Quality Evaluation of Images Printed on Frosting Sheets with Edible Inks

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Keywords: Edible Inks, Frosting Sheets, Inkjet, Quality

Abstract

Edible printing is the process of printing images with edible food colors onto various food products such as candies, cakes, cookies, pastries, and even dinner. The advancements of digital printing technologies along with consumers' demands have stimulated the growth of the edible printing market. One of the fastest growing business sectors is bakery, where photo cakes are getting more and more popular. Inkjet printers with edible ink cartridges are used to print images on a sheet of edible paper called frosting sheet, which is then applied to a cake. With the boom of the edible printing market, print quality becomes more and more important. Consumers would want legible small text and color-accurate photo images. In this study, two test charts were printed on frosting sheets with edible inks and image quality was evaluated.

An inkjet printer was used to print gray-scale and ColorChecker test charts on frosting sheets. The tints on the printed gray-scale test chart were used to measure dot gains. The color patches on the printed ColorChecker test chart were used to measure L*a*b* values, which were then used to calculate color difference delta E (ΔE_{ab}) values. In order to note any changes in quality within a short, realistic time frame, the prints were measured on the day they were printed as well as seven days later after being placed in an airtight, tin foil folder and stored inside a refrigerator.

It is found that fonts of 5 points or smaller were illegible and lines below 1-point thickness became nonuniform. The dot gain curve peaked at 15% for the 40% tint. This could be easily improved by adjusting the calibration curve of the inkjet printer. As for color reproduction, cool colors showed lower ΔE_{ab} values around 5, while warm colors had higher ΔE_{ab} values with patch 15 (red) having the highest ΔE_{ab} value of 46. Creating a printer profile for this specific frosting sheet is needed for color management. However, even a basic IT8.7/3 test chart has 182 color patches, and since it is difficult to measure on a brittle frosting sheet using an automatic measuring table, it would be time-consuming to measure all the patches by hand. Meanwhile, each substrate requires its own printer profile, so color management for edible printing substrates is very challenging. It is also found that one-week storage under low temperature didn't affect the print quality of edible inks, which indicated that they had good resistance to chilling.

Introduction

Edible printing is the process of printing images with edible food colors onto various food products such as candies, cakes, cookies, pastries, and even dinner (Knight, 2008). When thinking about edible printing, people might immediately relate to the letter m printed on m&m candies. An early patent (Bowling, 2001) described the method of applying a logo and/or trademark including ink jet printing or printing with a roller or plate and an edible coating. This was followed by dozens of other patents related to edible printing that described different processes, inks, substrates, apparatus, etc. The advancement of digital printing technologies, along with consumer demands, has stimulated the growth of the edible printing market (Ngo, 2015; Anonymous, Edible printing: a tasty market application, 2005). One of the fastest growing business sectors is bakery, where photo cakes are getting more and more popular (Stroh, 2000).

Designs can be either pre-printed or created with an edible printer, a specific machine which produces a food coloring-based ink image onto a provided sheet of edible paper. Specific printers may be available to convert, using edible ink cartridges, for recreational use, while professional-grade edible printers remain widely used for commercial use. The inks used within edible printing must be approved by the U.S. Food and Drug Administration (FDA), as well as the cartridges, as plastics used could react harmfully with the inks used (U.S. Food and Drug Administration, 2015). Switching from edible to non-edible inks is not viable, as residue can form from previous printing runs and cause issues concerning image and print quality as well as individual health and safety. The common ingredients in edible inks, essentially food coloring (Anonymous, Colorants: edible inks print on food surfaces, 1999), are propylene glycol, propylparaben, and water (Inkedibles, 2015). While substrates vary in nutritional information due to the variability in the flavors used, typical ingredients include water, cornstarch, corn syrup, cellulose, sorbitol, glycerine, sugar, vegetable oil, Arabic gum, polysorbate 80, vanilla, titanium dioxide, and citric acid (Inkedibles, 2015). Some edible inks and paper materials have been approved by the U.S. FDA and appropriately carry the generally recognized safety certification.

