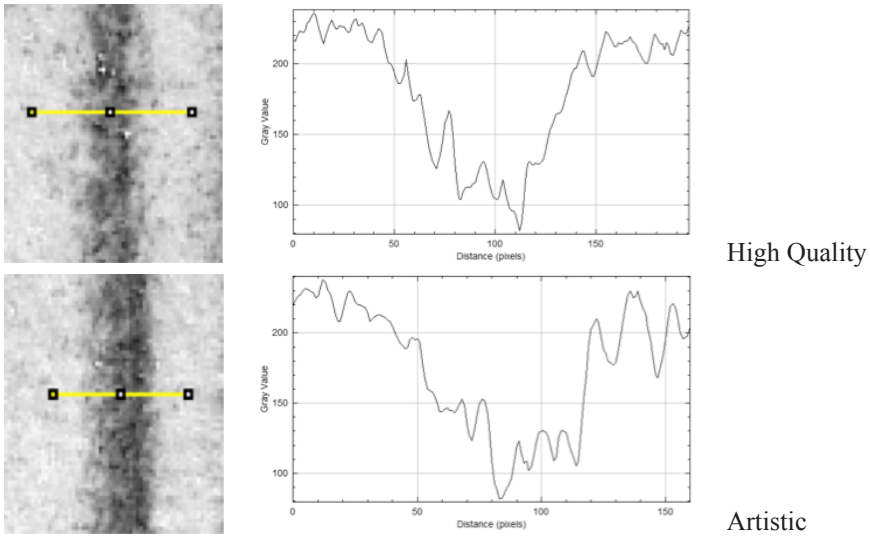


Figure 8: *Two-dimensional profile of line 0.20 pt for four print settings (corrugated board).*

Line Quality on the 12-pt SBS Paperboard

Figures 9 - 12 compare the quality reproduction of lines in positive and negative shapes on the 12-pt SBS paperboard. Just like corrugated board, the line with least edge noise is a line printed with Standard print setting. High speed print setting also resulted in double lines and had jaggedness edges. High Quality and Artistic print settings tend to reproduce smoother lines. Significantly dispersion or the appearance of dots near the edge of the full line are easily noticed visually, no matter which print setting has been applied.

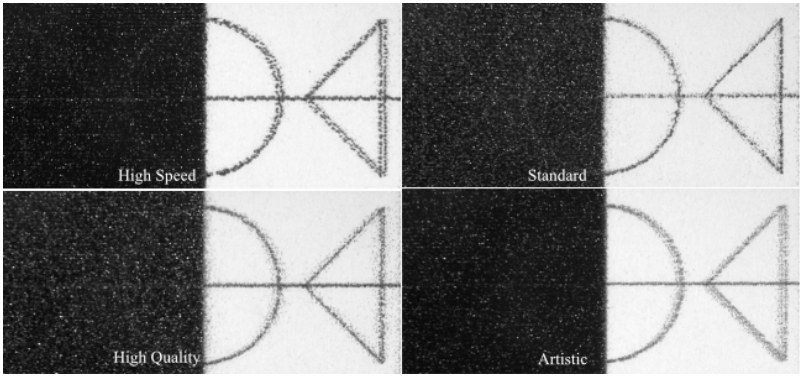


Figure 9: *Visual comparison of line reproduction (0.01 pt) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

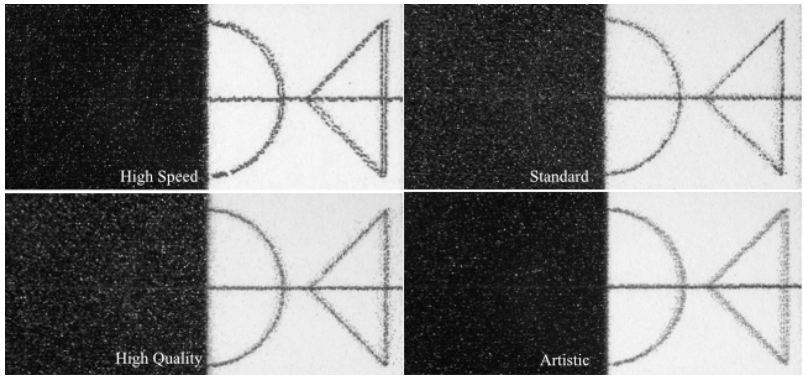


Figure 10: *Visual comparison of line reproduction (0.05 pt) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

