Lightfastness of Paperboards Coated with UV-Cured Varnish

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Abstract

UV cured varnish is gaining wider acceptance in packaging, as it offers very high gloss and excellent scratch resistance to the surface. Such packages are displayed in retail environments with varying lighting conditions. And it is important to understand the lightfastness of such materials. Two different commercially available UV varnishes have been coated on paperboards manufactured with & without fluorescent whitening agent (FWA). Accelerated lightfastness tests were conducted on those samples and results are interpreted in terms change in CIELAB color coordinates and the shifts in reflectance spectrum. The UV varnished paperboard samples demonstrated a significant yellowing, independently of the presence of fluorescent whitening agents in the paperboard.

Introduction:

The longevity of the visual appearance of a packaged product on the shelves of retail shops has become essential than ever before. Ultra violet (UV) cured overprint varnish on paperboards for packaging is now common, as high gloss levels and superior scratch resistance can be achieved quite economically. Good light stability would make those packages retain their appearance for a longer time.

A considerable amount of work has been done previously towards characterization of paper for improved lightfastness. Usage of papermaking additives like fluorescent whitening agents [9] has been identified as one of the most prominent causes

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which adversely affect the light stability of paper. This happens due to a fall in FWA efficacy [14] over prolonged exposure to UV radiation. The FWA dosage level [9] in the papermaking process is also known to have significant influence upon the light stability of paper. The usage of FWAs in conjunction with other ultra violet light absorbing agents [15] like metal cations (Ca & Mg), alum and TiO2 further reduces the FWA excitation.

One study of lightfastness [17] reports significant loss of color gamut volume of prints on papers containing FWA. They have also reported the ineffectiveness of UV protective overprint coating [17] to inhibit loss of gamut volume due to the fading of FWA papers. However the contribution of UV coating has not been distinguished from that of FWA in papers in affecting the fading behavior. Therefore this study aims to explain the lightfastness behavior of the final package, where fading could be a consolidated impact of both UV varnish and paper.

Experimental:

To achieve this goal, experiments have been conducted in three folds. The first phase was aimed at studying the lightfastness of unvarnished plain paperboards made with and without FWA, while the second phase studied the lightfastness of the same set of paperboard samples after UV varnishing. Two different commercially available UV varnishes have been chosen for this purpose. And in the third phase, the lightfastness of UV varnish alone was studied by applying varnish to the synthetic substrate Tyvek [5]. All the samples were subjected to accelerated lightfastness testing for 72 hours and the results are interpreted in terms of the change in CIELAB colour coordinates and also the shifts in reflectance spectra.

Two sets of uncoated Solid Bleached Sulphate (SBS) [3] paperboards of basis weight 170 g/m2, manufactured on the same paper machine under identical conditions, were chosen. Those samples are very similar in terms of fiber furnish (100% bleached chemical pulp), fillers (talcum), internal sizing (rosin & alum) and surface sizing (oxidized starch). One of the samples is FWA free, while the other contains high levels of FWA (make – Tinapol [10], dosage– 6 kg/mt, point of addition – wet end).

In the first phase of experiments, the two sets of paperboard samples have been subjected to a fading test using a Verivide[16] viewing cabinet under two D65 lamps of 65 watts each and one ultra violet lamp of 18 watts for 72 hours. CIELAB coordinates and reflectance spectra were measured using a L&W Elrepho[2] spectrophotometer at 12-hour intervals. The light source is pulsed xenon lamp and the illumination corresponds to CIE illuminant C and D65 with no UV blocking filters. CIE illuminant C has been used for measuring CIELAB values and D65 for reflectance spectra. The elrepho spectrophotometer used has a traceable calibration in accordance with the ISO's standard for photometric calibration (IR3 in accordance with provisions of ISO 4094) and UV calibration at level C and D65.

Before taking measurements the calibration was checked using standard tiles (FL 1496 and White 1496/A). The reflectance readings at all the wavelengths were found to be within the allowable tolerance of 0.1 from the reference values.

