EFFECT OF VARIOUS CONDITIONS OF ARTIFICIAL AGEING ON SELECTED PROPERTIES OF OVERPRINTED PLASTIC FILMS

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Abstract
Overprinted plastics films, which are mainly used as a packaging, may be exposed to the various factors during storage. The aim of this work was to study the influence of various conditions of ageing of overprinted plastic films. Laboratory printing was performed using various plastic films (PE, BoPP, PET) and three flexographic printing inks: water-based, solvent-based and biodegradable. The analysis was focused on two external factors: elevated temperature and UV radiation. The effect of temperature and UV radiation on printing ink colour was examined by studying the optical density of a full tone area and the total colour difference . The period of artificial aging, equivalent to nearly two months of natural aging, caused visible changes in the appearance of the quality of prints. The total colour difference increases with the time of artificial ageing, as it was expected. The changes of print quality during ageing are higher for PE prints than for PET and BoPP prints. Additionally, UV radiation causes major changes in the print quality than elevated temperature.
Key words: *artificial ageing, print quality, overprinted plastic films, colour changes*

Introduction

Plastic films are commonly used as a packaging materials overprinted using flexographic printing technology. The roles of modern packaging are now wider than in the past. The packaging must full fil same criteria and functions. Primary, packaging must protect the product, facilitate of portioning and delivery some of information on the packaging. However, the packaging must additionally fulfil some of new functions, such as advertising, promotion and friendliness to the environment (Izdebska, 2013). Last but not least, printed packaging should fulfil specific print quality criteria. The overprinted products and printing bases may be characterised by various optical properties, i.e. gloss, colour, thickness of dried ink film, transparency and opacity (Izdebska, 2013). In this work, we concentrated on colour parameters that could be described by optical density and L^*, a^*, b^* colour coordinate values.

Overprinted packaging are often exposed to light that changes the print colour. This effect may be observed as a fading of the print. Colour changes can make the overprinted package unattractive to a customer. The ageing of prints represents a complex problem. The light fastness of prints depends upon a number of factors: exposure conditions (type of light, humidity and temperature), time of exposure, substrate and ink film thickness, but primarily the type of colorants (dyes and pigments) and percentage of dye in the printing ink (Leach, 1993). Colour changes of prints, such as fading, makes the overprinted package unattractive to a customer.

Ageing is a process causing structural changes and chemical composition of the material leading to the changes in the functional properties of material (Izdebska, 2016). This changes are mainly observed as a deterioration of functional properties of the material. For example, ageing of prints can be observed as a fading of colours, or ageing of plastics may cause they poorer mechanical properties.

Ageing of materials can be either spontaneous (natural ageing) or forced (accelerated ageing). The natural process of ageing is very slow. Artificial ageing is intended to produce time-dependent changes in a much shorter time than that during the natural process. Hence, in order to observe the natural ageing of prints in a shorter period of time, artificial ageing may be used. Basic types of ageing, according to the involving factors, are thermal ageing, photo ageing, chemical ageing and biological ageing (Emanuel et al, 1998). However, mainly several factors occurs simultaneously (Izdebska, 2013) involving ageing process.

In this work we demonstrate the influence of various factors of artificial ageing: UV radiation and elevated temperature. The printing inks were cyan biodegradable, water-based and solvent-based. Various plastic films [polyethylene, poly(ethylene terephthalate) and polypropylene] were used as printing bases. The ageing process was monitored by measurement of various print quality properties such as the optical density of full tone area and L^*, a^*, b^* colour coordinate values.

Materials and methods

In this work three printing inks (colour Cyan), dedicated for flexographic printing technology, were used: solvent-based, water-based and biodegradable. This printing ink is recommended for flexographic printing on plastic films.

Three popular plastic films were used: polyethylene (PE), polypropylene (oPP) and polyethylene terephthalate (PET). The characteristic of films are summarized in Table 1.

Table 1 Properties of plastic films

Film	Appearance	Thickness µm		Tensile strength MPa	Ultimate elongation %	Thermal contraction %
BoPP	Transparent	30	MD	120	210	4
			TD	230	80	2
PET	Transparent	12	MD	1900-2500	90-120	< 3
			TD	1900-2600	80-110	< 1
PE	Transparent		MD	15	150	60-75
			TD	11	200	30-40

Laboratory printing was carried out with a K Paint Applicator (RK prints, UK). The wet ink film was 10 mm. Printing was performed under controlled environmental conditions (23 °C and 50% RH). The wet ink film has a thickness of 10 µm. All factors were kept constant during the printing process (printing speed and K roller). The adhesion quality test was assessed simply by a tape test using Tesa tape, which was attached firmly to the print and peeled off rapidly by hand according to the EN 15386:2007 standard. One test on two different overprinted strips was carried out for each sample 15 min and 48 h after printing. Adhesion was quantified by visual evaluation of the ink mark on tape strips removed from the printed substrate and by changes in the quality of the print.

