Comparison of Print Durability in Accelerated Weathering

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Abstract

Many packaging applications set strict demands for printing. When digital printing is used in packaging applications, these demands have to be taken into account. Packages stored outdoors in points of sales in the summer and in some cases even over the winter is a special group of consumer packages. These packages, for example plastic sacks, are exposed to daylight and rain over a long period of time.

*In this article, the results of accelerated weathering test are presented. The test was conducted in order to compare the weather fastness on digitally printed samples and conventionally printed samples. The test was based on the ISO standard that specifies methods for exposing specimens to xenon-arc light in the presence of moisture to reproduce the weathering effects that occur when materials are exposed in actual end-use environments to daylight. In the test series, CIE L*a*b* and densitometric values of the colour test fields were measured. The measurements were carried out in the beginning of the test and several times during the test, approximately every 24 hours.*

Clear differences between digital printing and conventional printing methods were found in the tests. Some samples offered excellent print durability even in harsh test conditions, while other samples faded considerably during the test.

Introduction

The packaging area is special, because there are numerous applications, (consumer and logistical) demands, packaging forms and sizes, (packaging and printing) materials, (printing, converting and packaging) production lines, print quality requirements, food contact challenges, strict demands of legislation, etc. When building a digital package production line, all of these aspects, which are strongly application dependent, have to be taken into account. [1]

However, there are several advantages of using digital package printing and customizing packaging designs, as they offer many ways of adding value to the packaging [1]. Thanks to very flexible digital production, last-minute changes can be made to add relevant, up-to-date and highly focused information on packages, for instance, for different consumer segments. This is a great development, given that the packaging as a means of communication becomes more and more important to making a product desirable to consumers and to selling it. The principal goal of a package as a messenger is to support the product: attract attention to the product, make it desirable, inform about the product, and build a brand relationship. Packaging communication is not only text and images on packages; it refers to all the messages packaging sends to consumers. [2]

The packages stored outdoors in the points of sale in the summer and in some cases even over the winter are a special group of consumer packages. These packages, for example plastic sacks, are subject to long-term daylight and rain exposure. Regardless of the harsh storage conditions, these packages should maintain their original appearance in order to communicate the desired message to consumers.

In order to establish how well packages stored outdoors will maintain their original appearance, an accelerated weathering test series was carried out. The special focus of the test was to establish the differences in weather durability between a conventional flexo printing method and the two main digital printing methods of electrophotography and inkjet. Commonly used commercial packaging plastics were used as substrates in the test and test field were printed on the materials using electrophotography and inkjet. In addition, flexo printed product packages were used in the test series.

The test was based on the ISO standard that specifies methods for exposing specimens to xenon-arc light in the presence of moisture to reproduce the weathering effects that occur when materials are exposed in actual end-use environments to daylight.

Concerning the results obtained, it needs to be remembered that only one electrophotography printer/toner and only one inkjet/ink combination was used in the test, thus, the results do not view these two technologies exhaustively. But we still believe that more general conclusions can be drawn from this single series of tests, because clear differences between digital printing and conventional printing methods were found.

Materials and Methods

Method of exposure and timeframe

The test was based on the International standard ISO 4892-2 Plastics – Method of exposure to laboratory light sources – Part 2: Xenon-arc lamps. ISO 4892-2 specifies methods for exposing specimens to xenon-arc light in the presence of moisture to reproduce the weathering effects that occur when materials are exposed in actual end-use environments to daylight [3].

The exposure was performed according to Method A (Cycle No. 1) described in the in ISO 4892-2. This meant that the exposure period was 120 minutes (102 minutes of dry light exposure and 18 minutes of water spray).

Generally, when consumer product packages, such as pharmaceuticals, household cleaners, or personal-care products, are tested, accelerated weather testing typically lasts from 24 to 96 hours, or even up to five days. Building products such as window profiles, roofing shingles and sidings are commonly subject to three to six months or even longer periods of accelerated weather testing. [4] Because the consumer product packages used in the test were for products which are often kept outdoors, 480 hours of total exposure time was selected.

Samples in the test

The test included 20 samples. These samples were all plastic substrates: plastic sack material and plastic labels. There were six samples of inkjet-printed plastic sacks, five samples of conventionally printed plastic sacks, six electrophotography printed labels, and three conventionally printed labels in the test. All the samples used in the test are listed in Tables 1 and 2.

Table 1: Printed plastic sack samples in the test.

Printing Substrate	Inkjet	Conventional (Flexo)
Plastic sack x 3	all test fields*	
Plastic sack x 3	blue and green test fields	
Plastic sack x 3		black test field
Plastic sack x 2		green test field

*All test fields refers to blue, green, red, black, yellow, magenta and cyan.