In the second phase, UV cured overprint varnishes of two different makes (referred as varnish S and varnish A) [6, 7] were applied to both the sets of paperboard samples. The varnishes were applied using a laboratory scale bar coater and the varnish coat weight was maintained at 2 g/m2. Since UV cured varnishes employ radiation polymerization for drying [4, 8] the varnished paperboard samples were put through a Prufbau UV curing chamber [1] for drying (2 x 1kW lamps) with a 25-second dwell time under each lamp. The UV lamp emission was over the range (180-410 nm). A lightfastness test was carried out on the varnished paperboard samples after curing and CIELAB & reflectance spectra were measured at 12-hour intervals as in phase one.

In the third phase, experiments were performed to study the lightfastness of UV varnish alone. This entailed identifying substrates that have a high degree of lightfastness. The ability of Tyvek synthetic substrates to endure prolonged exposure to light without fading made it a natural choice. The light enduring ability of Tyvek substrate was corroborated by performing a lightfastness test. UV varnish application, curing, fading tests and color values measurements of varnished Tyvek samples were carried out in a similar manner to the previous experiments in phases one and two.

Results and Discussion:

As expected unvarnished plain FWA free paperboard samples have shown minimal change in color values on continuous exposure to light inside the chamber.

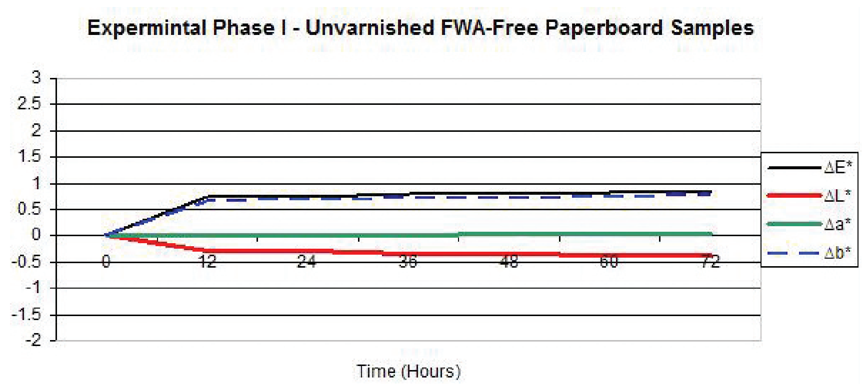


Figure 1: *Experimental Phase I - Change in CIELAB values for plain unvarnished FWA free paperboard sample.*

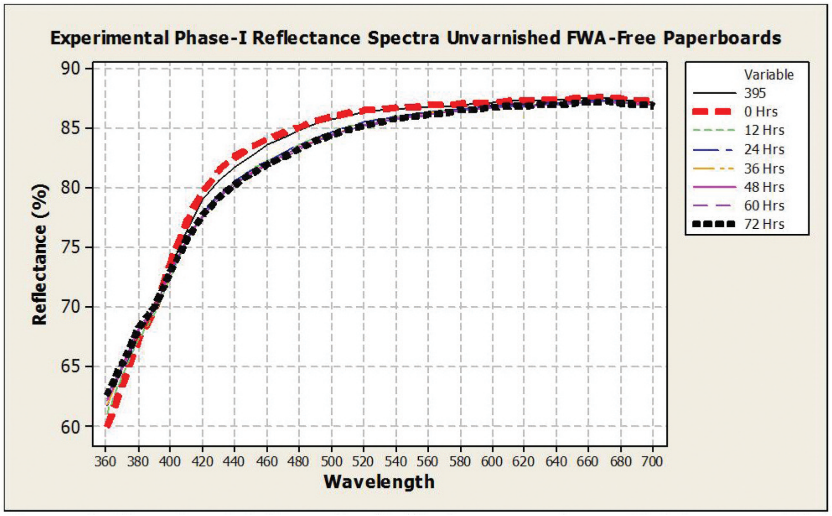


Figure 2: Experimental Phase I - Reflectance spectrum of plain unvarnished FWA free paperboard sample.

