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Application of image processing programs in color analysis of wood photodegradation

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Abstract. In general, polymer photodegradation is an important aspect of polymer science that is of great interest to chemistry, materials science, biology, and physics students who engage in this field of research. Wood consists of three main polymers, which makes it a good candidate for such photodegradation studies. Aside from structural changes based on chemical analysis, color change assessment can also be employed to check any extent of degradation on wood without the need for sophisticated analytical equipment. This study presents the application of two image processing programs in color analysis of wood photodegradation: *ImageJ* and Colormath library, which are Java-based and Python-based software, respectively. Images of unexposed and UV-exposed wood samples were taken using a smartphone as an affordable digital camera. RGB channel values from these images were analyzed and quantified by *ImageJ* software. These values were converted to the corresponding CIEL*a*b* parameters using the Colormath library to calculate the color change, ΔE . For the 3-hour exposed sample, ΔE is equal to 4.29. This value indicates appreciable color change, according to the criteria from literature. Regardless of the exposure time, the wood samples become darker as indicated by the negative value in the change in lightness L^* .

1. Introduction

The Covid-19 pandemic has prompted science educators and students to improvise methods and setups in analyzing various physical phenomena. Image processing programs can be a valuable asset to the researcher, especially for those working from home or to those who do not have access to laboratory equipment. These programs have numerous applications, including the description of basic topography or morphology in quantitative metallography [1]. Other applications include, but are not limited to, the estimation of pathogen concentrations, colorimetric analysis of iron ions in water, and the size measurements of polarized optical microscopy images [2–4]. In a study of wood, however, image processing programs are useful in color analysis to observe any color changes in a given wood type.

Color analysis is crucial in the determination of photodegradation in wood species. Samples are expected to show color changes over a period of ultraviolet (UV) irradiation time [5–7]. For some wood species, this color change is easily observed with the naked eye, while for others it is difficult. Regardless, it is necessary to quantify the results to support the qualitative observations. In practice, it is more common to utilize spectrophotometers in the laboratory, which use CIEL*a*b* measurements. However, it is still possible to measure the same set of data and analyze color changes in a work-from-home setup using image processing programs



and a quick conversion to CIEL*a*b* measurements. [8].

ImageJ is a free, online software with multiple functions, one of which is color analysis [9]. The images can be analyzed using the average method or the weighted method depending on the preferences, providing a set of measurements in the RGB scale [10]. Given any possible limitations on the access to spectrophotometers, finances and the ongoing pandemic, *ImageJ* is a useful alternative because it can be done at home and requires no elaborate setup [11]. This program is supplemented with the *Colormath library*, a Python-based library which can convert the RGB values gathered on *ImageJ* into CIEL*a*b* values [12]. This will provide a more detailed analysis on wood photodegradation.

Observing clear and obvious color changes through image processing programs is the first step in indicating possible chemical changes in the wood structure, particularly to its main polymer components: lignin, cellulose and hemicellulose. With the known polymorphs of cellulose, it is cellulose I that is naturally found in wood in parallel strands in the absence of hydrogen bonding [13]. Through chemical analysis later on, the formation of crystallized cellulose I is expected during photodegradation [6]. This indicates the presence of reactions within the wood samples during exposure.

Many experiments on wood photodegradation are conducted using natural sunlight. Results are significant and substantial, although it requires longer time period that can take hundreds of days [14,15]. Additionally, natural weathering is heavily reliant on the weather conditions, which are not constant and are difficult to control [16]. Artificial weathering is often used as an alternative, wherein wood samples are exposed to a UV laser or UV lamp [17]. Compared to natural weathering, artificial weathering can illustrate color changes immediately within the first few hours, whereas natural weathering generally can take up to a few weeks before observable color changes are visible [18]. While significant, the color changes observed will be supported by further characterization of the wood samples through chemical analysis in Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR) Spectroscopy.

2. Methodology

Shorea polysperma, commonly known as Tanguile or Tangile, wood samples were cut to a dimension of 6 cm x 6 cm x 1 cm in length, width, and thickness respectively. Afterwards, the edges and sides were smoothened with sandpaper to remove any blisters. The samples were then placed in a clean box to cover it from premature, natural and artificial weathering. The box was covered with a lid and stored in a space away from heat and light.

