

## EFFECT OF AGING ON THE AESTHETIC AND DECORATIVE FEATURES OF THE INNOVATIVE SALIXDUO PRODUCT FINISHED WITH ACRYLIC AND POLYURETHANE LACQUERS

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### ABSTRACT

An innovative research material called "Salixduo" was developed and patented as part of an ongoing shrub willow wood rods project. With a view to the final use of this product, it was decided to conduct aging tests of the finished product.

Two acrylic and one polyurethane lacquer were selected for testing. Their application by pneumatic spray in the form of two coatings was carried out in the technology laboratory of a leading manufacturer of lacquer products. After 28 days of seasoning under laboratory conditions (temperature 20±5°C and relative humidity 65±5%), the parts were cut into samples for aging tests. The coatings were then exposed to UV radiation, UV+IR radiation, and varying humidity and temperature acc. to the AMK procedure as a function of time. The parameters evaluated were appearance, color, and gloss.

Gloss testing of lacquer coatings was performed by a photoelectric method using a TESTAN DT-G268 gloss meter according to PN-EN ISO 2813:2001. Measurements were made at three angles of incidence of light at ten randomly selected locations in the direction along and across each sample.

The color determination was determined with a DT-145 colorimeter, using a CIELab measurement system equipped with a daylight illuminator and 45°/0° directional measurement geometry. Ten measurements were taken on each sample before and after application of varnish. They were carried out always in the same places, thanks to the marked measuring areas.

Based on the results of the tests, the most significant effect on changes in color and degree of gloss was found after exposure to UV, followed by UV+IR.

**Key words:** Salixduo, acrylic and polyurethane lacquer, aging, colour.

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### INTRODUCTION

In case of a shortage of wood on the market, alternative raw materials from, among others, fast-growing tree and shrub plantations are sought. One of the more popular species used for plantation crops is shrub willow (Boruszewski i in. 2021). This raw material is a valuable renewable energy source that corresponds to the sustainable development strategy. In addition to its ecological importance, it is used, among other things, for braiding and decorative purposes

in landscaping, in producing wood-based panels (Waliszewska i in. 2013, Warmbier i in. 2013, Goliński i in. 2016, Sandak i in. 2017, Sobczyk i Sobczyk 2019, Boruszewski i in. 2021, Konatowska i in. 2021, Stankova i in. 2022). One of the more interesting possibilities for using willow is to create a composite as an alternative to wood products. In 2021, as part of the Ministry of Education and Science's Science for Society programme entitled 'Science for Society for the 'Innovative shrub willow product for the wood industry, ' work began on using willows for furniture applications. A technology was developed as part of the ongoing work, and an innovative material made of consolidated *Salix viminalis* wood rods called "Salixduo" was patented. A unique appearance characterises the resulting product. Different visual effects can be achieved depending on the species, the age of the willow, and how they are prepared for the composite manufacturing process. This makes it a very original material for designers to create uncommon furnishing products. To preserve the beauty of this raw material, its surfaces should be protected with varnish products.

This study investigated the aesthetic and decorative properties of Salixduo treated with lacquers based on acrylic and polyurethane polymers as a function of accelerated ageing tests.

## EXPERIMENTAL METHODS

### MATERIALS

Salixduo from willow wood rods made by the Research and Development Centre of the Wood-Based Panels Industry in Czarna Woda were used for the tests. Before varnishing, the surfaces of the samples were treated by sanding using successively numbered abrasive paper: P100, P120 and P150. Two waterborne varnishes based on acrylic dispersions (AC2 and AC4), and a solvent-borne polyurethane varnish (PUR 2) were selected for the planned experiments. The products were applied in the Remmers Technical Centre (temp.  $23\pm 2^{\circ}\text{C}$  and RH  $50\pm 5\%$ ) by applying two layers to the substrate. In between, inter-layer sanding was carried out using P400 numbered abrasive paper. The samples were then air-conditioned for 28 days, after which the aesthetic and decorative characteristics were tested in terms of 3 accelerated ageing tests. Aging procedures:

- Cycles of changes temperatures and RH acc. to AMK-MB-005 (performing measurements for 3, 5 and 10 cycles):

- 0.5 h cooling to  $-20^{\circ}\text{C}$
- 1 h freeze-thaw at  $-20\pm 2^{\circ}\text{C}$
- 0.5 h thawing to approx.  $20^{\circ}\text{C}$
- 3 h storage at  $20\pm 2^{\circ}\text{C}$  and RH  $85\pm 5\%$
- 0.5 h heating to  $60^{\circ}\text{C}$
- 3 h heating at  $60\pm 2^{\circ}\text{C}$  and RH  $55\pm 5\%$
- 0.5 h cooling to approx.  $20^{\circ}\text{C}$ .