A marginal fall in reflectance values in the violet -blue region of the spectrum is observed after 72 hours of continuous exposure to light. By comparison, the lightfastness test on unvarnished plain paperboard samples containing FWA revealed significant change in the color values.

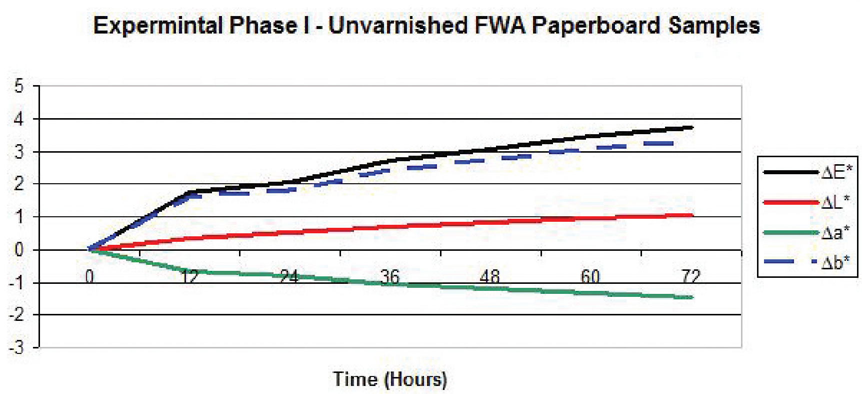


Figure 3: Experimental Phase I - Change in CIELAB values for unvarnished Paperboard samples containing FWA.

With FWA-containing samples, a higher reflectance in the blue region and reduced reflectance in the green region is observed initially. A possible explanation of such a behavior could be a "greening" effect [15] caused by over dosage of FWA. At low FWA dosage rates, the majority of adsorbed FBA molecules are isolated and non-interacting. However at high FWA dosage rates most of the available binding sites are occupied, causing formation of dimers and surface aggregations. Both absorption and emission bands are shifted to longer wavelengths for aggregated FWAs. Absorption in the violet-blue region with emission in the blue-green range contributes to the greening effect. The observed fall in reflectance in the blue region and increase in the green region of the spectrum following prolonged exposure to light is believed to result from a reduction in FWA efficacy.

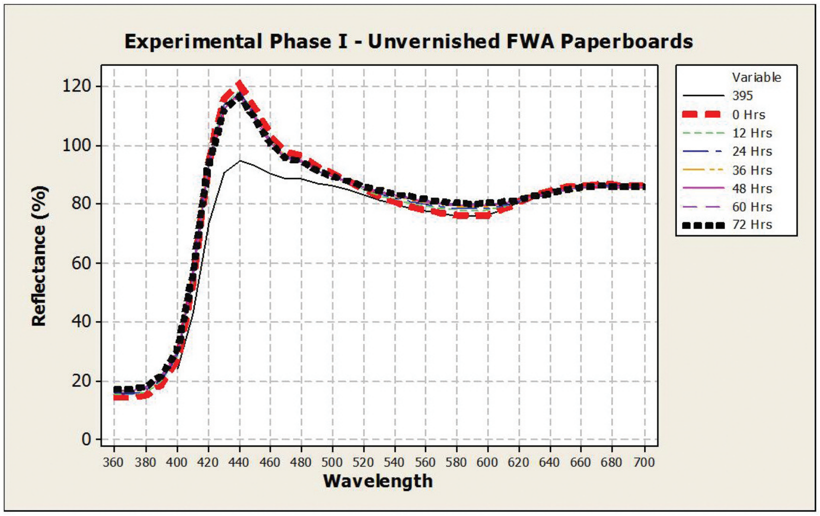


Figure 4: *Experimental Phase I - Reflectance spectrum of plain unvarnished paperboard samples with FWA.*

