A Study of PLA Printability with Flexography

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Keywords

Biodegradable, PLA (Polyactic acid), flexography, printability

Abstract

Biodegradable films have been introduced in the packaging industry recently. Most products are boxes, bottles and bags. The printability of biodegradable film has not been fully investigated. This study tested the printability on clear and white Polylactic acid (PLA) films, and compared the print qualities to common packaging films like Polypropylene (PP), Polyethylene terephthalate (PET). Water-based flexo ink was used to test printability on PLA films. The influence of anilox roll and plate screen ruling was also considered. The print qualities were reported as dot shape, tone reproduction, and mottle. This study showed that biodegradable films could achieve similar quality compared to common packaging films. While printed at different screen rulings, clear PLA showed the highest dot gain and white PLA showed the lowest. All tested films appeared to have similar quality in keeping dot shape. In terms of mottle, white PLA appeared to be the worst among the four tested films.

Introduction

Polylactic acid (PLA) is a linear aliphatic polyester and is known as a biodegradable polymer (Yamaoka 1996). PLA is produced by poly-condensation of naturally produced lactic acid or by the catalytic ring opening of the lactide group. Lactic acid is produced (via starch fermentation) as a co-product of corn wet milling.

This environmentally-friendly product has been utilized as the alternatives of PET (Polyethylene terephthalate), PP (Polypropylene) and PS (Polystyrene) in many applications. Initially, PLA was used as thermoformed products such as drink cups, take-away food trays, containers and planter boxes. The material has good rigidity characteristics, allowing it to replace PS and PET in packaging

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applications. Presently, PLA is commercially available in many different filmic forms and is commercially produced for many packaging applications such as wrap, label, shrink sleeve, and windowing applications (EarthFirst a).

As an alternative packaging material, PLA faces hurdles including high density, high polarity, poor heat resistance and poor barrier properties compared with conventional polymer films, such as PET, PP and PS. On the other hand, PLA film delivers low haze and has the same gloss has PET, PP and PS films. These make it suitable for high clarity packaging. However, the higher stiffness and higher tensile strength allow PLA film to run up to 20% faster than PET film. The natural surface energy of PLA is around 38 dyne/cm, which accepts a broad range of printing inks without surface treating the film first, including most water-based inks (Leavesuch 2002).

Printing on film is one the most important converting processes in the North American packaging market. Different printing methods can be used to print on film. Normally, films are either surface printed or reverse printed to fulfill different applications. Print quality is influenced by a combination of film properties, ink properties and printing methods. As conventional packaging materials, PET, PP and PS have been tested on many occasions, in numerous applications. Like these conventional films, it has been documented that PLA is printable with virtually all traditional printing processes (NatureWorks). As for printability, EarthFirst, which is one of the major PLA film manufacturers, claimed that print on EarthFirst PLA film results in better quality than on other films (PET, PP, PS, etc.) as long as converters learn how to adjust their tension controls to accommodate the new material (EarthFirst b).

Minimal research has been performed on PLA. Little is known about the quality of how well PLA film can reproduce half-tone images and how the film properties affect the overall print quality. In this study, we chose PET and PP as for comparison because of the similarities in chemical structures. The following figures showed the chemical structures of PLA, PET and PP.

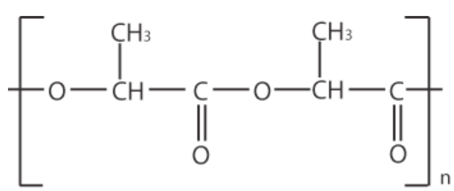

Figure 1: Chemical structure of PLA (Polylactic acid).

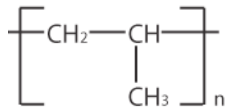

Figure 2: Chemical structure of PP (Polypropylene).

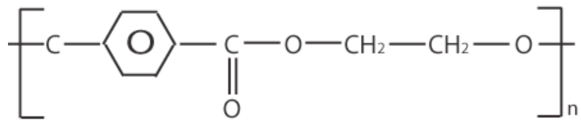

Figure 3: Chemical structure of PET (Polyethlyene terephthalate).

Clearly, PLA has the same carbonyl function group as in PET. PLA and PP both contain a methyl group. These similarities may contribute to similar print qualities.

This study is a preliminary investigation of the print qualities of water-based ink on conventional films and on PLA films with flexography. A lab printability tester was used to print on different films. The print qualities studied were tone reproduction, dot shape, and mottle. Essentially, we focused on: 1) could PLA achieve the same print quality as conventional films; and 2) how could print conditions and material properties affect printing qualities?

Experimental

Materials

EarthFirst® 2mil clear PLA and white PLA were used to study the print quality. 1.6 mil clear OPP and 1.6mil metalized PET were used for comparison.