Table 2: Printed plastic label samples in the test.

Printing Substrate	Electrophotography	Conventional (Flexo + letter press)
Plastic label x 3	all test fields*	
Plastic label x 3	blue and green test fields	
Plastic label x 3		blue and green test fields

*All test fields refers to blue, green, red, black, yellow, magenta and cyan.

Positions of the samples in the test chamber

The Xenon arc test chamber used in the test was Q-SUN Xe-3 Xenon test chamber. Because the amount of light exposure and the temperature in the chamber can vary in different parts of the test chamber, therefore, the samples were moved after every measurement (approximately 24 hours). This was done in order to compensate for a possible effect of the location of each sample.

Colour measurement

In this test series, CIE L*a*b* values of the colour test fields were measured using a spectrophotometer. In addition, the densitometry values of the test fields were measured with a densitometer. The measurements were carried out in the beginning of the test and several times during the test (approximately every 24 hours). Densitometry values were used as such in the tone value change analysis. The colour changes were determined by using L*a*b* values in the following equation:

$$\Delta E = [(L^*_o - L^*_c)^2 + (a^*_o - a^*_c)^2 + (b^*_o - b^*_c)^2]^{½}$$

in which o refers to the values of the first measurement before the test and c refers to the values measured during the test. ΔE means the distance between two colours in the CIE L*a*b* -colour space.

In practice, the human eye can just see a difference between two colours, when ΔE is 1, and, for example, in common printed products ΔE levels up to 5 can be said to be acceptable, but even larger ΔE differences can often be found. [5]

In addition, the samples were visually evaluated, and if there were any special changes in the samples, a note was made (colour changes visible to the eye, cracking, curling, etc.).

Results

Densitometry measurements

In Figure 1, the values of density measurements during the weather test comparing inkjet-printed and conventionally printed test fields can be seen. The plastic sack material was the substrate in this test. Inkjet-printed fields (blue, green, red, black, yellow, magenta, cyan) practically did not change during the test. Black flexo print was also very weather resistant, but green flexo ink faded quite significantly during the test.

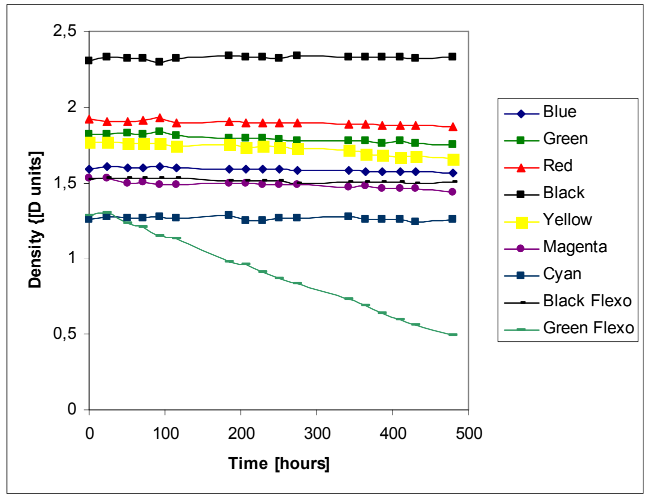

***Figure 1**. Density values for inkjet (blue, green, red, black, yellow, magenta, cyan) and conventionally printed (black, green) test fields on the plastic sack material.*

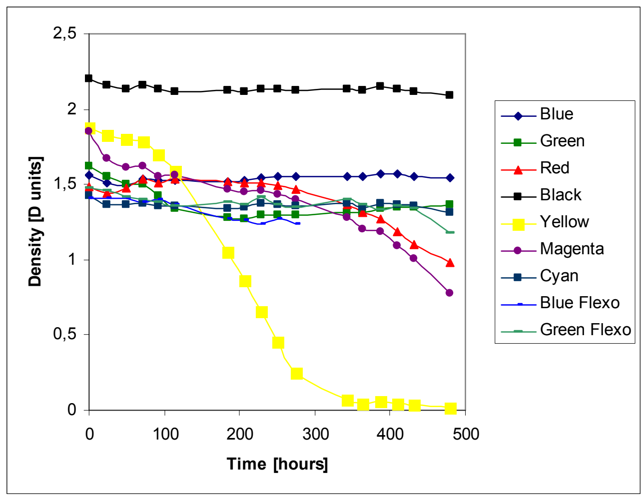

***Figure 2**. Density values for electrophotography (blue, green, red, black, yellow, magenta, cyan) and conventionally printed (blue, green) test fields on plastic label materials.*

In Figure 2, the values of density measurements during the weather test comparing electrophotography and conventionally printed test fields can be seen. Two plastic label materials chosen by the printer were the substrates in the test. Black electrophotographic toner seemed to resist harsh weather conditions very well, but others, such as magenta, suffered from the conditions. Yellow electrophotographic colour faded completely during the test. The green flexo colour test fields endured the test pretty well. The blue flexo colour test field also seemed good, but because of the mechanical breakage of the label material, caused by the weather conditions, colour values could not be measured after 280 hours. The flexo labels in the test were most likely varnished.