Industrially, online and local resources are available to produce edible prints. Due to the large market for recreational use of edible printing, there are printers, inks, and substrates available for purchase. Epson and Canon are the largest suppliers of edible printers and inks available on the current market, and allow for their printer models to be fitted with edible ink cartridges. Some custom edible printers can even directly print onto cakes, cupcakes, and edible sheets. Commercial edible printing availability is also valued online. Some of the major online vendors available include sites such as edibleprints.com, inkedibles.com, and sweetespressimages.com. Local bakeries such as Kroger and Meijer bakeries typically carry edible printers capable of commercial orders.

With the boom of the edible printing market, print quality becomes more and more important. Consumers would want legible small text and color-accurate photo images. However, there has been very few literature on quality evaluation of edible printing. It would be valuable to conduct a study on this topic. Therefore, in this study, test charts were printed on frosting sheets with edible inks and the image quality was evaluated as follows.

Methods

The experiment was completed with the help of Taylor's Bakery in Fishers, Indiana. The bakery used an Epson Workforce 30 inkjet printer, which includes a 4-color CMYK inkjet system, outputting up to 5760 x 1440 dpi, with a maximum sheet size of 8.5" x 44" (Epson America, Inc., 2015).

Two test charts were printed on frosting sheets at the bakery, a gray-scale test chart (Figure 1) and a 24-patch ColorChecker test chart (Figure 2). The gray-scale test chart was created using Adobe InDesign CS4 in the CMYK working space – U.S. web coated (SWOP) v2, but only black was used. The color test chart was a TIFF file in the Lab color space, which was obtained from former Candela, Ltd. The printing process and color management were controlled by Epson Printer Driver v6.63, which was released on October 9th, 2009 (Epson America, Inc., 2015).

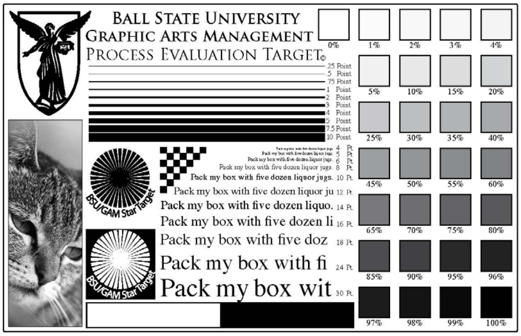

Figure 1. Gray-scale test chart

Figure 2. ColorChecker test chart

The print images were measured with an X-Rite SpectroDensitometer 528. The tints on the printed gray-scale test chart were used to measure dot gains, for which three measurements were taken and then averaged. The L*a*b* values of the 24 color patches on the printed ColorChecker test chart were also measured three times and then averaged. Color difference Delta E (ΔE_{ab}) values were calculated using the following equation:

$$\Delta E_{ab} = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2}$$

where ΔL*, Δa*, and Δb* are the differences between the reference and measured L*, a*, and b*, respectively. CIE L*a*b* values for the 24 color patches on the ColorChecker given by X-Rite, Inc. were used as the reference values (X-Rite, Inc., 2009).

In order to note any changes in quality within a short, realistic time frame, the prints were measured on the day they were printed as well as seven days later after being placed in an airtight, tin foil folder and stored inside a refrigerator.

Results and Discussion

The output quality of the edible printed objects in the gray-scale test chart had difficulties in some areas as seen in Figure 3, when compared to its original in Figure 1. The fonts used remained legible down to the 5-point range, while font sizes 6 through 30 points were moderately to considerably legible. The negative and positive star targets were mostly reduced in resolution and showed very obvious detail loss. Lines and margins of the edible print were fine above the 1-point mark, whereas below 1-point their thicknesses varied at inconsistent levels. The raster image of the cat was clearly visible and appeared to retain the majority of its detail. These visual strengths and weaknesses of the edible print in Figure 3 remain consistent with the contemporary uses of edible printing – bitmap image reproduction and font legibility.

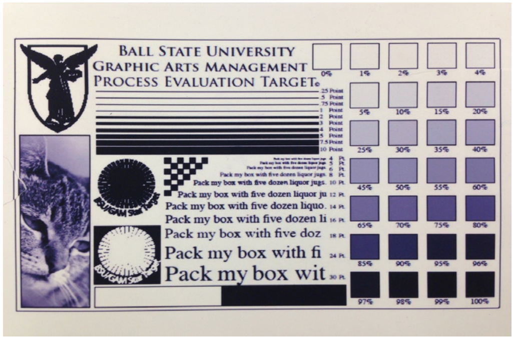

Figure 3. Printed gray-scale image

Although the gray-scale test chart only calls for black ink to reproduce the image, it is evident that the printer driver used a 4-color process, which resulted in a colored image. The blue casting indicates that higher amounts of cyan ink were used than magenta and yellow inks. The reason might be that frosting sheets usually have a yellow shade, so cooler grays were printed to counter that.