The wood samples were exposed to a 100-Watt UV germicidal lamp, as depicted in figures 1 and 2, having a quartz tube with peak emission wavelength at 254 nm [19]. Wood samples were exposed at a position 18cm away from the UV lamp tube. The exposure was done at three different time intervals (1, 2, and 3 hours). The samples were placed on a stationary placeholder such that the faces were perpendicular to the beam of UV light. To maintain control of the experiment, artificial photodegradation was conducted at the same time period, from 1:00 to 5:00 PM. No experiments were done during rainy days, both during and before the designated experiment time period. Before and after use, samples were placed in non-transparent plastic containers, to avoid any premature natural and artificial degradation.

A representative UV exposed-sample per batch was chosen consistently for image analysis, on the basis of its proximity relative to the center of the lamp. Before and after exposure, images of the samples were taken using a smartphone as an affordable digital camera. It is important to maintain the same setup for image capture before using the images in *ImageJ* analysis. In a home setup, as shown in figure 3, a tripod was used for stability and extended using a monopod so that it can clamp the camera in place and extend it directly above the sample. A flat surface is recommended to avoid any movement from the sample. Additionally, the background color for image capture should not be similar to the sample. Unless the sample in question is the color

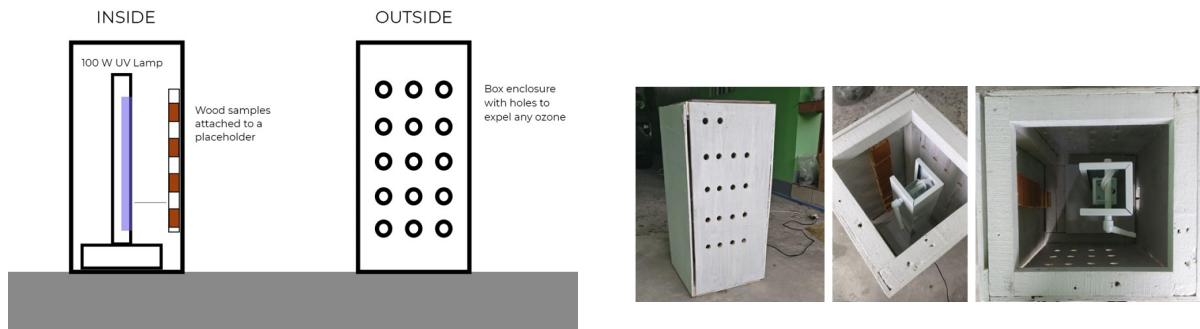


Figure 1. Diagram of the UV photodegradation setup for the wood samples.

Figure 2. Actual placement of samples during testing. The top lid was removed for picture-taking.

white, a regular A4 sheet of paper may be used as the background. Image capture was taken on a mobile phone, using High Dynamic Range (HDR) and no flash. The room lighting was consistent such that a white LED light illuminated the sample from above. Care was taken to remove or cover any possible disturbances to the image capture. Only one image of each sample was necessary before proceeding to image processing.

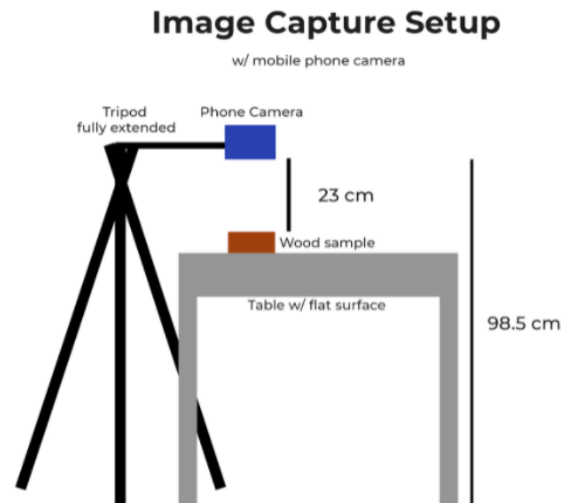


Figure 3. Phone capture setup for wood samples.