Colour change measurements

In Figure 3, the ΔE values during the weather test comparing inkjet printed and conventionally printed test fields can be seen. The plastic sack material was the substrate in this test. The results resemble the densitometry measurements, there are relatively small changes in other colours, but the colour change in the green flexo printed sample is considerable.

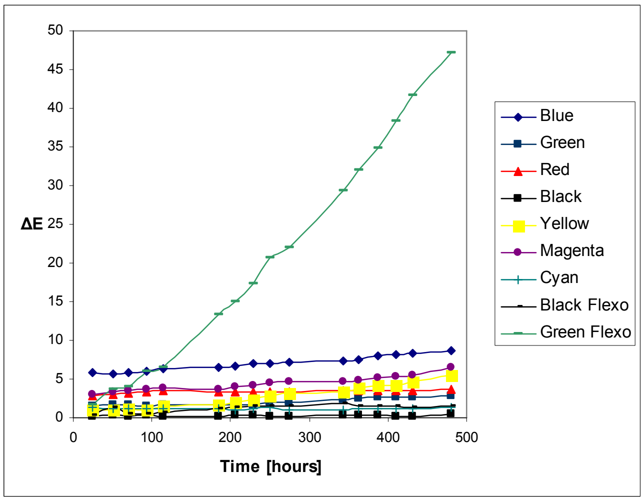

***Figure 3**. ΔE values for inkjet (blue, green, red, black, yellow, magenta, cyan) and conventionally printed (black, green) test fields on the plastic sack material.*

In Figure 4, a*b* values of inkjet-printed colour test fields are presented. The outer lines represent the colour values before the test and the inner lines represent the values after the test. It can be seen that all colour fields maintained their original colours very well.

In Figure 5, the values of ΔE measurements during the weather test comparing electrophotography printed and conventionally printed test fields can be seen. Two plastic label materials chosen by the printer were substrates in the test. The real changes in test fields can be seen here more clearly than when only densitometry values were compared. When ΔE value 5 is kept as the acceptance limit in the change of colour, only black toner passes this level. All other toner colours change significantly. For example, when yellow test field turns white, ΔE value changes from 0 to 110. In addition, for the green test field, when yellow disappears, or turns from green to cyan – a very significant colour change can be noticed.