Figure 4 shows the dot gain curve of black in the printed gray-scale test chart. As expected, the curve is peaked at the midtones, measuring as high as 55% at the 40% tint for a 15% dot gain. The darker the tint, the more accurately the edible printing process was able to reproduce the original image, with dot gain steadily decreasing down to 4% at the 90% tint. Such high dot gains at midtones were probably caused by the substrate. Frosting sheets are made of fine particles and thus have very rough and porous surface, which makes ink holdout more difficult.

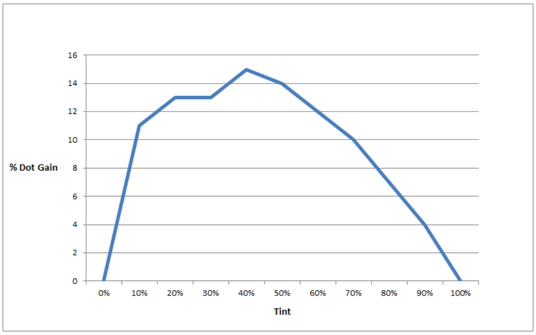

Figure 4. Dot gain curve of black

The printed ColorChecker image is shown in Figure 5. Visible strips on the printed image indicate the moving direction of the inkjet printhead. When visually compared with the original test chart in Figure 2, some color patches show significant variations, especially the red patch (third on the third row).

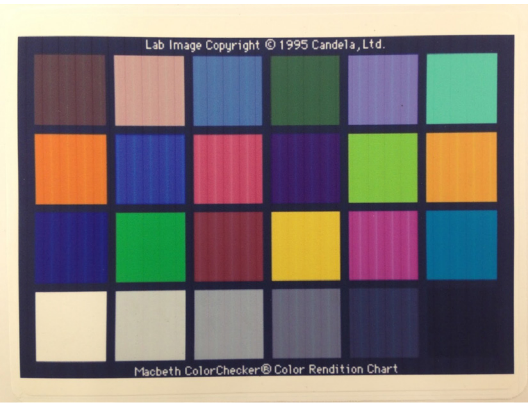

Figure 5. Printed ColorChecker image

To evaluate quantitatively, the calculated ΔE_{ab} values of all 24 color patches are illustrated in Figure 6, with the color ID numbers representing the corresponding color patches numbered from 1 to 24, as shown in Figure 7.

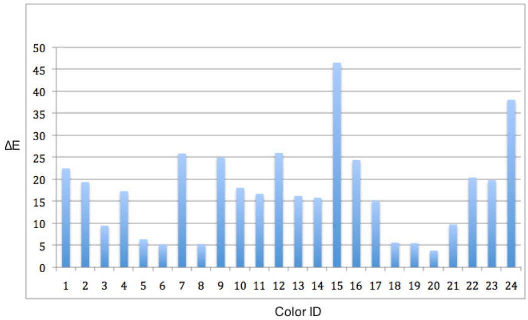

Figure 6. Delta E (ΔE_{ab}) values

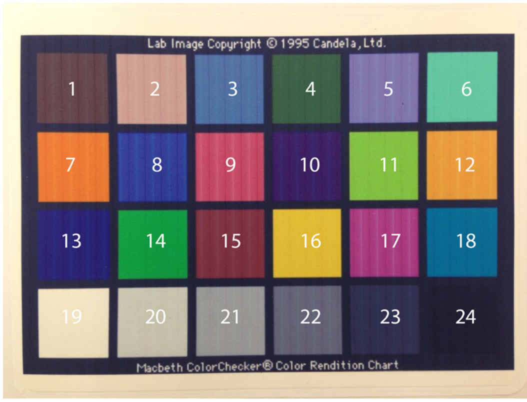

Figure 7. Printed ColorChecker image with color ID numbers

The colors that had the least significant color differences were the cool colors, with patches 6, 8, 18, and 5 having ΔE_{ab} values of around 5. The warm colors, however, showed intense variations from their original L*a*b* values, with patch 15 (red) having the highest ΔE_{ab} value of 46 while patches 12, 7, 9, and 16 having ΔE_{ab} values of around 25. It is well known that unlike cyan and yellow pigments/dyes, a close-to-ideal magenta pigment/dye has not yet be found to absorb all green light and reflect all red and blue lights (Eldred, 2001). That is why there are different magenta pigments/dyes used for printing inks, and magenta inks have higher hue errors than those of cyan and yellow inks. Warm colors in the ColorChecker image were printed with higher percentages of magenta ink, so it is no surprise that they had higher ΔE_{ab} values. The frosting sheet also had a yellow shade, which also contributed to higher ΔE_{ab} values for printed warm colors.