A SpectroEye spectrophotometer (GretagMacbeth, Switzerland) was used to determine the optical densities of the full tone area and the specific ink colour components L^*, a^*, b^*. The measurements were performed according to standards: ISO 13655: 2009 and ISO 2431:2011. The settings are summarized in Table 2. The reported results are the average measurements from a minimum of six areas.

Table 2 Spectrophotometer settings

	Colour components	Optical density
White standard	ABS	Proofing paper
Illuminant	D50	DIN
	2°colorimetric observer	

The process of artificial ageing was carried out with the use of a Suntest CPS+ (Atlas, USA) device supplied with an additional optical filter – a so-called UV external light filter. The use of such filters eliminates UV radiation of wavelengths shorter than 290 nm, which has the strongest negative effect on the material. It allows the simulation of outdoor solar radiation. The level of light intensity was 580 W m^{-2}. During the ageing experiments the temperature was kept at 33 ± 2 °C, however maximum temperature in the chamber was 40°C. The tests were carried out for each printed film in 8 cycles for a total of 90 h, which corresponds to nearly two months. Blue Wool Scale samples were exposed alongside the printed samples. Every hour spent in the ageing chamber corresponds to a dose of energy absorbed equal to 2040 kJ m^{-2}. The densitometry and spectrophotometric values of the samples were measured before and after every measurement cycle. Between measuring cycles the samples were kept under conditions suitable for the storage of plastic film: at room temperature, and in the absence of light.

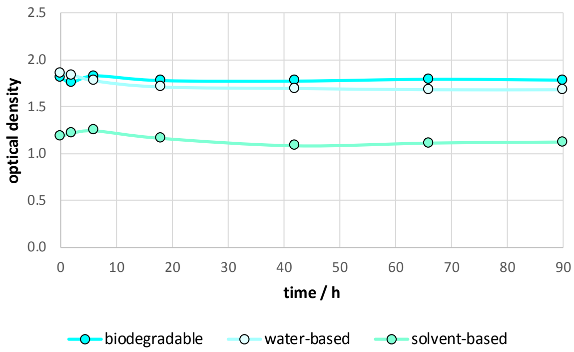
The process of ageing at elevated temperature was performed using laboratory dryer SLN 15 (POL-EKO-APARATURA, Poland). The samples were heated in temperature 40 ± 0.1°C. The process was carried out in 6 cycles for a total of 90 hours.

Densitometry and spectrophotometric parameters were measured during ageing by irradiation and at elevated temperature.

Results and discussion

The total dosage of energy absorbed by samples during artificial ageing with UV radiation corresponds to 183600 kJ·m^{-2}, what is equivalent to 45 days of ageing in natural conditions. The colour of the ink was Cyan, because our previous works revel, that cyan printing ink is the most resistant to colour changes during aging (Izdebska-Podsiadły, 2018). Measurements of the optical density of the full tone are related to the time of ageing with a UV radiation and at elevated temperature are shown on Figure 1–3.

a)



b)

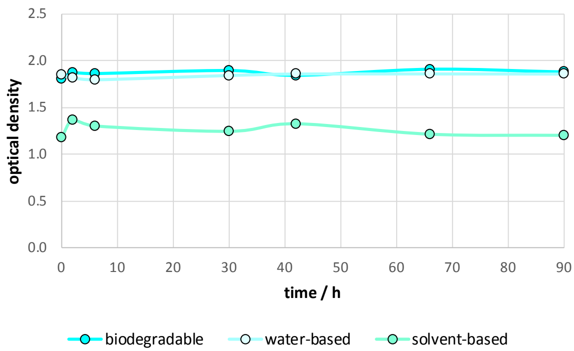
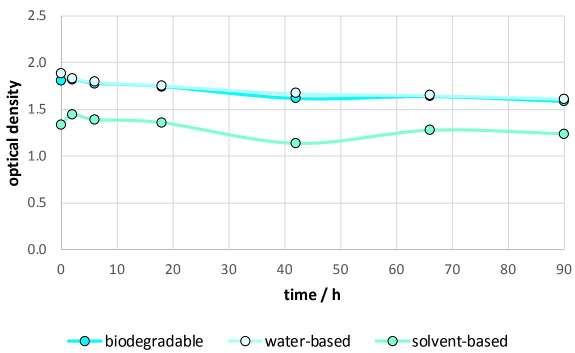