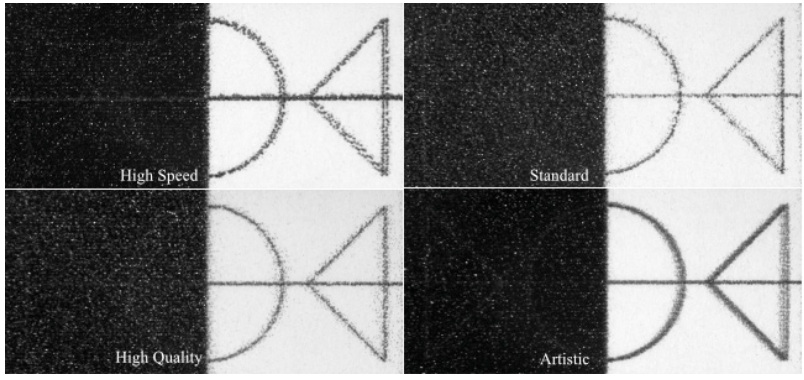


Figure 11: *Visual comparison of line reproduction (0.10 pt) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

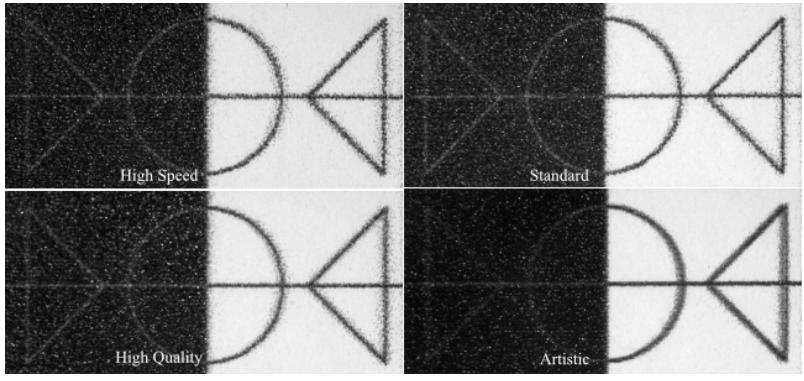
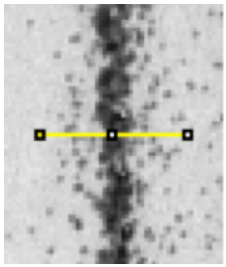
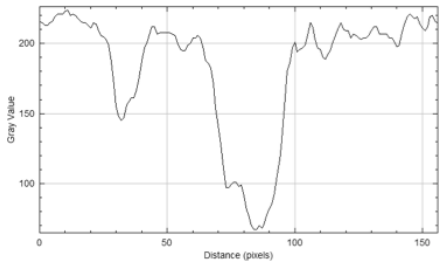


Figure 12: *Visual comparison of line reproduction (0.20 pt) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

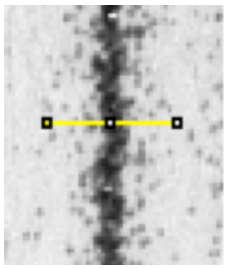
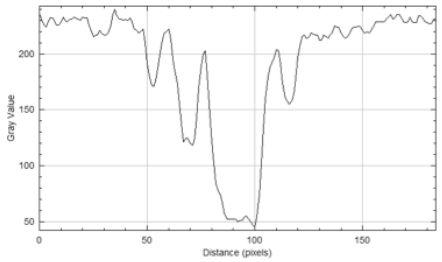
Figure 13 displays a two-dimensional graph of the intensities of pixels along a yellow line for a line of 0.20 pt on the 12-pt SBS paperboard for four print settings. A line printed with High-Speed and Standard print setting tends to have a shaper edge, with sudden transition on both edges. A line printed with High-Quality print settings resulted in blurry, smoother edges, where the transition from full line color to the color of the printing substrate is gradual. Artistic print setting also reproduced a sharper edge, however, the spreading of the ink dots in the positive shape leads to an increase in the thickness of the line.

Text Quality on the E-flute Corrugated Board

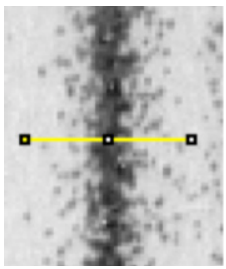
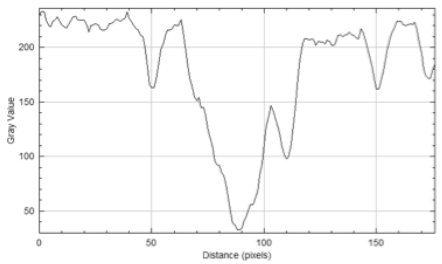
The quality of text reproduction is visually evaluated based on the edge degradation, fidelity of the character shapes and uniform ink layer, which is manifested in the touching, breaking and smearing of text characters, and it significantly influences the legibility of the text.