After closely observing and measuring the printed images on the day they were printed and then again on the seventh day of being stored in a refrigerator, it was found that any physical changes between the two sets of the gray-scale and ColorChecker images were restricted to the substrate itself and had little to no effect on the image quality. The only notable change that the prints showed upon being chilled for seven days was that they became slightly firmer and more brittle than their earlier counterparts. According to the nearly identical measurements taken from both prints on both days, the images were essentially unaffected, which indicated that the edible inks had very good resistance to low temperature within a week.

Conclusions

This study evaluated the image quality of edible printing on frosting sheets. It is found that fonts of 5 points or smaller were illegible and lines below 1-point thickness became nonuniform. The dot gain curve peaked at 15% for the 40% tint. This could be easily improved by adjusting the calibration curve of the inkjet printer. As for color reproduction, cool colors showed lower ΔE_{ab} values, while red and warm colors had higher ΔE_{ab} values. Therefore, creating an ICC printer profile for this specific frosting sheet is needed for color management. However, even a basic IT8.7/3 test chart has 182 color patches (ANSI, 2010), and since it might be difficult to measure on a brittle frosting sheet using an automatic measuring table like iOi1, it would be time-consuming to measure all the patches by hand. An alternative way might be using a scanner or camera to digitize a printed IT8.7/3 test chart. Then, the scanner or camera profile could be used to assign the scanned IT8.7/3 test chart to transform the device RGB values to CIELAB values. Consequently, the obtained CIELAB values could be used to generate a custom ICC printer profile. However, each substrate requires its own printer profile, so color management for edible printing substrates is very challenging.

It is also found that one-week storage under low temperature didn't affect the print quality of edible inks, which indicated that they had good resistance to chilling. There are other factors that affect print quality, such as printer, substrate, ink, and cartridge variation. This study is limited to one printer, one substrate, and one type of ink and cartridge. More knowledge would be gained with these factors being individually controlled and studied.

Literature Cited

[1] Anonymous. (1999, September 1). Colorants: edible inks print on food surfaces. Food Ingredient News, 7(9).

[2] Anonymous. (2005, June 1). Edible printing: a tasty market application. Graphic Arts Monthly, 77(6), p. 11.

[3] ANSI. (2010). IT8.7/3-2010 Graphic technology - Input data for characterization of 4-color process printing.

[4] Bowling, S. (2001).

[5] Eldred, N. R. (2001). What the Printer Should Know about Ink, 3rd ed. Sewickley, PA: GATF Press.

[6] Epson America, Inc. (2015, November 1). Epson WorkForce 30 Inkjet Printer. Retrieved from http://www.epson.com/cgi-bin/Store/jsp/Product.do?sku=C11CA19201

[7] Inkedibles. (2015, November 1). Edible printer inks. Retrieved from https://www.inkedibles.com/edible-ink.php

[8] Knight, C. (2008). Freshly printed dinner. Engineering and Technology, 3(1), 20-23.

[9] Ngo, C. (2015, June 2). Biting into edible printing market. The Express, p. 7.

[10] Stroh, M. (2000, April 27). Technology has bakeries picturing a business boom: cake decoration enhanced by inkjet printing with edible ink. Edmonton Journal, p. 4.

[11] U.S. Food and Drug Administration. (2015, May). Summary of Color Additives for Use in the United States in Foods, Drugs, Cosmetics, and Medical Devices. Retrieved from http://www.fda.gov/forindustry/coloradditives/coloradditiveinventories/ucm115641.htm

[12] X-Rite, Inc. (2009). ColorChecker Colorimetric Data. Retrieved 8 10, 2017, from http://xritephoto.com/documents/literature/en/ColorData-1p_EN.pdf

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