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Study of PLA Printability with Flexography Ink: Comparison with Common Packaging Polymer

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ABSTRACT

Today, the economic consumption of biodegradable polymers is of capital importance in many applications. One of the most commonly used biopolymers is polylactic acid (PLA). The printability of the biodegradable film has not been fully investigated. This work tested the printability of polylactic acid (PLA) films and compared the print qualities to common packaging films like low density polyethylene (LDPE), corona treated LDPE, polyethylene terephthalate (PET). Solvent -based flexo ink was applied to test the printability of the films. The surface tension of films and densitometry of printed samples were evaluated. Also the inks adhesion to the substrate as an essential parameters that influence the quality of printed samples were measured. It has been found that the PLA can be successfully printed with flexographic solvent inks and could achieve similar quality to common packaging films. Prog. Color Colorants Coat. 12 (2019), 101-105© Institute for Color Science and Technology.

1. Introduction

Paper was the first printing substrate and it is nevertheless a prevalent one. Very diverse properties of plastics led to the state of affairs in which they commenced to act as an important role in various areas, including printed materials. Packaging is a major group of plastic fabrics. European market of the biodegradable plastics is continuing its active evolution and modifying. Nowadays, bioplastics covers less than 5-10% of plastic market, but a substantial gain is anticipated [1]. The problems of packaging waste and ecology become of increasing importance and universal pursuit. Biodegradable polymers seem to be a safe option to traditional ones. They degrade within several months to several years depending on the condition, where the traditional synthetic, oil-based [2]. As an alternative packaging material, polylactic acid (PLA) faces hurdles, including high density, high polarity, poor high temperature resistance and poor barrier properties compared with conventional polymer films, such as polyethylene (PE), polyethylene terephthalate (PET) and polypropylene (PP). On the other hand, PLA film delivers low haze and has the same gloss like conventional polymer films. These make it desirable for high clarity packaging. Nevertheless, the higher stiffness and higher tensile strength allow PLA film to be given up to 20% faster than PET film [3].

Virtually every software system requires minimum printing information, although much higher demands are levied on the majority of them [4]. The natural surface energy of PLA is just about 50 dyne/cm, which accepts a full scope of printing inks without surface treating the film first [2, 3]. Print quality is determined by a combination of film properties, ink properties and publishing methods. As conventional packaging materials, PET, PE and PP have been tried on many functions, in numerous applications. Like these conventional films, it has been documented that PLA is

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printable with virtually all traditional printing processes [5]. As for printability, Earth First, which is one of the major PLA film manufacturers, took that print on Earth First PLA film results in better quality than on other films (PET, PP, PE, etc.) as long as converters learn how to set their tension controls to accommodate the new material [6].

On a series of prior publications, print, quality of infrastructures such as biodegradable films in printing by flexographic technique was investigated [2]. Besides printing, heat-sensitive biodegradable PLA fabrics using UV-curable inkjet inks were examined. The outcomes, showing that UV-curable inkjet printing of PLA fabrics could be a potential answer to overcome the processing limitations of heat-sensitive PLA fibers [7]. The correlation between motion picture properties and flexographic print quality was also observed [8].

In these research investigations, polymeric substrate were investigated separately, and also the printing and mechanical properties were not considered together. So it seems that further research in needed to compare the performance of common and new bio packaging substrates. In the prolongation of the other researchers works, In the current study, we compared the printability of polylactic acid (PLA) films with that of common packaging films such as low density polyethylene (LDPE), corona treated LDPE, polyethylene terephthalate (PET) with solvent-based flexography ink.

2. Experimental

2.1. Materials

PLA Pellets (Ingeo™ 4043D resin, 1.24 g cm^{-3}) were purchased from Nature Works, USA. PLA film was biodegradable and compostable according to EN 13432 standard [9].

Blown films of LDPE having a thickness of 100 microns and a density of 0.92 gcm^{-3} were supplied by the Bandar imam branch of the Petrochemical Company (Iran), and were used throughout this study.