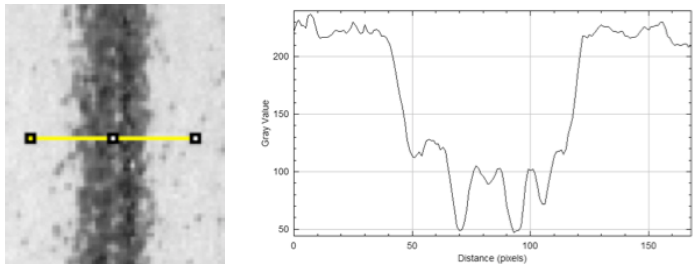
High Speed

Standard

High Quality



Artistic

Figure 13: *Two-dimensional profile of line 0.20 pt for four print settings (12-pt SBS paperboard).*

Figures 14 - 16 compare the quality reproduction of text in positive and negative shapes on the E-flute corrugated board. Quality reproduction of a smaller size text (2 pt and 4 pt) is extremely difficult to achieve as the spreading of the ink in the positive shape makes the text blurry and unclear, reducing its visibility and legibility. Positive shape of 4 pt text printed with Standard print setting tends to have a sharper, clearer characters, compared to other print settings results. The main characteristics of the text quality in a negative shape is openness. Thinner characteristics printed in negative shape are particularly sensitive to filling, which influences their visibility. Negative shape of 2 pt and 4 pt text are filled in and unreadable.

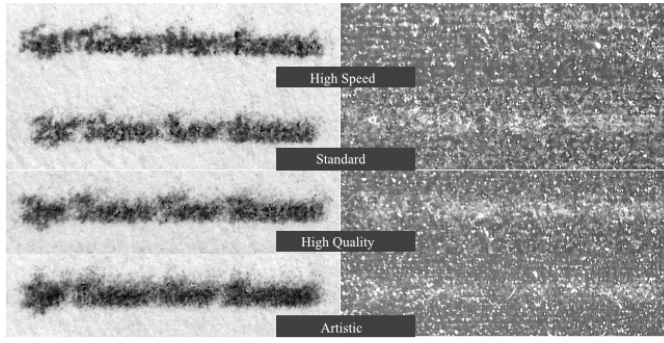


Figure 14: *Visual comparison of text reproduction (2 pt text) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x*

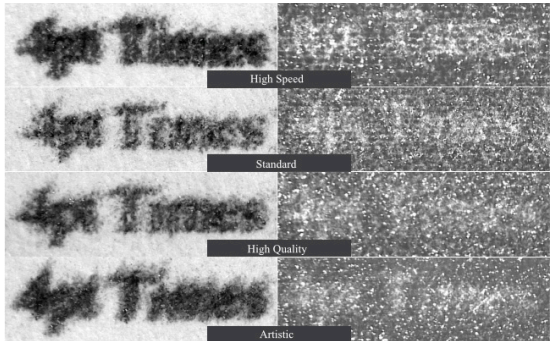


Figure 15: *Visual comparison of text reproduction (4 pt text) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

Overall, positive or negative shapes of 6 pt text are clearer and readable. However, High Speed and Artistic print settings produced excessive noise at the edge of the strokes of the characters makes the text blurry. The smearing or some other ink spreading mechanism has modified the shape of the characters to some extent. As shown in Figure 16, text deformation in a negative shape, where mild closures of characters occur due to the spread of ink. Therefore, the character area is smaller than in the text deformation in a positive shape.

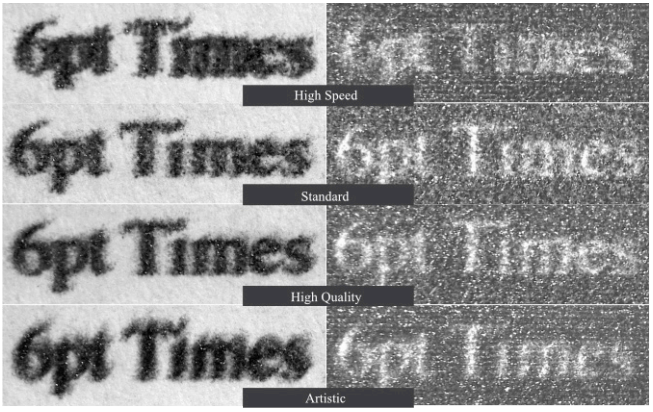


Figure 16: *Visual comparison of text reproduction (6 pt text) printed in positive and negative shapes on the E-flute corrugated board, magnification of 150x.*

Text Quality on 12-pt SBS Paperboard

Figures 17 - 19 compare the quality reproduction of text in positive and negative shapes on the 12-pt SBS paperboard. The coating of the 12-pt SBS paperboard resulted in better text reproduction of a small size text (2 pt), compared to corrugated board. With High Speed print setting, the spreading of the ink in the positive shape still makes the text blurry. Although the positive shape of 2 pt text printed with Artistic Print setting produced sharper characters, it is hard to read with naked eyes. Positive shape of 4 pt text printed with High Quality and Artistic Print settings yielded clearer, sharper characters, improving the readability and legibility of the text. Positive shape of 4 pt text printed with High Speed and Standard Print settings have noise at the edge of the characters, making the text blurry and reducing its readability and legibility. Negative shape of 2 pt and 4 pt text are filled in and unreadable, except for the negative shape of 4 pt text printed with Artistic print setting.

