Printability Analysis of Flexographic Printing On Compostable Films

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Abstract

As quality requirements of packaging continue to increase, flexographic printing still remains very important. Although many substrates are widely used for flexible packaging, bio-based materials are becoming popular because of their sustainable characteristic that results in the usage of bio-based films as a flexo-packaging substrates. This research focused on the printability of flexography using water based acrylic ink on compostable films produced in Thailand such as PLA/PBAT and PBAT/starch. Surface properties of these films were evaluated to observe how they affected the print quality (density, TVI and tone reproduction) of samples under certain conditions (running speed and anilox line screen). The examined properties of substrates were surface roughness, surface morphology and wettability. Results showed that print quality was influenced by substrates' surface properties and printing conditions. In addition, surface treatment was needed, but having limitation. Images of printed surface from SEM and SPM indicated that fracture surface and void of films could lead to defects of print quality. This suggests that raw materials mixed with additives are necessary to improve ink laid-down and hold-out on the surface.

1. Introduction

PLA (polylactic acid) PBAT (polybutylene adipate-co-terephthalate) are a new generation of compostable plastic films. PLA is derived from renewable raw materials such as corn, potato, tapioca etc. While PBAT is an aliphatic–aromatic copolyester derived from petroleum. They are compostable in compliance with ASTM D6400-04 and EN 13432 norms. Their advantages are not hazardous in production and decomposed back to carbon dioxide, water and biomass.

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PLA product was initially 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 applications. Nowadays, it is commercially available in flexible forms for many packaging applications such as wrap, label and shrink sleeve. It gives superior mechanical properties equivalent to LDPE/HDPE film [1,2]. However, PLA is more expensive and it degrades slowly in the environment over a period of several months to 2 years. To improve its functional properties, efforts have been made to develop a blended PLA products with thermoplastic starch (TPS) and PBAT [3,4].

PBAT is considered as a good candidate for the toughening of PLA [3]. PLA/PBAT blend is a well-known one in the Thai market. It is a kind of immiscible, two-phase system where PBAT disperses evenly in PLA matrix. Jiang et al found the decrease of tensile strength and modulus of the product. However, elongation and toughness were dramatically increased [5].

PBAT/Starch is another choice of compostable film. This system consists of the hydrophilic starch granules and the hydrophobic PBAT. Starch is used to blend to improve the mechanical and barrier properties of PBAT film [4]. Corn starch was chosen as it gave greater expansions and lower densities than wheat or potato.

It should be noted that these compostable products shall be certified according to EN 13432 / 14995 standards. Thus, in addition to printed advertising images, the logo and certificate number displayed on the packages are needed to assist in the decision on purchasing and disposal (sorting). At present, flexography is considered as a sustainable printing process. However, a few research has been performed on compostable films. Little is known about the quality of how well this type of film can reproduce half-tone images and how the film properties affect the overall print quality This research aimed to understand the effects of anilox roll and printing speed of flexography on print quality of these compostable films.

Flexographic Printing

Printing on film is one the most important converting processes in packaging industry. Print quality is influenced by a combination of film properties, ink properties and printing methods.

Flexography is a form of HYPERLINK “http://en.wikipedia.org/wiki/Printing” \o “Printing” printing process which utilizes a flexible relief plate. The advancement of flexographic printing are in the area of non-toxic ink, HYPERLINK “http://en.wikipedia.org/wiki/Photopolymer” \o “Photopolymer” photopolymer plates, including improvement of the method of digital plate making. Anilox roller makes flexography unique as it meters the predetermined ink that is transferred for uniform thickness. It has engraved cells that carry a certain capacity of inks. Printing speeds of up to 600 meters per minute are possible with modern technology of high-end printers.

In an era of growing environmental awareness, waste disposal issue is becoming a driving force in the choice of printers. Using water based ink is one example, but it tends to be more difficult to print on film substrates. Thus, to achieve the satisfied printed density and optimum tone reproduction is a challenging task for printers. It is a must to understand how to set up the printing machine and the effects of printing conditions on relevant print quality parameters. Resolution of anilox roll must be properly selected to obtain a uniform and sharp printed image without dot dipping problem; and the amount of ink transferred on substrate should be at satisfactory level by adjusting proper ink viscosity and printing speed [6].

