Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 88, 2014: 287-291
(Ann. WULS - SGGW, For. and Wood Technol. 88, 2014)

Comparative studies of ipe (*Tabebuia* spp.) wood photodegradation caused by treatment with acid and alkaline buffers

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Abstract: *Comparative studies of ipe (Tabebuia spp.) wood photodegradation caused by treatment with acid and alkaline buffers.* A study on photodegradation of ipe wood using xenon lamp and UV lamp light has been carried out. Colour of the samples was measured using a Datacolour 600 spectrophotometer prior to their soaking in acid and alkaline buffers, after soaking and successively after 1, 5, 10, 25, 50 and 100-hour irradiation. It was concluded that the treatment with acid and alkaline buffers causes opposite changes of the investigated colour coordinates. Samples after treatment with the acid buffer were lighter and yellower in colour, but less red, while after treatment with the alkaline buffer they were darker and redder, bur less yellow. Generally treatment with the alkaline buffer caused more significant changes of ipe wood in comparison to treatment with the acid buffer. Samples treated with the acid buffer were more prone to changes of colour (ΔE^*) due to light irradiation in comparison to the samples treated with the alkaline buffer. More significant changes of colour were observed in the case of UV irradiation in comparison to irradiation cause by xenon lamp light.

***Keywords*:** ipe (*Tabebuia* spp.) wood, photodegradation, acid buffer treatment, alkaline buffer treatment, xenon light, UV light

INTRODUCTION

Ipe, the common name for the lapacho group of the *Tabebuia* genus, consists of more than 100 species of trees, naturally found in South America. The colour range varies considerably based on where it grows. It can vary from a light yellowish tan colour with greenish overtones to an almost blackish brown with light or dark streaks. These species are commonly used as construction material for external structures, stairs and parquets, because they are exceptionally resistant to degradation caused by termites and fungi (Scheffer and Morrell 1998). However, the colour of ipe wood may change as a result of coating with varnish or oil paints and light irradiation (Jankowska 2011). Artificial light sources (xenon lamps, UV lamps, mercury vapour lamps) are often used in experiments to clarify the mechanism of wood photodegradation. The spectrum of light emitted by a xenon lamp (290-800 nm) is similar to that of the Sun. An important role in changes of wood colour is played by the reaction of coatings (Zborowska et al. in press).
The aim of this study was to determine changes in colour of ipe wood treated with acid and alkaline buffers and then exposed to xenon and UV lamp irradiation resembling solar light found outdoors.

MATERIAL AND METHODS

Preparation of samples

The investigated material was ipe wood (*Tabebuia* spp.) Samples of 40 × 15 × 5 mm (±1 mm) (long. × tang. × rad.) were prepared from the same board. They included both early- and latewood. Tested samples were polished with sandpaper (400 P) prior to the experiment. Then they were divided into 3 groups. The first group comprised the control, while the second and third groups consisted of samples soaking in acid (pH = 4.0) and alkaline (pH = 10.0) buffers. Buffer treatment lasted for 24 hours and it was performed under laboratory conditions (23°C, 45 RH). After treatment the samples were dried at 40°C for 24 hours.

2.2. Light irradiation

Light irradiation was carried out with an ATLAS apparatus equipped with UV lamps with a wavelength range of 290 – 400 nm and a SUNSET CPS apparatus equipped with xenon lamps with the range of emission at 290-800 nm. The UV and xenon lamps emitted ultraviolet light resembling solar light found outdoors. The intensity of UV-A light projected onto the tested surfaces was 0.5 W/m^2 and that of xenon lamps was 550 W/m^2. The temperature of Black Panel (BPT) in both cases was 38°C. Irradiation was carried out under air atmosphere. The total irradiation time was 100 h in all cases.

Colour measurements

All the colour measurements were taken on the radial surface of the samples. The samples (the control and after treatment in acid and alkaline buffers) were analysed before and after irradiation. The light treatment was interrupted after 5, 10, 25, 50 and 100 hours of irradiation to acquire data. Colour coordinates in the CIE L*a*b* system of wood were recorded with the Datacolour 600 spectrophotometer, using the D_{65} standard illuminant and a 10° standard observer. The sensor head diameter was 10 mm. The measurement of colour coordinates L*, a*, b* and evaluation of colour changes were performed on 3 samples per each variant. Three points of fixed locations were measured on each sample. Data, listed in this study, is the average of 9 replicated measurements.