- Simulated UV-IR in conditions acc. to PN-88/F-06100/08 standard, for 3, 5 and 10 hrs (quartz lamp type VT 800 with a power of 740 W).

- Simulated conditions in the SOLARBOX 1500 model 522 chamber, UV wavelength 280 nm, energy of radiation –  $550 \text{ W/m}^2$ , BST –  $65^{\circ}\text{C}$ , carried out measurements at every 3, 5 and 10 hrs.

The appearance of coatings was evaluated by PN-88/F-06100/01 standard guidelines.

Colour measurements were carried out with a colourimeter DT-145, recording the coordinates in the CIELab system. The ranges in Table 1 were used to interpret the colour difference between the samples ( $\Delta E$ ) before and after ageing.

**Table 1: Range of  $\Delta E$  values indicating colour change**

Interval Variation	Colour difference
$0 < \Delta E < 1$	Invisible
$1 < \Delta E \leq 2$	Very small, recognizable only by an experienced observer
$2 < \Delta E \leq 3,5$	Medium, recognizable also by an inexperienced observer
$3,5 < \Delta E \leq 5$	Clear
$\Delta E > 5$	Large

Gloss was tested using the photoelectric method with apparatus DT-268 PN-88/F-06100/02 standard by performing measurements at various angles of light incidence along and across. The gloss degree in verbal form was determined according to a scale (Table 2).

**Table 2: Classification of gloss levels at a light angle of 60° including verbal evaluation**

Gloss degree	Verbal form
< 10	Mat
10 – 35	Semi-matte
35 – 60	Semi-gloss
60 – 80	Gloss
> 80	High gloss

## RESULTS

Salixduo submitted for testing was characterised by its attractive and striking appearance. However, the willow rods did not always adhere perfectly to each other along the entire length of the Salixduo and voids (discontinuities) or areas filled with the bonding binder – occurred between them.

Evaluation of the surface of the samples immediately after application of the varnish products showed their beneficial effect on the appearance of the substrate. The varnishes applied enlivened the natural grain of the substrate. Despite the imperfections of the substrate, there were no defects on the coatings as a result of the application in the form of craters, blisters or streaks. This demonstrates that the application steps of the individual paint product layers were carried out correctly.

Colour changes of the tested finishes including the adhesive located in the discontinuities of the substrate were noted. In the case of the Solarbox test, a livening up of the systems with PUR2 coating was observed, while with AC2 a less saturated colour was noticed, which gave the impression of a slightly muted colour. The changes assessed visually were then confirmed using an instrumental method. The colour assessment was based on the parameter characterising the total colour difference ( $\Delta E$ ). Fig. 1 shows the values after 10 ageing cycles.