2. Experimental

The objective of this research was to analyze the printability of flexography on compostable films. The PLA (Tg = 58 °C, Tm = 155 °C) and PBAT (Tg = −29 °C, Tm = 110–115 °C) resins were utilized to produce blown films. Two recipe of blended products were provided by two manufacturers in Thailand. One was PLA/PBAT blend (40:60) at 100 micron thickness and another PBAT/corn starch (50/50) at 40 micron thickness. Thermoplastic starch (TPS) was blended with PBAT in prior before blowing film. These resins were supplied by FKuR (Bio-Flex©) and Novamont (Mater-Bi©). The data of physical properties of those two samples was given in Table 1. Black water acrylic based flexo ink was developed by *Panorama Soy Ink Company*. The ingredients were given in Table 2. The surface tension of ink was 40 mN/m (dyne/cm).

Samples	Tensile strength (Kg/mm2)		Elongation* (%)		Density (g/cm3)	surface energy (dyne/cm)
	MD	TD	MD	TD		
PLA/PBAT	1.68	1.86	443	460	1.4	38
PBAT/starch	2.30	1.42	461	744	1.2	38

*at break: ASTM-D882-02 / MD: machine direction, TD: transverse direction

Table 1. *Physical properties of two compostable products*

Ingredient	Amount(%)
flush pigment	20
water	20
polypropylene glycol	5-10
acrylic copolymer	35-45
ethoxylated alcohols	5-10

Table 2. *Ingredients of water acrylic based ink*

Surface wettability on film examples was examined by contact angle measurement using *sessile ink drop method* through VDO capturing device. DI water and black ink sample were compared. A 1.14 mm thickness digital flexo plate which had surface hardness 64˚ shore A was used. The grey-scale and images files were exposed with their resolution at 133 lpi. Printing experiment was done on a *Nilpeter- FB 3300 S press*, with medium soft type packing by *TESA*®. The viscosity of ink was controlled at 20-23 seconds measured by *Zahn cup No. 3*. The effects of anilox line screen from 400 to 700 lpi (lines per inch) and printing speed from 15 meter per minute to 30 meter per minute on print quality such as tone reproduction, tone value increase (TVI) and optical density were examined. Tone reproduction was considered by densitometric measurement.

The *JSM-6400 Scanning Electron Microscope* (SEM) was used to analyze surface morphology and the body of films. Surface roughness was investigated by *Scanning Probe Microscope (SPM) Controller type NanoScope IV*. Ink rub resistance was evaluated by *Sutherland Ink Rub Tester*.

3. Results and discussion

3.1 Surface wettability

Contact angle measurement implied that these film samples were hydrophobic nature as the data shown in Table 3. The water minimized contact angle with the surface and formed a compact liquid droplet. While the ink gave moderate contact angles at 29˚ and 34˚ on PLA/PBAT and PBAT/ starch films respectively as shown in Figure 1. The difference of contact angles on both samples may come from different surface roughness and the effect of starch on the PBAT/starch film. It was found that the ink did not penetrate well in the surface within 1 second. Wet and dry rub resistance of print was poor. This phenomenon might relate to ink formulation. This suggests that the ink's surface tension shall be readjusted to improve the rapid penetration and wettability. In addition, the surface treatment of substrates could be done to achieve it.