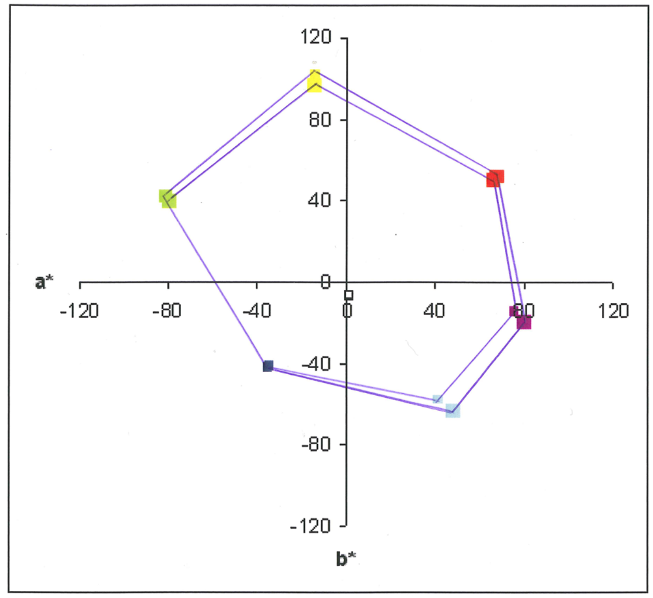

***Figure 4**. a*b* values of inkjet-printed colour test fields on the plastic sack material.*

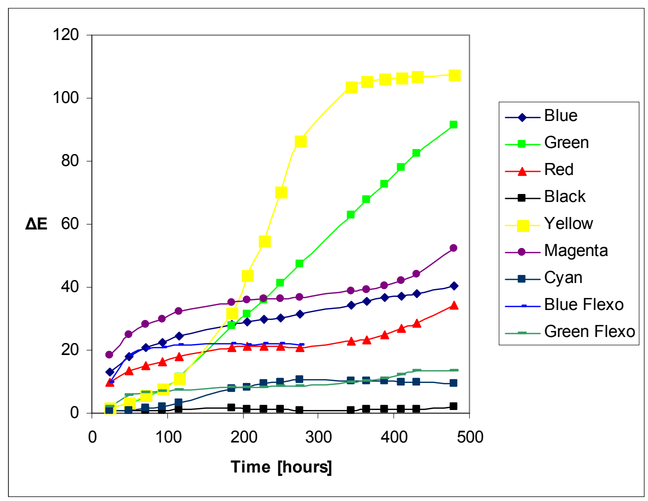

***Figure 5**. ΔE values for electrophotography (blue, green, red, black, yellow, magenta, cyan) and conventionally printed (blue, green) test fields on plastic label materials.*

In Figure 6, a*b* values of electrophotography printed colour fields are presented. The outer lines represent the colour values before the test and the inner lines represent the values after the test. It can be seen that the colour space completely collapsed and of all the original colours, only cyan could be maintained.

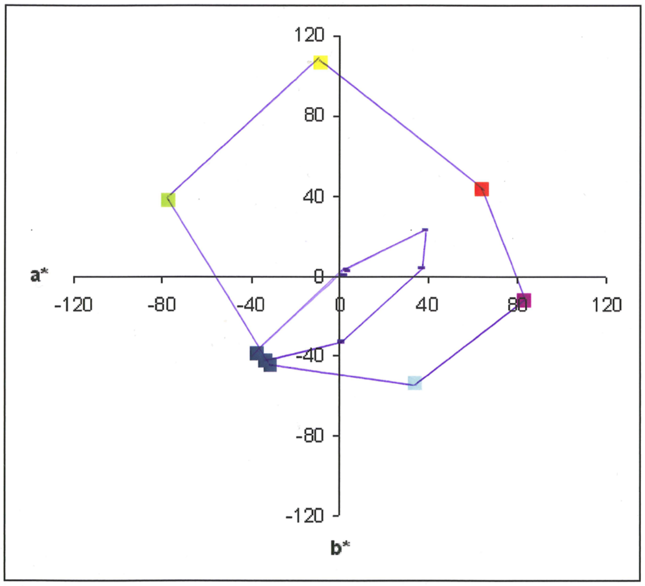

***Figure 6**. a*b* values of electrophotography printed colour fields on plastic label materials.*

Discussion

The colour space of the electrophotography samples collapsed completely during the test. According to this test, electrophotography is not a method for harsh weather conditions. This is most likely partly due to the thermoplastic nature of electrophotography toners, but of course, the selection of colour pigments has its bearing, which was the case with the yellow toner in the test. When packages are printed using electrophotography, it should be remembered that the packages are meant for indoor use and only short-time outdoor storage is allowed.

A complete set of colour test fields printed with flexography was not available, and only sample colours, chosen from a commercial sack and label designs, were used. But even with the small set of colours, it was noticed that black flexo print was very weather resistant. Green flexo colour, on the other hand, faded significantly during the test, which should be kept in mind when flexo printed sacks are stored outdoors over a longer period of time. However, the fading was even over that period of time. In the case of the electrophotography printed label samples, the fading was a more stepped process, and therefore seen as less acceptable.

Inkjet-printed fields practically did not change during the test. This is understandable, because when UV ink is exposed to UV light, it changes due to the photopolymerisation process, mainly into solid plastic. Thus, the test suggests that UV inkjet can be a very good method when weather resistant print is needed.

Conclusions

An accelerated weather test series was carried out to establish the differences in print durability between traditional flexo printing and digital printing methods, electrophotography and inkjet. Clear differences between the printing methods were found in the tests. According to the results, the UV inkjet technology seems to be the ideal printing method for the packages stored outdoors.

References

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Author Biography

Jali Heilmann (MSc) is a Senior Scientist at VTT. In his Master of Science thesis, he developed new research methods for colour electrophotography, but later, his main research has focused on the different applications of inkjet technology. His current research activities incorporate for example technical solutions, uses and appliances for smart packages, new application areas of inkjet, electronic book technology, and other new information carriers like flexible displays. He has also worked as a Visiting Scholar at the University of California, Berkeley. He has published over 140 articles.

Elina Rusko (MSc) works as a Senior Scientist at VTT, and her current research work focuses on packaging development and digital printing applications. She has a Master of Science in Technology; she graduated from the Helsinki University of Technology, Forest Products Technology Department in 2006, where she studied Packaging and Paper Technology.