Color analysis was first done on *ImageJ* software. Opening this software will display the *ImageJ* console. To analyze a picture of interest, go to File > Open, as depicted in figure 4.

After selecting the picture from a file, the picture will be opened as a new window on *ImageJ*, as in figure 5. An image was split into RGB channels through Image > Color > Split Channels as depicted in figure 6. Three different color images of the wood sample were shown in figures 7.

The macro option was used to ensure that the measurement is taken in the same area. This is done by going to Plugins > Macros > Record, given in figure 8. When the Recorder window

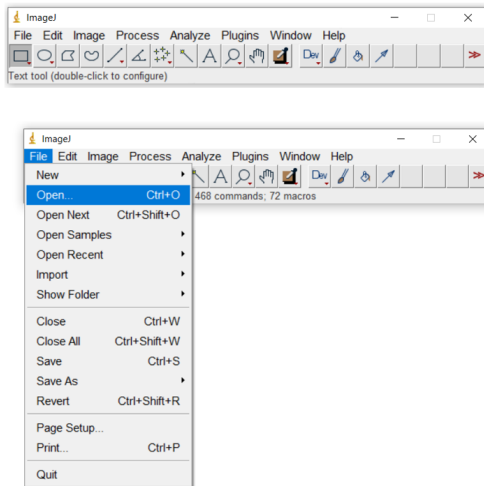


Figure 4. The *ImageJ* console appearance.

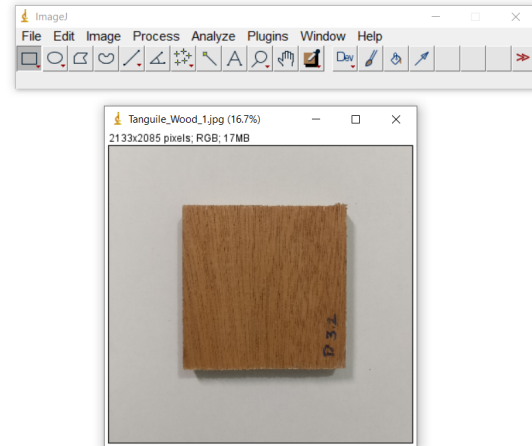


Figure 5. The file appearance as it is opened on the software.

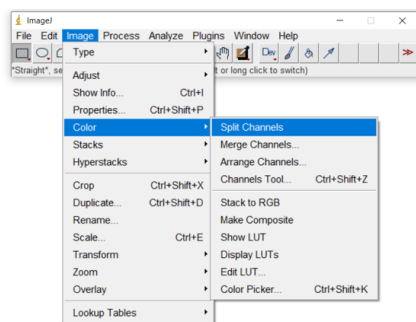


Figure 6. Process to split to the color channels.



Figure 7. Resulting split channels for the wood sample.

opens, select the rectangle tool from the toolbar, which is the leftmost option on the console. By default, the rectangle tool is already selected when you open *ImageJ*. The rectangle formed on the sample will be the area of analysis for *ImageJ*.

A rectangle was traced over the middle portion of the wood sample using the rectangle tool. This was recorded on the Recorder window with the coordinates of the rectangle corners, as depicted in figure 9.

To measure the color brightness of this particular area, press M on the keyboard. This will run the measure function on the Recorder. A new Results window will appear displaying the results of the rectangle area, as well as the mean, minimum and maximum brightness measurement inside the rectangle, like in figure 10.

To officially make the macro, click Create on the Recorder window. A new macro window will appear on the screen, as in figure 11. Save this macro with File > Save As, like in figure 12. The macro will be renamed to the chosen File name. The macro is officially made and you

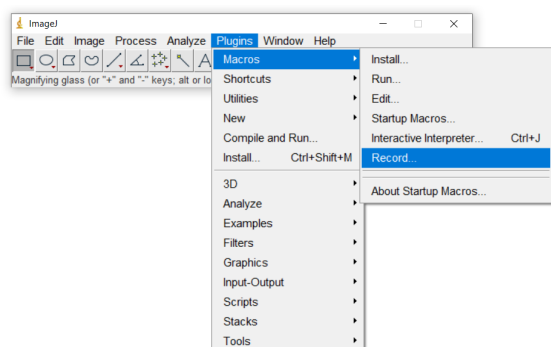


Figure 8. The process for making macros.