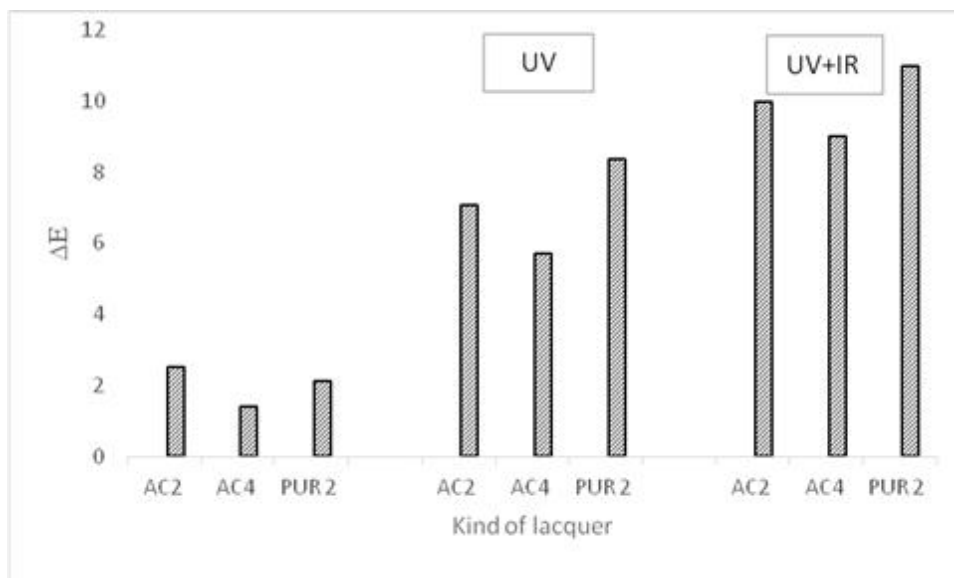


Figure 1: Development of the  $\Delta E$  parameter after 10 ageing cycles

The criterion in Table 1 was used to discuss the results. In general, the final result of the colour perception of the tested samples was influenced not only by the used kind of lacquer, but also by the type of willow rods, the surface structure (roughness), the proportion of the adhesive used to form the tested composite, which was subject to pronounced discolouration. These relationships may have influenced the colour values recorded. The greatest changes were recorded after UV radiation tests, i.e. after Solarbox and UV+IR, as the radiation passed through transparent systems. It can be assumed that in the case of UV exposure, the resulting discolouration is the cause of photochemical degradation of both some substrate components and varnish products. In the experiment, after one ageing cycle, the values obtained indicated noticeable colour changes visible to an inexperienced observer. After further exposures, a further increase in the value of this indicator was recorded. The highest change tendency for this parameter was recorded for the PUR2 finish. In the case of the AMK test, the colour change process was slower and after two ageing cycles, a level noticeable only to an experienced person was achieved. Again, greater differences were registered for measurements on the PUR2 finish than on the acrylic varnishes. In the case of the AMK test, the colour change process was slower and after two ageing cycles, a level noticeable only to an experienced person was achieved. Again, greater differences were registered in the PUR2 coating than in the acrylic varnishes. At the end of the last aging cycle, the evaluated parameter exceeded the level of two units, making a noticeable difference for an inexperienced observer in the finish with PUR2 and AC2. In this case, PUR2 achieved a level 0.4 units lower than the coating with AC2. Overall, the coatings in terms of colour stability under the various ageing tests can be ranked as follows (from highest to lowest): AC4>AC2>PUR2.

The results of the gloss level tests for the finishes considered in the study after 10 ageing cycles are shown in Figures 2–3.