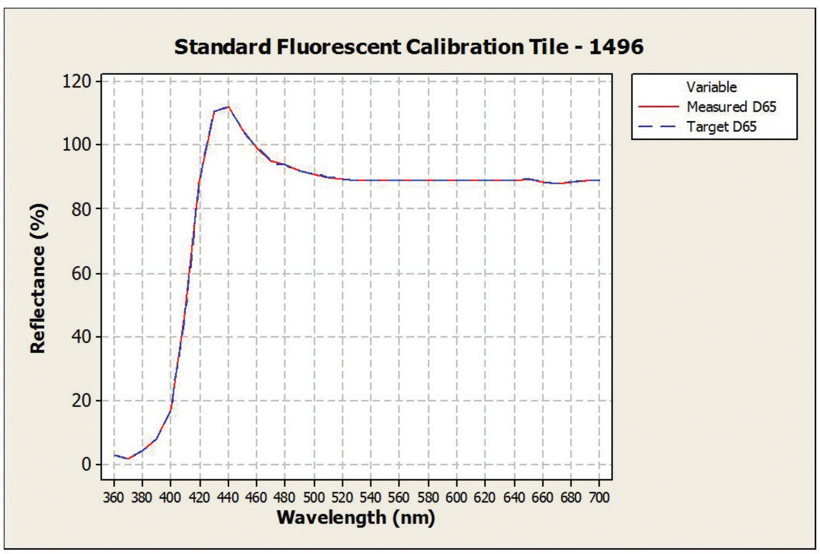


Figure 5: *Comparison of measured reflectance spectrum of standard fluorescent calibration tile with calibration data for the tile.*

Significant changes in color coordinates were seen after continuous exposure of UV varnished paperboard samples. Both makes of UV varnishes show this phenomenon on paperboard samples both with and without FWA. A major shift in the CIELAB b* value towards yellow is manifested as a visible yellowing effect.

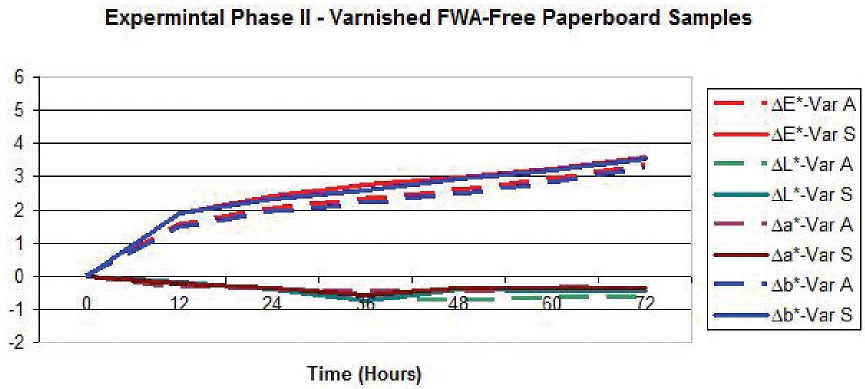


Figure 6: *Experimental Phase II - Change in CIELAB values for FWA free paperboard samples after UV varnishing (both varnish A and S).*

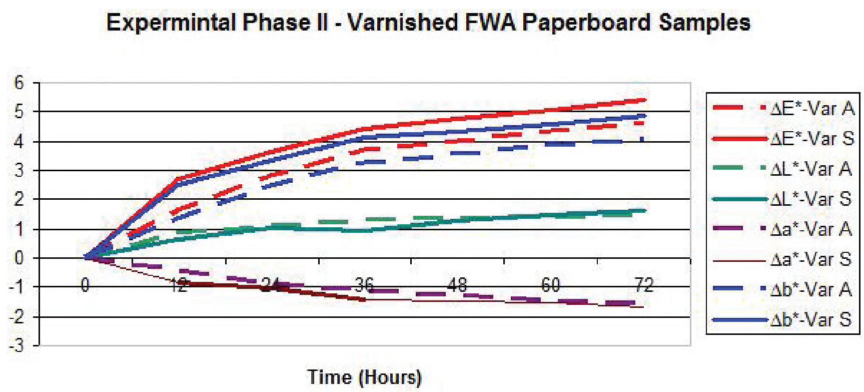


Figure 7: *Experimental Phase II - Change in CIELAB values for FWA paperboard samples after UV varnishing (both varnish A and S).*