DuPont Cyrel® DFM digital plates (shore A 65 degree) with 100lpi, 133lpi and 150lpi screen rulings were created on an EskoGraphics Cyrel Digital Imager (CDI). The plates were produced at a temperature of 68 degree Fahrenheit.

Water-based flexo ink from Environmental Inks and Coatings (EC009732 film III Jet Black) was used to print. \The ink viscosity was controlled to be 200-250 cp using water-based viscosity reducer. pH of the ink was measured as 9.5.

Apparatus

IGT-F1 Flexography Printability Tester was used to print on different film substrates. Anilox force was set to be 10N. Printing force was set to be 10N. Printing speed was 0.2m/s. A 402.227 anilox roll was used. This anilox roll contains 4 engravings with 10mm width each. The stylus is 140 degree and the cell angle is 53 degree. The screen ruling of each engraving is 150, 200, 250 and 350 line anilox patterns respectively. The cell volume of each engraving is 12.3 ml/m^2, 9.2 ml/m^2, 6.8 ml/m^2 and 5.0 ml/m^2 respectively. All conditions including ink viscosity, pH and printability tester parameters were kept the same during the testing.

Results and Discussion

1. Tone reproduction

For halftone printing, the tone curve is important in characterizing prepress and color reproduction. Plates with different screen rulings were printed with 150, 200, 250 and 350 line anilox roll patterns respectively. Due to the quality of prints, only images printed with 350 line anilox roll were analyzed. The dot percentages of each step were plotted in the following figures. In the figures, legend PET and OPP represent two traditional films. WPLA represents white PLA. CPLA represents clear PLA.

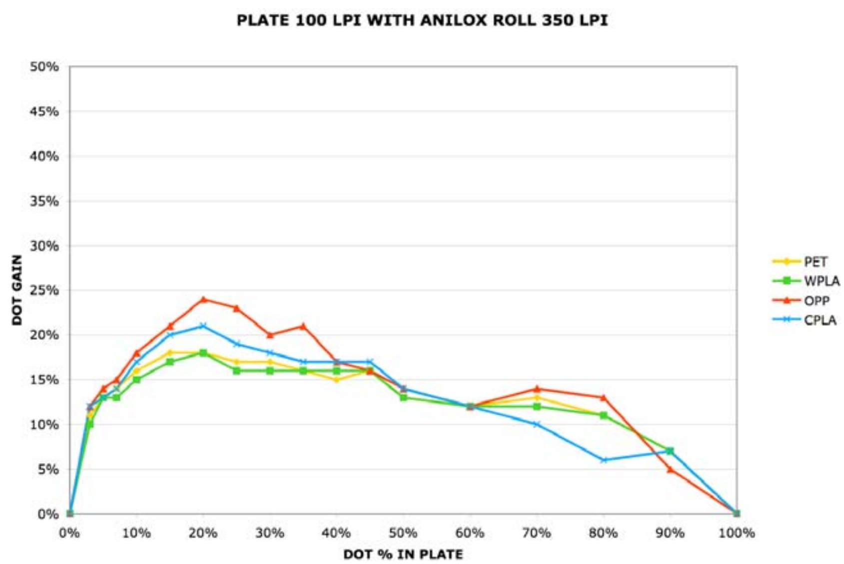

Figure 4: Flexo plate at 100lpi printed with 350 line anilox roll.

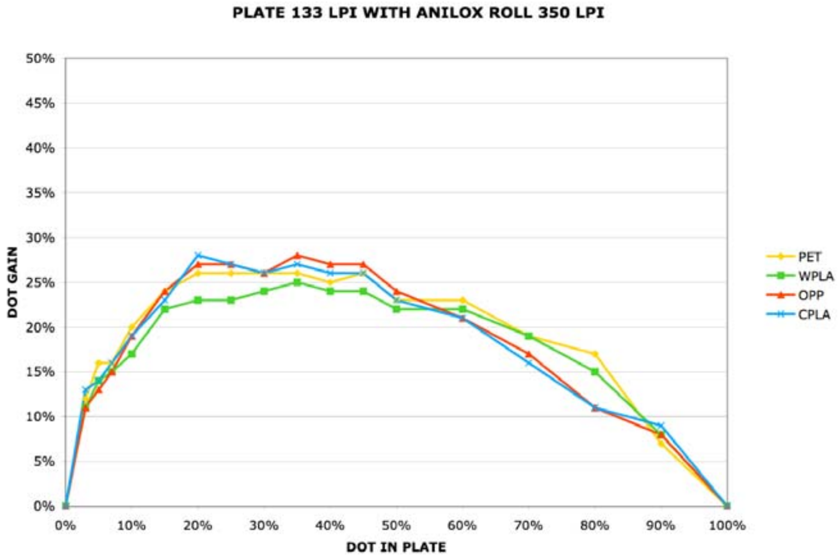

Figure 5: Flexo plate at 133lpi printed with 350 line anilox roll.