Colour change in the CIE Lab system was calculated according to the following formula:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where:

ΔE* – colour change,

L* – achromatic coordinate (brightness),

a*, b* – chromatic coordinates.

Colour coordinates of ipe surface before and after 24h treatment with acid and alkaline buffers, as well as before and after light irradiation were referred to the white standard (L = 96.29, a = - 0.34, b = 1.25).

RESULTS

Figure 1 shows values of changes in colour coordinates (ΔL*, Δa*, Δb*) and the colour ΔE* of the control ipe wood samples and the samples after treatment with acid and alkaline buffers in comparison to the white standard. It was observed that treatment with the acid buffer brightened, while the alkaline buffer darkened ipe wood samples. The opposite changes were also found in the case of the Δa* coordinate. The samples treated with the acid buffer were less red than the control, whereas samples treated with the alkaline buffer showed a noticeable tendency to reddening. What is more, samples treated with the acid buffer turned out to be more prone to yellowing, while those after treatment with the alkaline buffer were less yellow than the control. Generally greater changes of colour (ΔE*) were found in samples treated with the alkaline buffer.

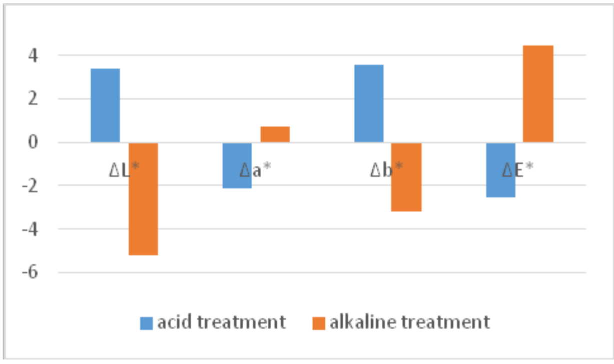

Figure 1. A comparison of colour parameters of ipe wood caused by treatment with acid and alkaline buffer (referred to the white standard)

Changes in colour coordinates (ΔL*, Δa*, Δb*) and the colour ΔE* of the control ipe wood samples and the samples after treatment with the acid and alkaline buffers, subsequently exposed to light irradiation at a wave length of 280 – 800 nm (xenon lamp) and 340 nm (UV lamp) are shown in figure 2. It was observed that ΔL*(brightness) decreased in the control sample surface exposed to light at a wave length of 280-800 nm. However, irradiation with the UV light caused an increase of coordinate "L". The samples treated with the acid buffer showed darkening after light exposure, with more significant changes being observed in the case of samples treated with the UV light. Treatment with the alkaline buffer triggered marked darkening of samples (fig. 1.), but photodegradation caused by the use of xenon lamp light and UV light changed brightness to a limited extent.

As a result of exposure to light irradiation the surface of the control samples and the samples treated with the alkaline buffer became less red. Only the samples treated with acid buffer showed a tendency to reddening after light exposure. Values of coordinate "a" after xenon lamp and UV light irradiation in the above mentioned cases differed non-significantly. Yellowing of wood surface is interpreted as a sign of degradation of lignin structure. The analyzed ipe wood contains approximately 40% lignin. This suggests significant changes of the "b" coordinate. This analysis showed that the control and the samples treated with the acid buffer became less yellow as a result of irradiation. Additionally, more significant changes were observed after exposure to UV (340 nm) radiation. The differences between yellowing of the samples treated with the alkaline buffer and then exposed to light irradiation were non-significant, amouting to less than 1. The small changes of the "b" coordinate may result from the dark colour of ipe wood. Generally the greatest changes in colour (ΔE) after photodegradation caused by light at wave lengths of 290-800 nm and 340 nm were observed in the case of samples treated with acid buffer. What is more, in the case of these samples UV irradiation was more effective than xenon lamp light. A similar phenomenon was observed in the control. The surface of samples treated with the alkaline buffer turned out to be more resistant to light irradiation that the other tested samples.