Samples	Ink	Water
PLA/PBAT	29˚	87˚
PBAT/Starch	34˚	92˚

Table 3. *Contact angle of ink, water and alcohols on two compostable products*

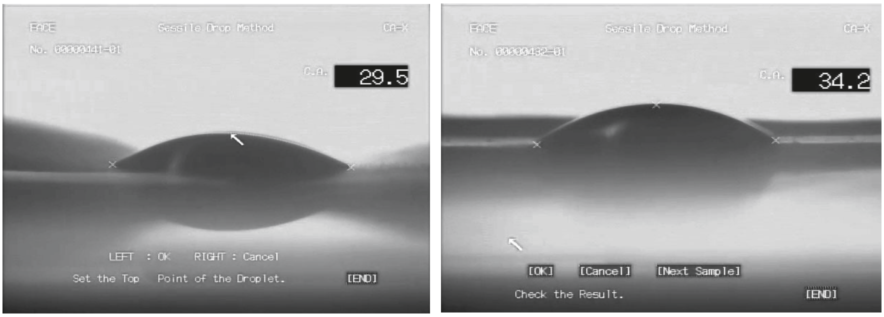
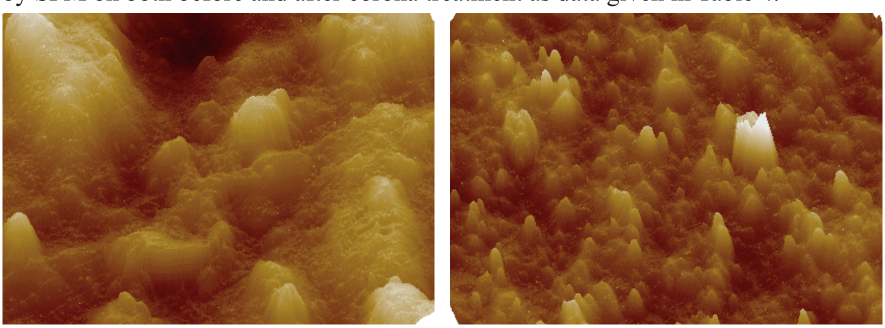


Figure 1.*Images of ink drop on PLA/PBAT (left) and PBAT/Starch (right) plastics*

3.2 Surface properties

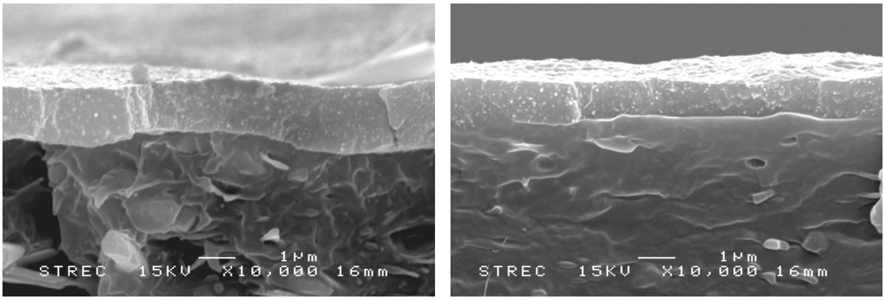
Non treated films gave explicitly unsatisfactory printed quality result by poor ink wettability. Both film samples had equal surface energy at about 38 dyne. The corona discharge was done by varying applied power levels at 500, 1,000 and 1,500 watt-min/m^2. We found that print uniformity did not relate well to high corona dosage. Corona dosage at 500 and 1,000 watt-min/m^2 was acceptable. While the dosage at 1,500 watt-min/m^2 increased the surface energy of films up to 50 dyne/cm but damaged their surfaces by which print non-uniformity reappeared.

SPM and SEM images of PLA/PBAT and PBAT/starch films shown in Figure 2 and 3 confirmed their surface morphology fractured as PBAT's molecular chain was more flexible than that of PLA and was easier to entangle. Oval cavities and enclosed round PBAT particles were visible in the film body. For PBAT/starch sample, the appearance of fractured surface was rugged. Some of starch granules were removed from the fracture surface leaving behind cavities. The more the dispersion between starch and PBAT during film production is improved, the smaller the size of starch granules becomes by which the surface of film will be smoother. Interestingly, in this case, PLA/PBAT sample gave RMS surface roughness higher than that of PBAT/starch sample measured by SPM on both before and after corona treatment as data given in Table 4.