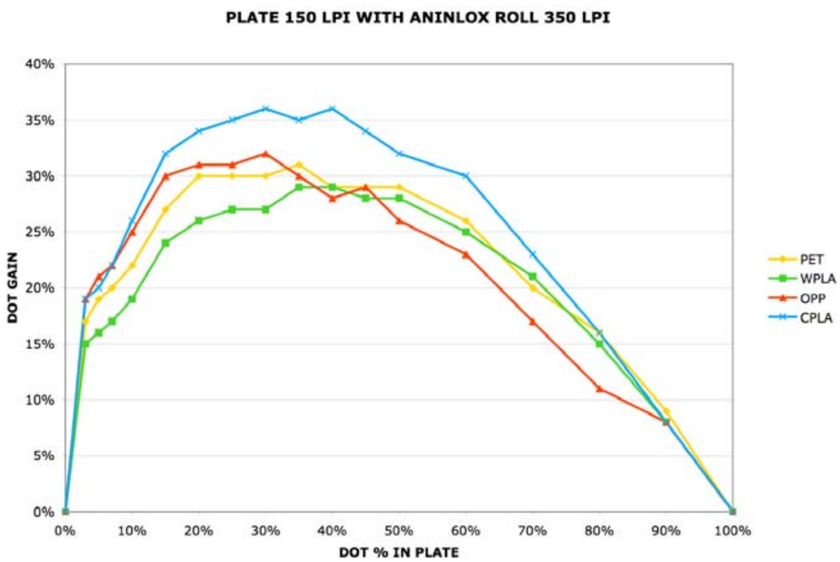

Figure 6: Flexo plate at 150lpi printed with 350 line anilox roll.

The figures showed that when images were printed by the plates with low screen rulings (100lpi and 133lpi), all four types of film had similar tone reproduction curves. Clear PLA and OPP had slightly higher dot gain from 20% to 50% dot range. When the films were printed by the plate with relatively higher screen ruling (150lpi), clear PLA showed the highest dot gain, while white PLA showed the lowest dot gain from 20% to 50% dot range.

2. Highlight dot shape and dot reproduction

As shown in tone reproduction, the films printed at low screen rulings appeared similar in print quality. Further investigation is necessary to explore issues surrounding print quality at higher screen rulings. 5% dots of each film were captured by ImageXpert. The captured images were shown in the following figures.

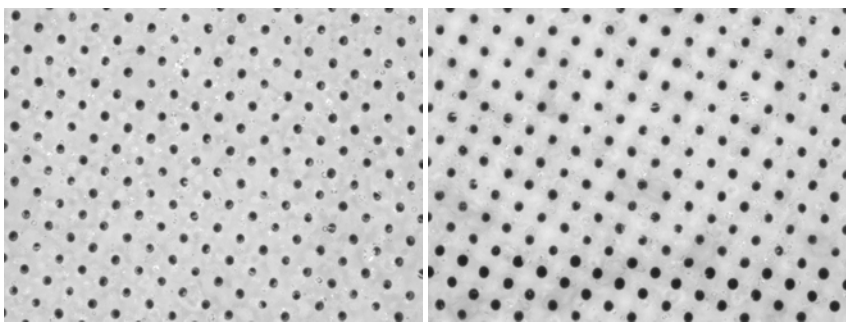

Figure 7: 5% dots on clear PLA (left) and OPP (right), films were printed with plate at 150lpi with 350 line anilox roll.

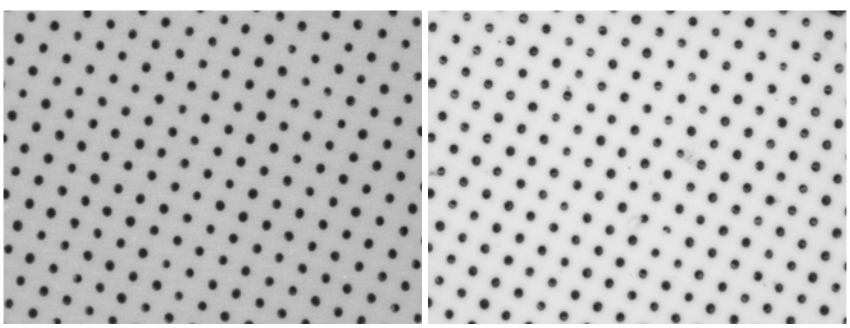

Figure 8: 5% dots on PET (left) and white PLA (right), films were printed with plate at 150lpi with 350 line anilox roll.

The roundness and average dot size were calculated to analyze the dot quality and ink transfer on different film substrates. Average dot size was calculated as the average dot area of the entire captured imaged. The results are shown in the following table.