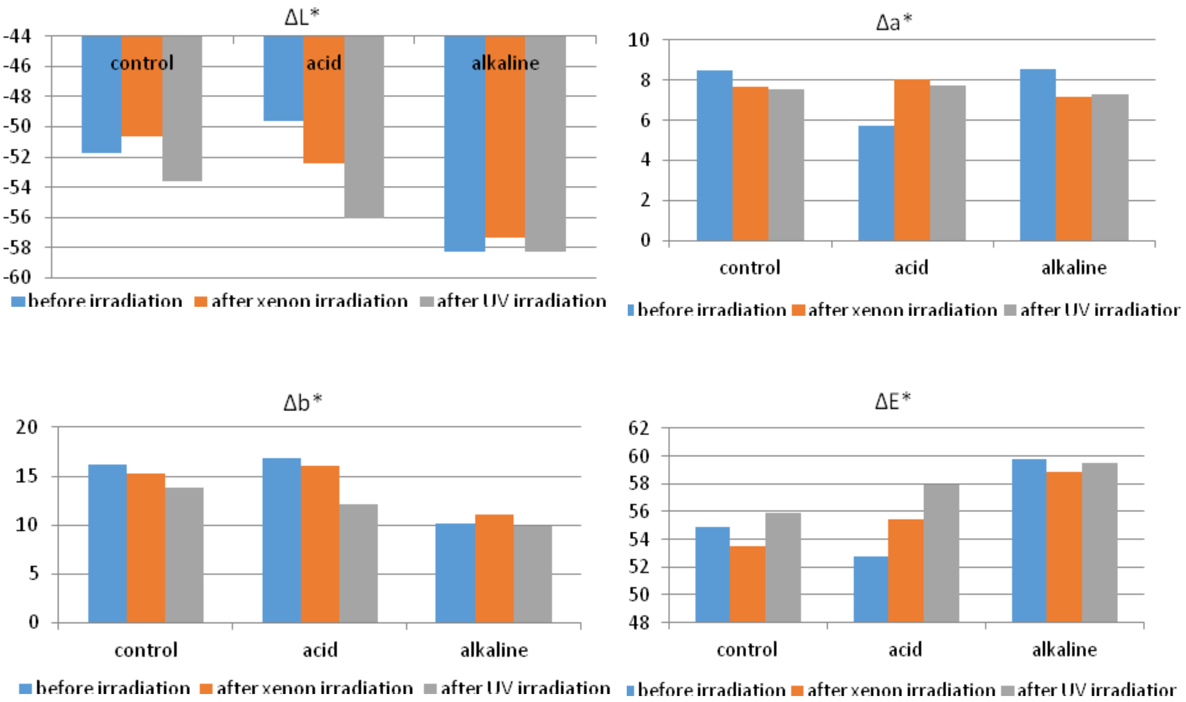

Figure 3. A comparison of colour parameters of ipe wood caused by treatment with acid and alkaline buffer and light irradiation (referred to the white standard)

SUMMARY

On the basis of conducted research it may be stated that:

1. Treatment with acid and alkaline buffers causes opposite changes of colour coordinates. Samples after treatment with the acid buffer became lighter, yellower and less red, while samples after treatment with the alkaline buffer were darker and redder and less yellow.
2. Treatment with the alkaline buffer caused more significant changes of ipe wood in comparison to treatment with the acid buffer.
3. The surface of ipe wood samples treated with alkaline buffer turns out to be more resistant to light irradiation that the control and samples treated with acid buffer.
4. The most important factor in colour change (ΔE*) of ipe wood samples treated with acid seems to be the L* coordinate.

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Streszczenie: *Porównawcze badania fotodegradacji drewna ipe (Tabebuia spp.) spowodowanej działaniem zewnętrznego i wewnętrznego światła UV-A.* Badaniom fotodegradacji poddano drewno ipe (*Tabebuia* spp.). Naświetlanie prowadzono za pomocą lampy ksenonowej, emitującej światło o długości fali 290-800 nm oraz lampy UV emitującej światło o długości fali 340 nm. Obie lampy emitowały światło imitujące zewnętrzne promieniowanie słoneczne. W celu sprawdzenia jaki wpływ na zmianę barwy ma odczyn (pH) powłoki wykończeniowej drewna, próbki przed naświetlaniem poddane były obróbce za pomocą kwasowego i zasadowego buforu.

Stwierdzono, że próbki drewna ipe po obróbce za pomocą buforu zasadowego ulegają ciemnieniu, a po obróbce za pomocą buforu kwaśnego jaśnieją. Próbki poddane działaniu bufora zasadowego wykazują większą całkowita zmianę barwy (ΔE*) drewna niż te po działaniu buforu kwaśnego, jednak stają się bardziej odporne na działanie promieniowanie światła, zarówno od długości fali 340 nm jak i 280 - 800 nm. W przypadku próbek drewna ipe poddanych działaniu bufora kwasowego stwierdzono znaczną zmianę barwy (ΔE*) pod wpływem naświetlania, szczególnie w przypadku światła UV o długości fali 340 nm.

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