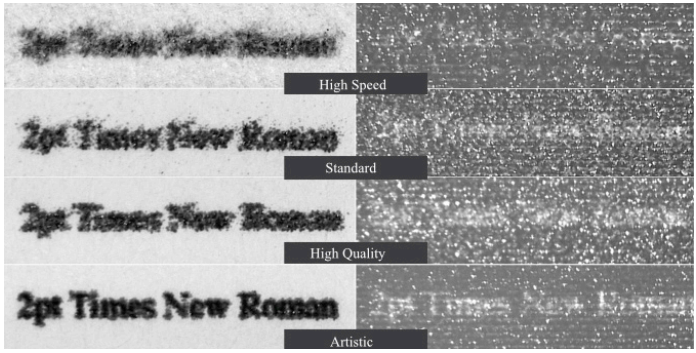


Figure 17: *Visual comparison of text reproduction (2 pt text) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

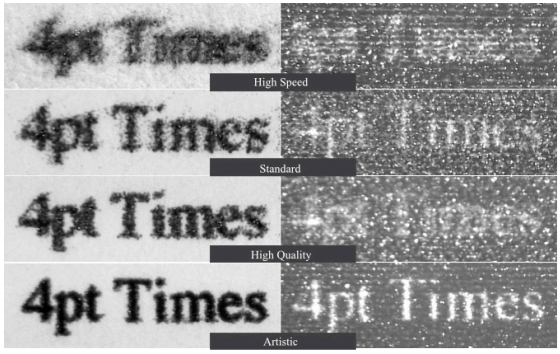


Figure 18: *Visual comparison of text reproduction (4 pt text) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

For the positive shape of 6 pt text, noise around the edge of the characters affect readability to some extent when printed with High Speed, Standard, or High Quality print setting. Positive shape of 6 pt text printed with Artistic print setting has the most clear, sharpest edge, compared to other print settings. Negative shape of 6 pt text printed with Artistic print setting is most readable, followed by the one with Standard print setting.

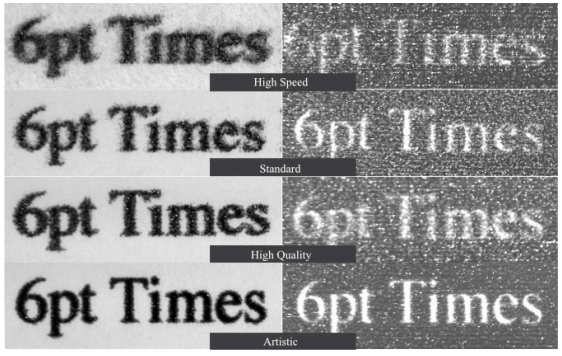


Figure 19: *Visual comparison of text reproduction (6 pt text) printed in positive and negative shapes on the 12-pt SBS paperboard, magnification of 150x.*

Conclusions

In this research, lines and text quality for paperboard and corrugated board using UV Wide-format Inkjet printing technique were evaluated. The results of this research have shown that printed packaging with information such as barcode, QR code, and intelligent mail barcode are readable and/or scannable. The nutrition facts are generally readable. Due to ink spreading, fine elements printed in the positive shape have the tendency to expand, and those printed in the negative shape have the tendency to close.

The smoothness of the paper surface is directly related to ink spreading on the surface of the print. The rough surface of the tested E-flute corrugated board has better absorption characteristics, which influence the properties of the print and ink absorption and spreading. When printed on E-flute corrugated board, positive font size can be as small as 4 pt. Ink spreading have a negative effect on the print quality of fine elements, especially tiny text in a negative shape, which can result in poor text legibility. Negative font size can be as small as 6 pt. Positive line elements can be as small as 0.01 point, while negative line elements can be as small as 0.40 point (can be seen by naked eyes).

The tested 12-pt SBS paperboard has better coating surface, which reproduce sharp images with clear details, compared to corrugated board. When printed on paperboard, positive font size can be as small as 2 pt with Artistic print setting. Negative font size can be as small as 4 pt. Positive line elements can be as small as 0.01 point, while negative line elements can be as small as 0.20 point. Noise around the edge of the characters were more noticeable when printed on 12-pt SBS paperboard, making the text blurry and reducing its visibility and legibility to some extent.

This research used microscopic images to perform subjective visual assessment for lines and text quality. Further research could employ professional image analyzer software to provide objective analysis in lines and text quality evaluation.

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