Film	Clear PLA	OPP	PET	White PLA
Dot roundness	0.97	0.98	0.91	0.97
Average dot size (%)	10.35	11.22	11.89	11.52

Table 1: Dot roundness and average dot size of each tested film; images were printed with plates at 150lpi with 350 line anilox roll.

When printed on different film substrates, dots showed similar roundness and average dot size at 5% step. This fact indicates the differences in ink transfer on different substrates in highlight areas were minimal. In terms of dot shape, similar quality can be achieved on all four substrates in reproducing highlight tones.

3. Solid reproduction and mottle

Shadow reproduction is another important quality issue. Usually higher density is associated with higher shadow dot gain, which affects the shadow detail reproduction. Because surface properties of different film substrates differ from each other, the quality of solids differs as well. Mottle is the parameter to identify the uniformity in appearance of solid area. Mottle values of each film were calculated as the unevenness of gray level in a gray scale image by Verity Print Quality software. The enlarged solid images are shown in the following figures.

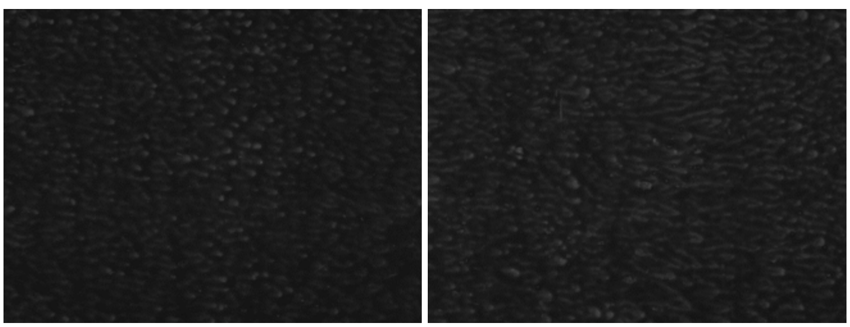

Figure 6: Enlarged solid areas of print on clear PLA (left) and OPP (right); images were printed with plate at 150lpi with 350 line anilox roll.

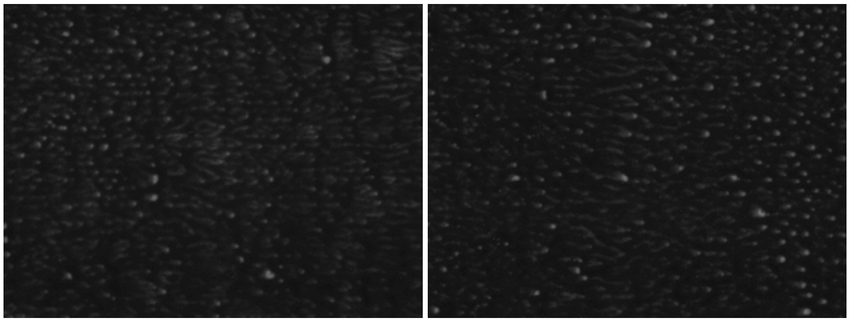

Figure 7: Enlarged solid areas of print on PET (left) and white PLA (right); images were printed with plate at 150lpi with 350 line anilox roll.

Mottle values of each film are listed in the following table.

Film	Clear PLA	OPP	PET	White PLA
Mottle	9.86	21.23	64.73	85.61

Table 2: Mottle values of solid area on different film substrates.

Clearly, White PLA had the highest mottle value, which means the solid printed areas were highly uneven. Clear PLA had the lowest mottle value, which appeared the best uniformity in solid printed areas.

4. Surface energy of film substrates

Ink transfer on film substrates is related to surface energy of the substrates. The lower the surface energy, the better the ink spreading and transferring. The surface energy of film substrates was measured by Accudyne Test Solutions. The results are listed in the following table.

Film	Clear PLA	OPP	PET	White PLA
Surface energy (dynes/cm)	38	37	39	36

Table 3: Dyne measurements of different film substrates.

The surface energy tested by this method did not associate with the results very well. But it may explain why white PLA showed the smallest dot gain among the tested films, since it has the lowest surface energy. All tested films have the similar surface energy, which also explains the similarity in dot shape reproduction. How the chemical structures of film affect the ink transfer and mottle require further investigation.

Conclusions

Biodegradable PLA films were printed and compared with common packaging films like PET and OPP. The results showed that PLA could achieve similar print quality in terms of tone reproduction and dot shape. When printed at higher resolution, white PLA showed the smallest dot gain among the four tested films, while clear PLA showed the largest dot gain. All tested film showed similar dot shape when measured as dot roundness. White PLA showed the highest mottle in solid areas among the tested films, followed by PET, OPP and clear PLA. Further research of how chemical structures and film manufacturing processes affect ink transfer may explain why white PLA showed the highest mottle while clear PLA showed the lowest.

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