PLA/PBAT PBAT/starch

Figure 2. *SPM images of the non-printed surfaces of PLA/PBAT and PBAT/starch films (x5,000)*



PLA/PBAT PBAT/starch

Figure 3. *SEM images of cross section of printed PLA/PBAT and PBAT/starch films (x10,000)*

Samples	Non treatment	Corona 1000 (watt-min/m^2)
PLA/PBAT	435.3	541.0
PBAT/Starch	207.8	236.7

Table 4. *Average RMS surface roughness (μm) of compostable films*

From our findings, we anticipated that PBAT/starch film shall have ink rub resistance better than that of PLA/PBAT film, particularly after corona treatment. Using *Sutherland Rub Tester*, a motor-driven instrument for moving a 4 pound-weights over a printed film through an arc, it was found that the abrasion damage found less in PBAT/starch film in all cases.

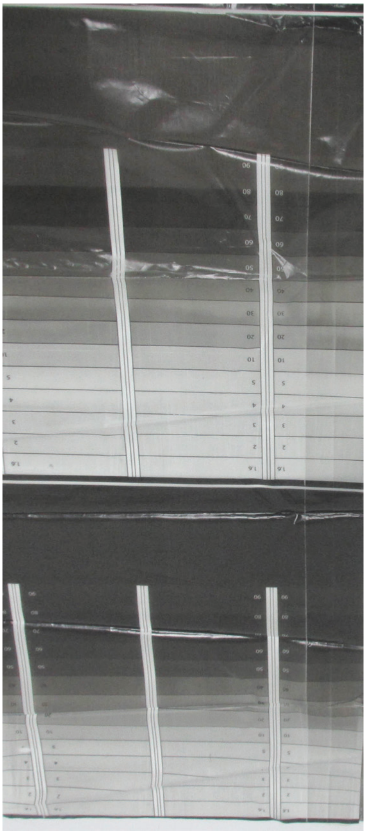
3.3 Printability

In printing, wettability is an important factor because it affects ink spreading and TVI values of prints. As the printing pressure and ink viscosity were constant in this experiment, thus TVI would depend on the amount of ink transfer and the ink absorption rate. Prior result implied that the surface morphology of substrates was a critical parameter to affect the TVI as it related to the ink absorption rate. It was found that higher ink absorption rate increased TVI values while ink spreading was limited. PLA/PBAT film showed higher TVI values than those of PBAT/starch film as shown in Figure 4 and 5. This was confirmed in all printing conditions. It was because the surface fracture of PLA/PBAT film with high porosity resulted in higher TVI values.

To consider the effect of printing speed on print quality, we found that higher printing speed transferred less amount of ink from printing plate to substrates. It was because shorter time-lapse in the printing nip. The TVI values of PBAT/starch samples were decreased as shown in Figure 6.

In flexographic printing, anilox line screen controls the amount of ink transfer from anilox cells to printing plate. Figure 7 shows the effect of anilox line screen on tone value increase (TVI) of printed PLA/PBAT. We found that higher anilox line screen gave lower TVI values. In this study, 700 lpi was a good choice.

Print contrast was then evaluated from all printed samples based on the optimum printing condition whereby the highest value was the target. Print contrast was obtained by measuring the densities of the image between solid tone and 80% tint on printed testform. It was found that the printing condition using anilox line screen 700 lpi and printing speed at 30 m/min was preferable by which the maximum solid tone density fell in the range of 1.5 -1.6 and the obtained highest print contrast reached about 25% and 18% for PBAT/starch and PLA/PBAT films respectively. Accordingly, PBAT/starch film gave shadow detail or print contrast better than that of PLA/PBAT film. It was due to the differences in surface structure of two films. Note that we recommended the corona dosage was at 500 watt-min/m^2.