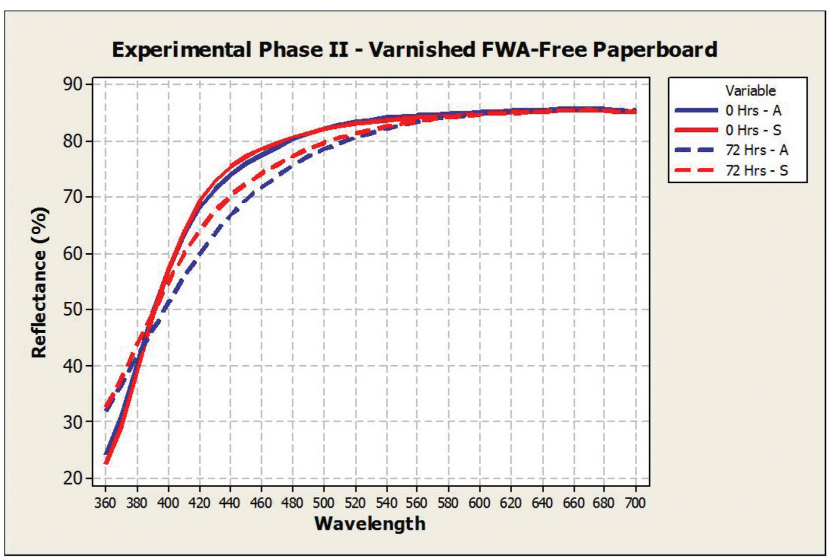


Figure 8: *Experimental Phase II - Reflectance spectrum of varnished FWA-free paperboard sample.*

After conducting a lightfastness test upon varnished FWA-free paperboard samples, significant drop in the violet-blue reflectance has been noted. Though marginal, the same tendency was observed after fading of unvarnished plain FWA-free paperboard samples.

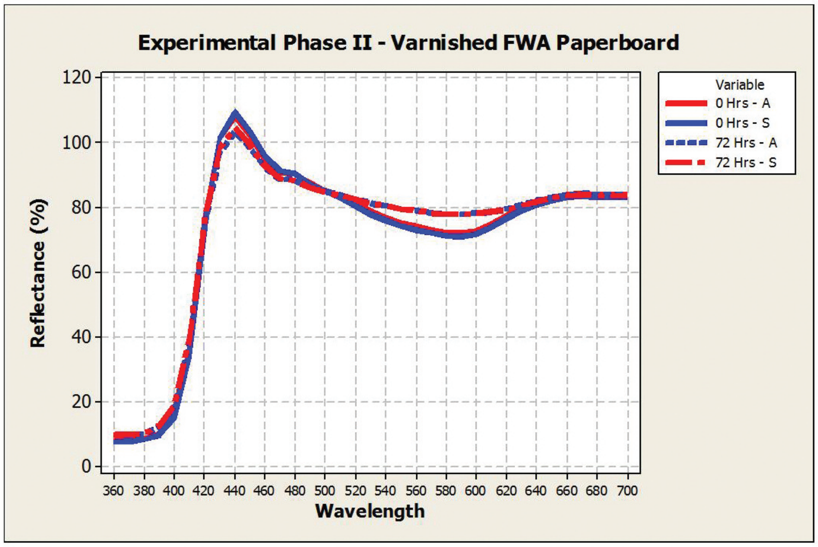


Figure 9: *Experimental Phase II - Reflectance spectrum of varnished FWA paperboard sample.*

Further experiments have been carried out upon light stable Tyvek synthetic substrates for substantiating the contribution of UV varnish alone towards the overall yellowing tendency of varnished paperboard samples. The lightfastness test on plain unvarnished Tyvek substrates suggests excellent fading resistance of Tyvek.