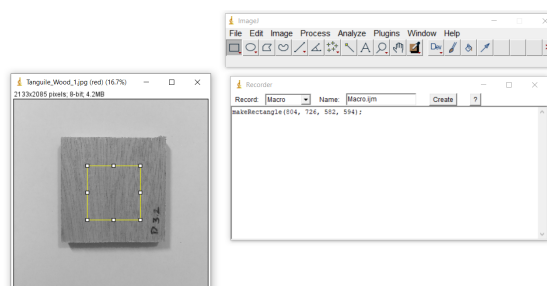


Figure 9. The mechanism for the rectangle measurement.

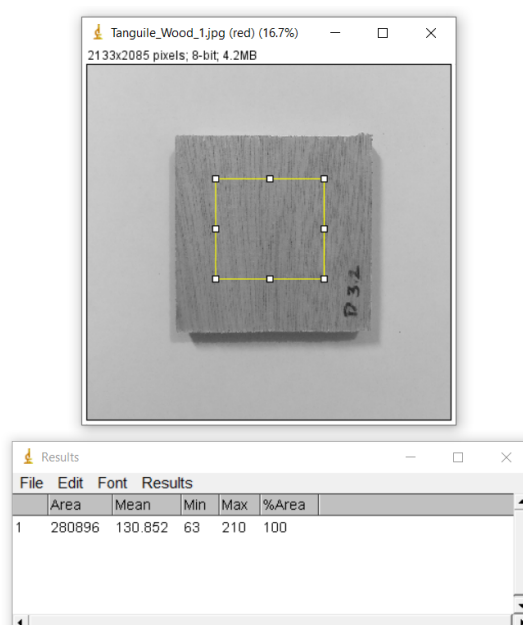
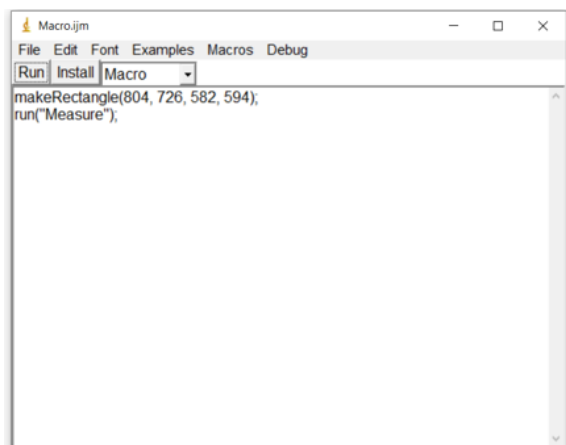
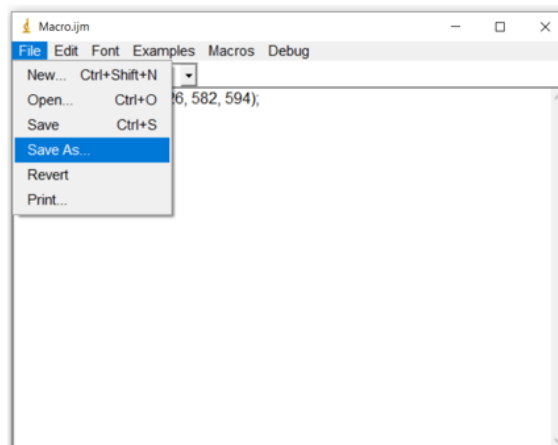
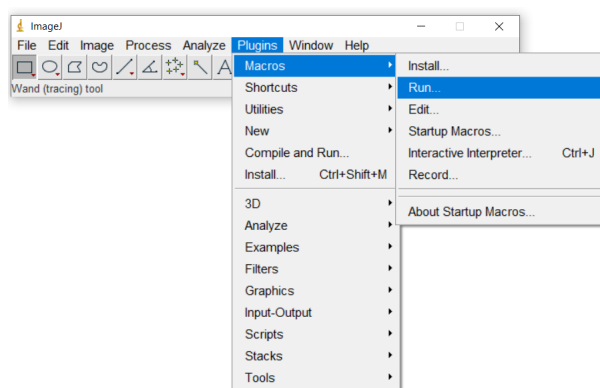


Figure 10. The color measurement for the image on *ImageJ*.

can close the Recorder window.