Figure 1. Changes in optical density of the full tone area overprinted PET films depending on the time of ageing a) with UV irradiation b) at elevated temperature

a)



b)

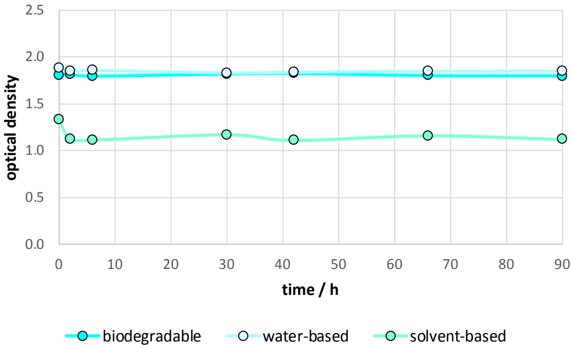
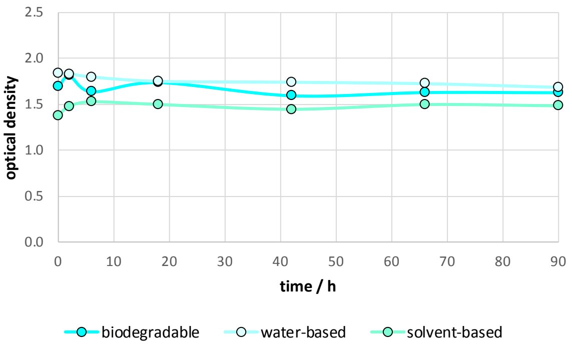


Figure 2. Changes in optical density of the full tone area overprinted BoPP films depending on the time of ageing a) with UV irradiation b) at elevated temperature

a)



b)

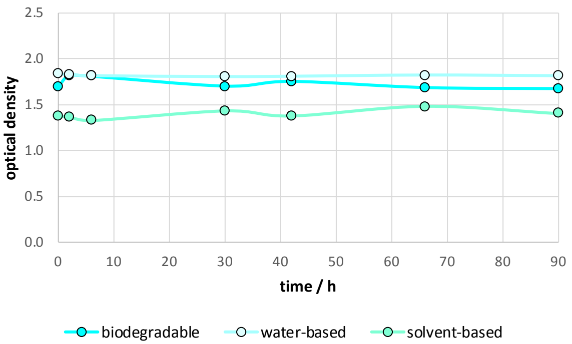


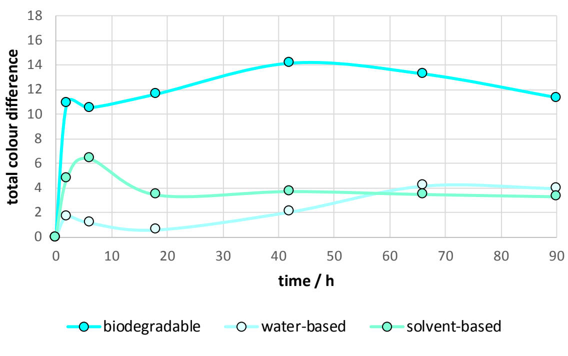
Figure 3. Changes in optical density of the full tone area overprinted PE films depending on the time of ageing a) with UV irradiation b) at elevated temperature

The values of optical density for overprinted PET, BoPP and PE film are comparable. In particular, the values of optical density of prints made by solvent based ink are much lower than for biodegradable and water-based inks, which may be related with lower surface tension and better wettability of solvent based-inks on plastic films. Furthermore, the values optical density values were slightly decreased during ageing, because UV light causes changes in and a reduction of the protective activity of the surface (Bieleman, 2008). However, the elevated temperature does not causes changes in the optical density values.

Prints exposed to prolonged sunlight or radiation emitted from artificial light sources may lead to a change in colour. Figure 3–6 presents the changes in total colour difference, which depended on time of artificial ageing. The total colour difference was calculated from wellknown equation as a difference in colour parameters before ageing and after a certain time. It was expected that ΔE^*_{ab} values would increase with time of artificial ageing.