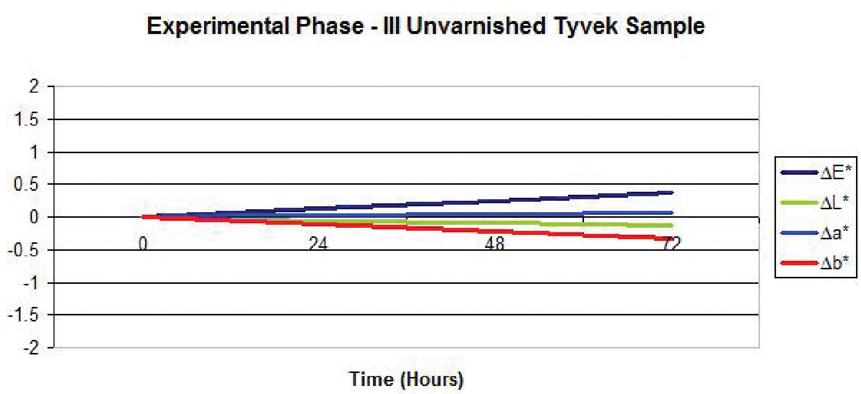


Figure 10: *Experimental Phase III - Change in CIELAB values for unvarnished plain Tyvek.*

Tyvek substrates demonstrate a marginal reduction in b* value upon exposure to light, which is unlike paperboard samples. The reason for this is not known.

Though Tyvek substrates demonstrate good light stability, a significant change in the color coordinates, especially in the b* value, has been witnessed after fading upon UV varnished Tyvek substrate.

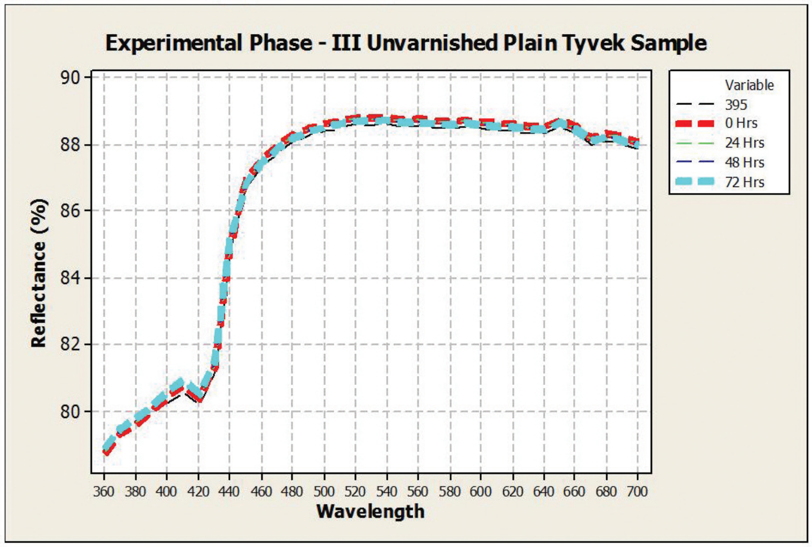


Figure 11: *Experimental Phase III - Reflectance spectrum of unvarnished plain Tyvek substrate.*

A larger change in violet-blue reflectance values, compared to other regions of the spectrum, has been observed after putting UV varnished Tyvek samples through the fading test.

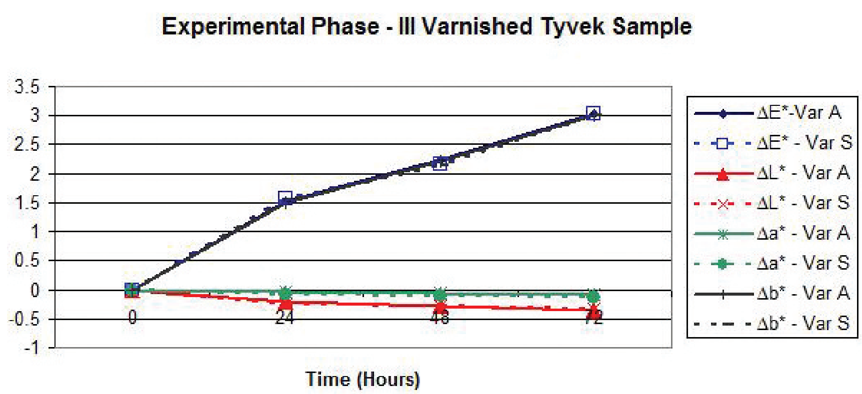


Figure 12: *Experimental Phase III - Change in CIELAB values for Tyvek samples after UV varnishing (both varnish A and S).*

The shift of reflectance spectrum shown in Figure 13, after subjecting varnished Tyvek substrate to the fading test, can thus be attributed to the change in UV varnish alone.