To recall the macro and subsequently get the brightness for the other color channels, go to Plugins > Macros > Run, and then select the saved macro, as in figure 13. The software will draw the rectangle in the same position according to the exact coordinates and get the brightness measurements in the same Results window. Once all measurements are taken from the samples, the data can be saved with File > Save As, or copied and pasted onto data processing software, like Microsoft Excel.

The measurements on *ImageJ* are done in the RGB scale. However, most data reported in the literature for wood photodegradation is done in the CIEL*a*b* system [14]. To convert the RGB measurements into CIEL*a*b*, we can use the Python *Colormath library* [20]. For this program, Spyder with Python 3.8 was used, although it is possible to do the conversion on other python integrated development environments (IDEs). On the console, import sRGBColor and

**Figure 11.** Recorder feature on *ImageJ*.**Figure 12.** Saving the macro on *ImageJ*.**Figure 13.** Running a macro on *ImageJ*.

LabColor from Color Objects and convert_color from Color Conversions. Insert your RGB color values inside the sRGBColor function. Do note that the conversion is done with the RGB values scaled from 0 to 1. To do this, simply divide the RGB values by 255.

Convert your RGB values to L*a*b* values with the convert_color function [20]. The parameters are the original color system, and the system you want to convert into. For the CIE L*a*b* system, there are two extra parameters concerning the observer and illuminant. For this conversion, the 10 degree observer was used, along with the D65 illuminant. The white point D65 is an estimation of the white color produced by mid-day sunlight [21]. These specifications are in line with reported literature on photodegradation of wood [22]. To get your converted values, simply use the print function. The values will be displayed on the console, like in figure 14.

3. Results and Discussion

By qualitative observation with the naked eye, it can be rather difficult to observe any obvious color changes like in figure 15 depending on the type of wood, which makes quantitative color analysis necessary.


```

1  # -*- coding: utf-8 -*-
2  """
3  Created on Thu Oct 28 14:44:44 2021
4
5  RGB to LAB color conversion using the colormath library
6  """
7
8  #import colormath library
9  from colormath.color_objects import sRGBColor, LabColor
10 from colormath.color_conversions import convert_color
11
12 #set the RGB color values, scaled from 0 to 1 by dividing by 255
13 rgb = sRGBColor(127.076/255, 82.691/255, 45.832/255) #scaled from 0 to 1
14
15 #convert to LAB values with 10 degree observer and D65 Standard Illuminant
16 lab = convert_color(rgb, LabColor, observer='10', target_illuminant='D65')
17
18 #print numbers as values
19 print(lab)

```

Figure 14. Color conversion using the Python *Colormath* library.



Figure 15. Tanguile wood before and after exposure to UV light.

Table 1 shows the mean RGB channel values similar to the one depicted in figure 10, and the corresponding CIEL*a*b* parameters obtained from the color conversion console in figure 14. As shown in table 1, Tanguile wood samples displayed a decrease in the lightness values, L^* , regardless of the exposure time, meaning the samples got darker overall [23]. This is in contrast with the varying changes across the green-red axis, a^* , which had samples that turned more red, while others became less red [7]. The results for the blue-yellow axis, b^* , were slightly more consistent, displaying a decrease in the b^* value for 1 and 2 hours of exposure and turned less yellow [24]. However, by the 3 hour exposure time, b^* increased, which implies that the sample turned more yellow.

Using the converted CIEL*a*b* measurements in table 1, it is possible to get the overall color change, ΔE , given by the square of the differences between two values as indicated in equation (1). This is in accordance to the ISO 11664-6 (2014) standard, which takes the color change between exposed and unexposed samples for all CIEL*a*b* measurements [25]. The parameters L_1^* , a_1^* , and b_1^* refer to the CIEL*a*b* measurements before artificial weathering while L_2^* , a_2^* , and b_2^* refer to the measurements after artificial weathering. Using equation (1) yielded a value of a maximum of 4.29 after three hours displayed in table 2, which, according to the literature, represents appreciable color change [25]. This is further represented by figure 16, which appears to show a linear increase in the overall color change after three hours. Even at three hours of UV exposure, UV light already has an effect on wood. For future experiments it would be interesting to observe the effects on wood beyond three hours to have a greater understanding on the degree of photodegradation on the wood samples.