The LDPE were corona treated by mounting single board strips (50 cm×5 cm) along the rotating aluminium drum (Fakhrazar, Iran), programmed at varying applied power levels (W) and drum surface speeds (up to 50 m/minute). The corona level chosen in the treatment represents typical doses and energies used in industrial printing on these substrates [10].

PET bottle grade chip (highly viscous) was supplied from Shahid Tondguyan Petrochemical Co branch, Petrochemical Company, Iran. This is a condensation polymer which is produced by continuous melt phase polymerization followed by solid state polymerization with an I.V of 0.75-0.85. dL/gr Flexographic ink (FI) was a cold-set solvent-based cyan ink purchased from the Persia Ink Co. (Tehran, Iran). A typical formulation of the used ink is shown in Table 1 [11]. The ink was applied with K Hand Coater (UK) on films.

2.2. Methods

Static contact angle of samples was measured on a Krüss G10 instrument of German origin at room temperature. About 5µL of wetting liquid was used for each measurement at 20 °C. Readings within 5 s of drop formation were taken for the critical surface tension.

The surface free energies of sample were estimated by the aid of two liquid water (72.8 mJ/m^2) and diiodomethane (50.8 mJ/m^2). The Owens–Wendt method, utilizing the theory of adhesion work between solid and liquid phases from which polar (γ^P) and non-polar or dispersive (γ^D) surface free energies could be derived [12]. The contact angle was measured by using the sessile drop method [13].

Table 1: A typical formulation of the Flexographic ink.

Component	Amount (%)
Organic pigment (Phthalocyanine)	20
maleic resin varnish	16
nitrocellulose varnish	38
wax	4
plasticizer	4
methylated spirits	11
isopropyl acetate	7

The optical density (OD) of the printed samples was measured using a spectrophotometer (S900; Ihara, USA) over the range of 400 to 800 nm using a 0/45 geometry. The obtained toner was characterized by employing an Ihara Spectro Cam (Japan) spectroscope. The spectral reflectance factor of each sample was determined and then transformed into the CIELAB colorimetric coordinates (L*, a* and b*) under ASTM E308 standard using D65 standard CIE (international commission on illumination) illuminant and standard CIE 1964 colorimetric observer [14].

Cross Hatch Ink Adhesion Tape Test (ASTM D3359) was used to evaluate the adhesion of the ink to the substrate. This method specifies a procedure for assessing the resistance of inks, to separate from substrates when a right-angle lattice pattern is cut into the coating, penetrating through to the substrate. The method may be used for a quick pass/fail test. For reference, the following adhesion ratings are the typical product requirements for Graphics and Reflective products. A rating of 4B to 5B is preferred; 3B or less is unacceptable [15].

3. Results and Discussion

Ink transfer on film substrates is related to the water contact angle or surface energy of the substrates. The lower the contact angle or the higher the surface energy, better the ink is spreading and changing. The open energy of film substrates was measured by The Owens–Wendt method [12]. The attained contact angles between double distilled water and polymeric films as well as surface energies are shown in Figure 1 and Table 2, respectively. The untreated LDPE had the highest contact angle, while untreated PLA had the lowest one. However, the values of PET are also acceptable. Likewise, all data agree well with data in the literature [16]. As required, the contact angle of corona treated LDPE is higher than the untreated one, although it is lower than PLA and PET and not suitable for good adherence in the printing procedure. Psychoanalysis of the results received show that individual films tested differ in the value of their surface free energy, as considerably as in the polar and dispersive components of surface free energy (Table 2). The highest values of surface free energy were found for the PLA and the lowest one belong to untreated LDPE. This difference, strongly depends on the nature of the polymer (Figure 1) [17].

Table 2: Surface free energy of the films.