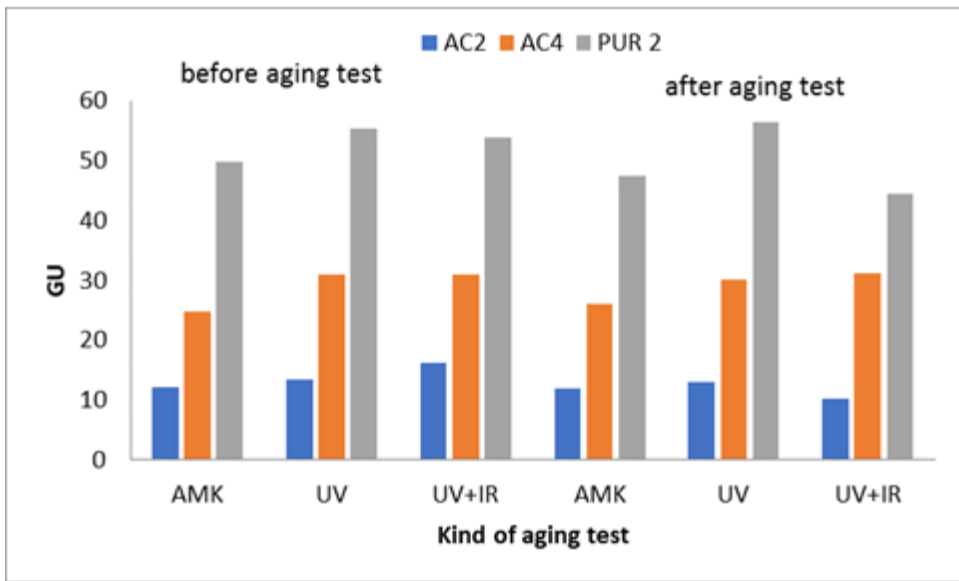


Figure 2: The course of the gloss degree along the sample at an angle of 60°

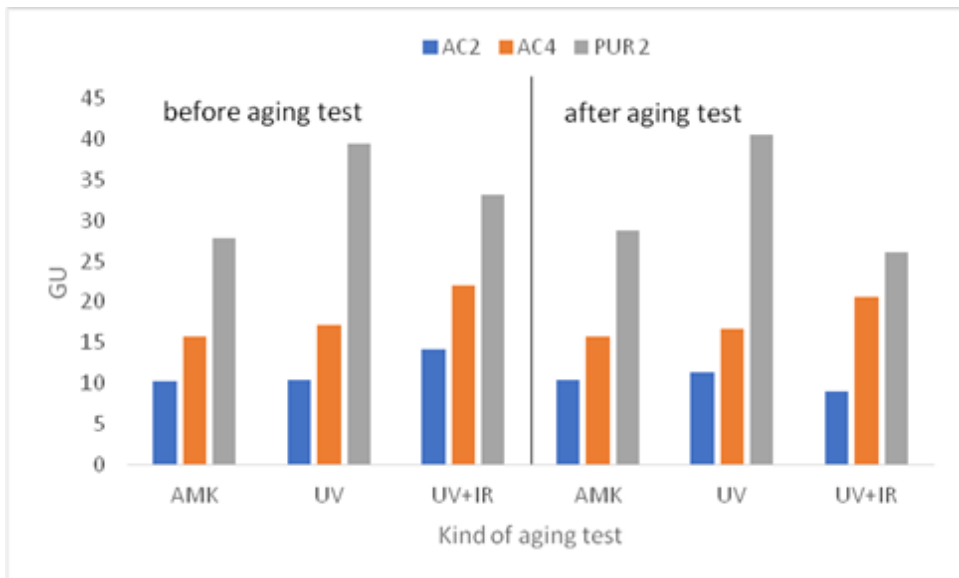


Figure 3: The course of the degree of gloss across the sample at an angle of 60°

The results obtained were characterised by a varied coefficient of variation  $v$  in the range of 3.0-44.4. A high value indicates large differences between the samples, indicating their heterogeneity. There was also a significant scatter of results for each sample tested. It should be mentioned that the degree of gloss is significantly influenced by the specific nature of the substrate surface, which causes additional scattering phenomena of the incident light. Undoubtedly, the results obtained were affected by voids in the substrate, areas filled with the binding agent – adhesive or changes in the smoothness of the surfaces protected after application.

These factors may have led to changes in the scattering of incident light on the surface. Variations in the values obtained were also found during exposure to different ageing conditions.

In general, a higher gloss of the coatings was obtained by measuring along the fibres than across them. Analysing the average values according to the criterion in Table 1 obtained at an angle of 60° on the control coatings formed from AC2 and AC4, the parameter in question was assessed as semi-matt regardless of the direction of measurement. The exception was the AC4 sample exposed to UV+IR for 3h for which the value slightly exceeded the range giving a semi-gloss. The PUR2 coating was classified as semi-gloss, while semi-matt/semi-gloss was recorded across the sample, which was reported to be due to differences in light scattering caused by the quality of the substrate. Variations in the recorded values were noted concerning the control samples during ageing. However, the same verbal evaluation was obtained in most cases. During ageing in the AMK and Solarbox test conditions, the systems with AC2 and AC4 remained stable. In the UV+IR test, after 10h of ageing, this parameter was slightly reduced in the measurements across the sample with AC 2 coating, classifying the surface to matt. In contrast, a value in the borderline was obtained along the fibres.

For PUR 2 varnish finishes, the ageing tests did not affect the development of this parameter in measurements along the sample, while across the length of the sample, it decreased to semi-matt regardless of the ageing time after the UV+IR test, after 5 and 10 cycles of the AMK test and after 3 and 5h after the Solarbox.

## CONCLUSIONS

1. As a function of ageing, the greatest colour changes were observed after UV (Solarbox) and UV+IR tests. In the case of the AMK test, the colour change process was slower. In terms of colour stability under different ageing tests, the following can be ranked (from highest to lowest):

AC4>AC2>PUR2

2. The gloss tests of the coatings showed a higher degree of gloss when measured lengthwise than crosswise. Coatings with AC2 and AC4 were rated semi-matt regardless of the measurement direction. PUR2 finishes, on the other hand, were classified as semi-gloss, while semi-gloss/semi-gloss was recorded transversely. Variations in the recorded values were noted during ageing. However, the same verbal rating was obtained in most cases.

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