PLA/PBAT PBAT/starch

Figure 4. *Printed images on compostable film samples using anilox line screen 700 lpi and printing speed at 30 m/min*

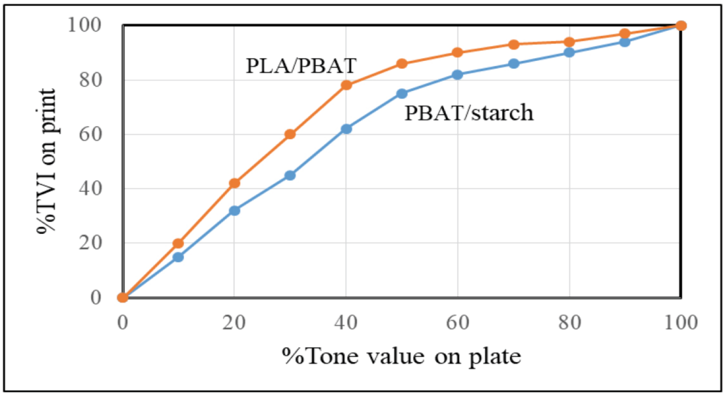


Figure 5. *Comparison of tone reproduction curves on printed PLA/PBAT and PBAT/starch film samples*

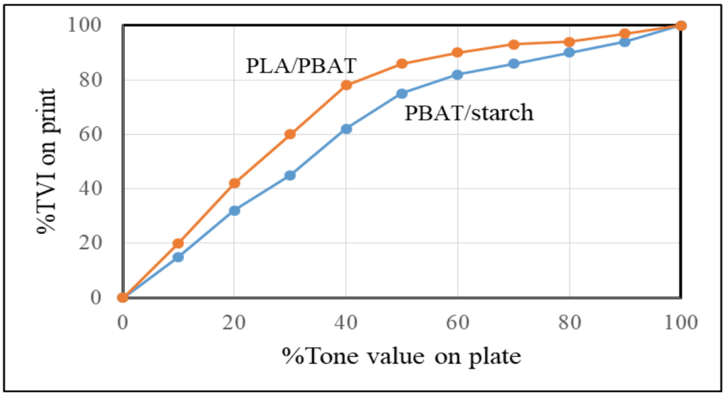


Figure 6. *Printing speed vs tone reproduction on PBAT/starch films (anilox line screen 700 lpi)*

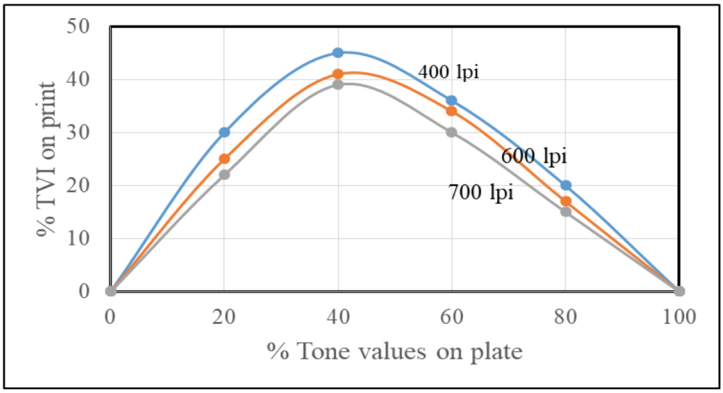


Figure 7. *Effect of anilox line screen (lpi) on TVI values of printed image on PLA/PBAT (Corona treatment at 500 watt-min/m2)*

4. Conclusion

It is possible to apply flexographic printing on compostable PLA/PBAT and PBAT/starch films. Film structures on the surface and voids play an important role in print quality such as density and tone value increase. Their hydrophobic property needs to be improved by corona treatment to achieve print uniformity and ink rub resistance. Note that corona dosage has limitation due to the weakness of film surfaces. Anilox line screen 700 lpi and printing speed at 30 m/min are preferable to achieve optimum tone reproduction and print contrast. This will be based on the resolution of image on flexo plate 133 lpi and the corona dosage at 500 watt-min/m2. Although PBAT/starch film showed print quality better than that of PLA/PBAT film, but the print contrast still needs to be improved. Ii is suggested that used raw materials ratio be reconsidered to match well with the water acrylic based ink. The aim is to improve ink hold-out on the surface with low spreading, including the ability to run the flexo machine at higher speed.

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