Polymer	Surface free energy (mJ/m^2)	γ^P (mJ/m^2)	γ^D (mJ/m^2)
PLA	49.7	7.2	42.5
PET	43.4	5.3	38.1
LDPE	31.9	4.6	27.9
Co-LDPE	38.4	5.8	32.6

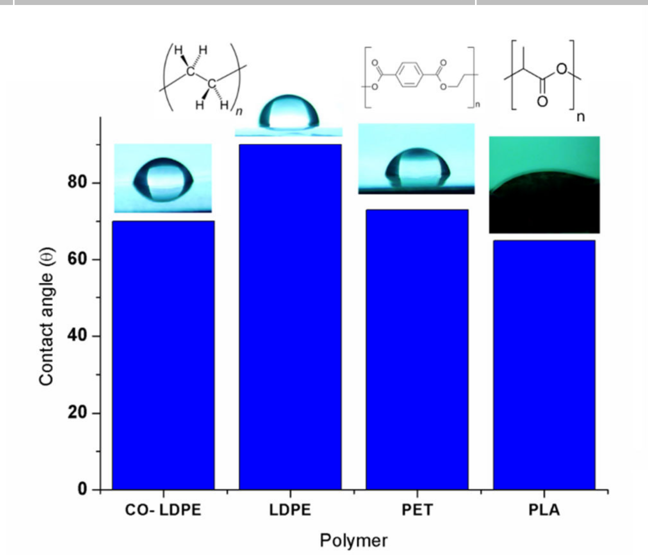

Figure 1: Contact angle and photograph of a water drop on a film surface.

Table 3: Optical density of fully coated fields printed on different films.

Polymer	Optical density
PLA	1.1
PET	1
LDPE	0.8
Co-LDPE	1.2

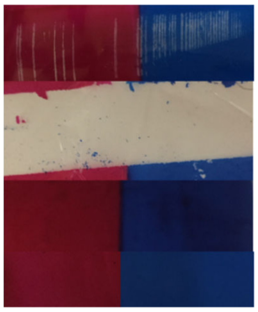

Figure 2: Tape strip from the ink adhesion test.

The resolutions of the preliminary study of the correlation between film properties and flexographic print quality described by the optical density of solids are shown in Table 3. Established on the analysis of the obtained results we try to resolve the question whether traditional plastic films can be replaced by biodegradable, compostable films as printing substrates and fabrics for promotion. Optical density is the most useful parameter which influences the tone of the mark. Optical density represents the light blocking ability of a cloth, and it is the percentage of absorption of the ink film of light descending upon it. The following logarithm mathematically represents the relationship between the quantities of light reflected from a stage along the ink film to the quantities of light falling on the same point (equation 1):

$$D=\log L_W/L_R \qquad (1)$$

Where L_W is the intensity of light reflected from the white region of the paper, and L_R is the intensity of light reflected from the process ink region printed on the paper [18].

In that location were no significant differences in the optical density of four films (PET, PLA, LDPE and co-LDPE), while after the tape test for untreated LDPE we reported a significantly lower value of optical density which is required due to the very low adhesion of such film. Despite the fact that the ink was dedicated to the PET and LDPE film, the results obtained from the PLA film were really full and comparable or even sounder. These effects are comparable to those obtained by Jacobson, et al. [19].

A stronger adhesion of printing ink to the film surface enables to get a thicker ink layer on the marks. With regard to measurement of adhesion of tape peeling, the standard deviation from the replicates for each sample has an average value taken over all samples of 0.01%, and thus the trends are again important. Figure 2 shows that ink adhesion on PLA and PET was perfect (5B). On LDPE, however, it was obvious that the lowest treatment level (0B), resulting in a not sufficient good adhesion. Although the adhesion on co-LDPE generally was much better [20].

4. Conclusions

Biodegradable films have been inserted in the packaging industry recently. In the current study, we compared the printability of polylactic acid (PLA) films to common packaging films like low density polyethylene (LDPE), corona treated LDPE, polyethylene terephthalate (PET) with solvent-based flexography ink. Experimental tests and analysis of the results obtained enable to submit that the biodegradable films PLA in comparison to available film on the market like PET, co-LDPE and LDPE could achieve similar print quality in terms of visual density and bond. The highest values of surface free energy were found for the PLA. Therefore ink adhesion on PLA and PET was maximum and 5B.

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