The fading rate curves of inks and the change of total colour difference, ΔE^*_{ab}, as a function of time indicated that investigated inks are type II. According to (Cristea, 2006). fading initially occurs at a rapid rate followed by a slower fading at a constant rate. Furthermore, the highest resistance to artificial ageing with UV irradiation exhibited overprinted BoPP films and poorest PET films. Additionally, the prints colour are more sensitive to UV radiation than the elevated temperature. However, this both factors, UV radiation and elevated temperature couses changes in the quality of prints – in the colour (ΔE^*_{ab}) and the thickness of the ink layer (optical density).

a)



b)

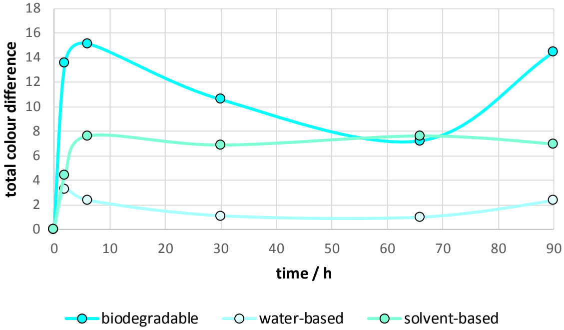
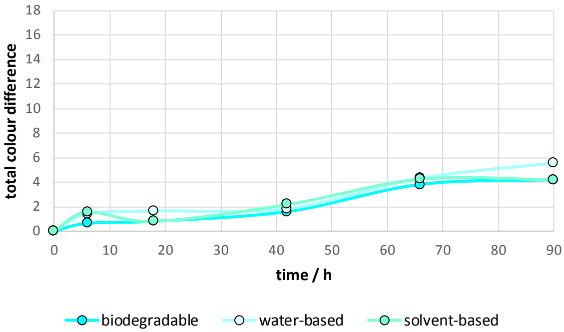


Figure 4. Changes in total colour difference, ΔE^*_{ab}, of overprinted PET films depending on the time of ageing a) with UV irradiation b) at elevated temperature

a)



b)

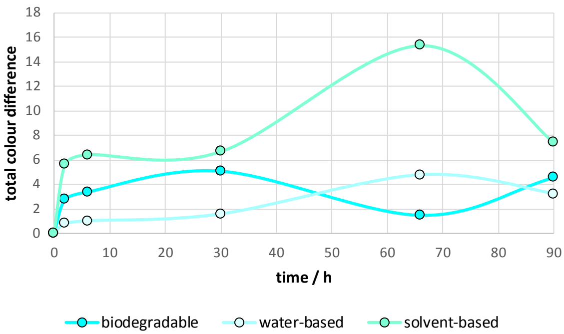


Figure 5. Changes in total colour difference, ΔE^*_{ab}, of overprinted BoPP films depending on the time of ageing a) with UV irradiation b) at elevated temperature

a)

b)

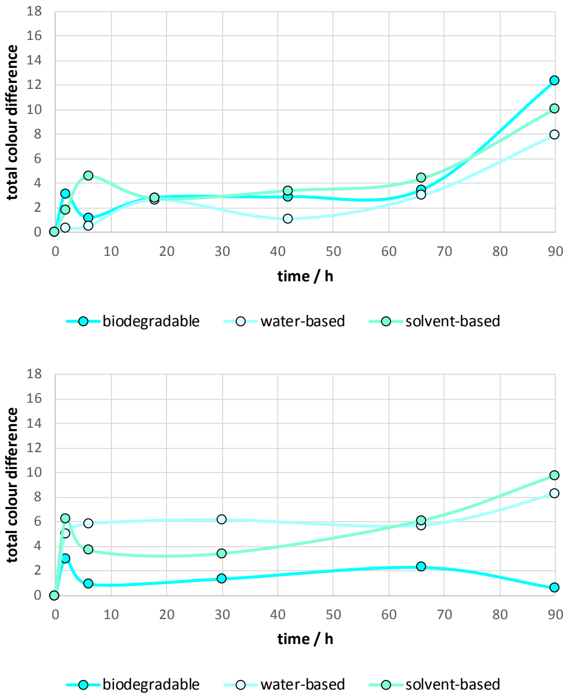


Figure 6. Changes in total colour difference, ΔE^*_{ab} *, of overprinted PE films depending on the time of ageing a) with UV irradiation b) at elevated temperature*

Conclusion

The study has been made to analyse the changes in prints during artificial ageing taking into account two factors: UV radiation and elevated temperature. We have used three various plastic bases overprinted with flexographic printing inks: water-based, solvent based and biodegradable. The period of artificial aging, equivalent to nearly two months of natural aging, caused visible changes in the appearance of the quality of prints. As it was expected, the total colour difference increases with the time of ageing simultaneously the optical density of full tone area decreases with the time of ageing. The changes of print quality during ageing are higher for PE prints than for PET and BoPP prints. Additionally, UV radiation causes major changes in the print quality than elevated temperature.

Reference

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