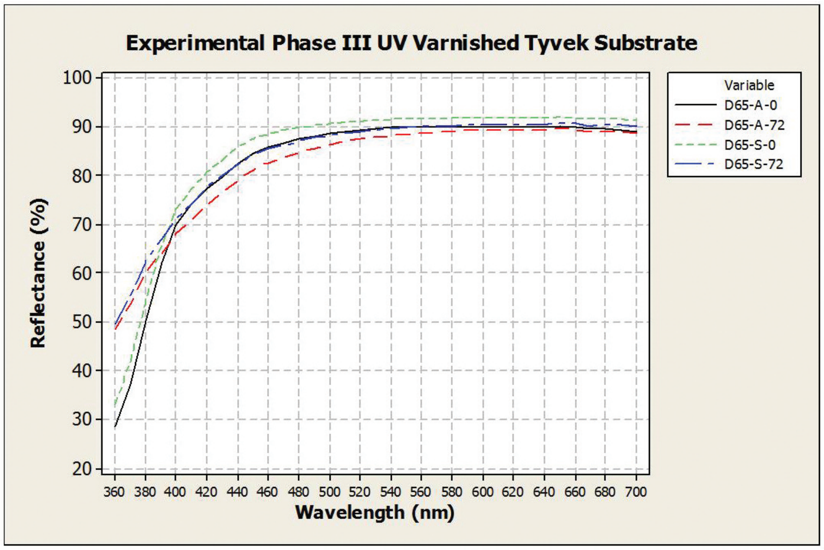
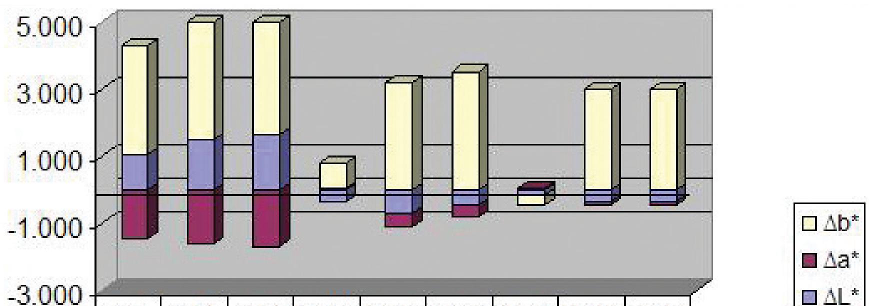


Figure 13: *Experimental Phase III - Reflectance spectrum of UV varnished Tyvek substrate.*

CIELAB ΔL*, Δa*, Δb*



	FWA-Plain	FWA & Var A	FWA & Var S	No FWA-Plain	No FWA & Var A	No FWA & Var S	TYVEK PLAIN	TYVEK & Var A	TYVEK & Var S
Δb*	3.265	4.050	4.875	0.770	3.225	3.527	-0.334	3.010	3.005
Δa*	-1.445	-1.585	-1.680	0.050	-0.400	-0.350	0.060	-0.095	-0.125
ΔL*	1.030	1.495	1.630	-0.360	-0.680	-0.450	-0.130	-0.355	-0.330

Figure 14: *Change in CIELAB values for all the experimental combinations.*

Conclusion:

The individual contributions of UV cured varnish and FWAs in paper to the lightfastness of varnished paper-boards, has been analyzed in this work. While FWAs are known to affect the light stability of paper, UV cured varnishes either used independently or in conjunction with FWA in paper, have been identified as a potential source of poor lightfastness and consequent yellowing of the final product. The theoretical explanation of the mechanisms responsible for this tendency is not known at this time, and future work is planned to further understand the problem.

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