Table 1. Mean RGB channel values and converted CIEL*a*b* measurements for samples of Tanguile wood exposed to UV for 1, 2, and 3 hours.

Time		R	G	B	L*	a*	b*
1 hr	Before	130.41	87.207	45.605	40.94	13.53	30.96
	After	125.469	83.48	42.292	39.30	13.23	30.71
2 hr	Before	138.102	94.978	50.764	44.00	12.86	31.93
	After	132.129	88.932	47.635	41.64	13.45	30.70
3 hr	Before	141.789	97.671	52.58	45.18	13.10	32.44
	After	131.104	87.05	42.283	40.95	13.71	32.80

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \quad (1)$$

Table 2. Calculated values for ΔL^* , Δa^* , Δb^* , and ΔE at different exposure times for Tanguile wood samples.

Time	ΔL^*	Δa^*	Δb^*	ΔE
1 hr	-1.64	-0.30	-0.25	1.69
2 hr	-2.36	0.59	-1.23	2.73
3 hr	-4.23	0.61	0.36	4.29

Although chemical analysis is beyond the scope of this paper, it is noteworthy that the color analysis measurements were supported by the decrease in the absorbance (A) ratio at A1340/A1320 during ATR-FTIR spectroscopy in table 3, where A1340/A1320 denotes the absorbance at 1340 cm^{-1} wavenumber divided by the absorbance at 1320 cm^{-1} . $(A1340/A1320)_0$ denotes the ratio before artificial weathering, while $(A1340/A1320)_t$ denotes the ratio for both wavenumbers after artificial weathering. Colom, Carrillo, Nogués, and Garriga used the absorbance (A) ratio between 1335 cm^{-1} and 1316 cm^{-1} , but for this study the closest set of data for the Tanguile wood were at the 1340 cm^{-1} and 1320 cm^{-1} [6]. The decrease in ratio infers that there is increased cellulose I content of the wood that evolves and crystallizes [6]. This then supports the idea that reactions are taking place within the wood samples during photodegradation.

4. Summary and Conclusion

In the absence of a spectrophotometer, the use of image processing programs in color analysis can be a reliable alternative to probe wood photodegradation. As shown in this study, color analysis was successfully conducted using *ImageJ* and *Colormath* library software for a simple, work-from-home setup. Regardless of the exposure time, the wood samples become darker as indicated by the negative value in the change in lightness L^* . Our data show a linear increase in the overall color change ΔE as a function of UV exposure time from one to three hours. After three hours of exposure, the maximum ΔE value of 4.29 indicates appreciable color change, according to the criteria from literature. This suggests photodegradation in the wood samples and can be supported in later characterization under ATR-FTIR spectroscopy.

Table 3. Absorbance (A) ratios for 1340 cm^{-1} and 1320 cm^{-1} wavenumbers of the Tanguile wood samples exposed in UV for three hours.

Ratio	Value
$(A_{1340}/A_{1320})_0$	0.978
$(A_{1340}/A_{1320})_t$	0.567

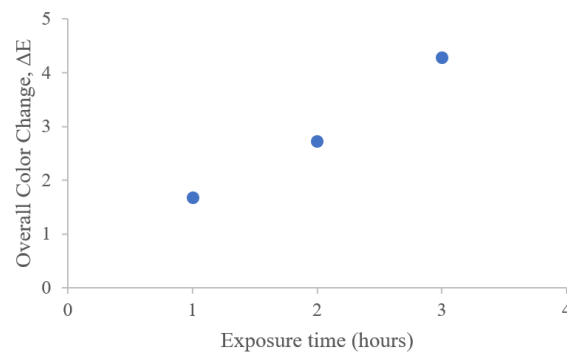


Figure 16. Overall color change as a function of exposure time for Tanguile samples during UV photodegradation.

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