WOOD RESEARCH doi.org/10.37763/wr.1336-4561/67.5.888893
e-ISSN 2729-8906
67(5): 2022 888-893 pp.

SHORT NOTES

CAN THE PHYSICAL PROPERTIES OF WOOD SAMPLES BE PREDICTED FROM PHOTOGRAPHS DISPLAYED ON A MONITOR?

EUN-SUK JANG, CHUN-WON KANG
JEONBUK NATIONAL UNIVERSITY
REPUBLIC OF KOREA

(RECEIVED OCTOBER 2021)

ABSTRACT

This study focused on evaluating the physical properties of wood from photographs displayed on a monitor. Sample photos of 475 hardwoods and their physical information were collected from a wood database. R, G, and B values were extracted from the wood photos using color picker software. Statistical techniques such as Pearson's correlation coefficient and multiple regression analysis were applied to investigate relationships between wood color and physical properties. From results of Pearson's correlation coefficient, R, G, and B values were most affected by specific gravity. In a multiple regression analysis, tree size, specific gravity, and modulus of rupture (MOR) were significant in the positive (+) direction by color (R, G, and B). On the other hand, modulus of elasticity (MOE) was significant in the negative (-) direction at the 1% level by color. The specific gravity of wood had the most significant effect on R, G, and B values in multiple regression analysis. In conclusion, the color and specific gravity of wood were related closely. Additionally, it is possible to predict the physical properties of wood from the R, G, and B values of a wood sample photograph displayed on a monitor. These results could provide useful information for wood researchers as well as wood exporters and importers.

KEYWORDS: Wood color, RGB, specific gravity, modulus of rupture, modulus of elasticity.

INTRODUCTION

Wood has many advantages as a material as well as environmental benefits. Wood is lighter than other materials, is convenient to process, and has excellent thermal insulation properties. Wood has a humidity control function and acts as a filter of harmful substances.

In addition, the unique scent and color of wood can have an emotional effect on humans (Hong et al. 2012, Kotradyova et al. 2019). Wood color is one of the most critical aesthetic aspects for customers (Hidayat et al. 2017). In a survey by Bigsby et al. (2013), the most critical wood properties for consumers of solid wood furniture in New Zealand, were the grain and color of the wood. In particular, Jo and Seo (2021) investigated the furniture color preference of university students in Korea, and found they prefer warm colors. Hence, wood color is an essential attribute in marketing (Moya and Calvo-Alvarado 2012).

The main chemical components of wood are cellulose, hemicellulose, and lignin, and extracts are also present. These extracts determine the color of wood (Yazaki 2015). Wood color is an inherent characteristic that is related to growth environment. Moya and Calvo-Alvarado (2012) reported that dark wood color was associated with arid climates. Sousa et al. (2020) investigated the correlation between specific gravity and color in 10 Amazon hardwood species samples and reported that wood with high specific gravity was darker and had more red pigment. As such, the color of wood can reflect its physical properties.

However, a limitation of previous studies is that the color and physical properties of wood were investigated only in a few species. Therefore, this study collected photographs and physical information of 475 hardwood samples from a wood database (Meier 2015). The R, G, and B values were extracted using color picker software from wood sample photographs. The RGB color model expresses colors using the three primary light colors, red, green, and blue, using three light sources. Statistical techniques such as Pearson's correlation coefficient and multiple regression analysis were applied to investigate the relationship between wood color and physical properties.

The primary purpose of this study was to investigate the relationship between the color and physical properties of wood. Additionally, this study proposes a method that can evaluate the physical properties of wood from a photograph of the wood. Such information is expected to be of great utility to wood scientists and exporters and importers of wood.

MATERIALS AND METHODS

Collection of information on physical properties of wood

The physical properties of the hardwoods in this study were sourced from “The wood database (https://www.wood-database.com/)” (Meier 2015). The physical properties of 457 hardwoods were tree size, specific gravity, modulus of rupture (MOR), and modulus of elasticity (MOE). All physical data in the wood database were represented as the minimum and maximum values. For convenience, the average value was calculated for this study.

Color picker software (Any Studio, Seoul, Korea) was used to extract RGB color information from each wood sample photograph, as shown in Fig. 1. The R, G, and B values were extracted from upper, middle, and lower portions of the wood sample photograph and were averaged.

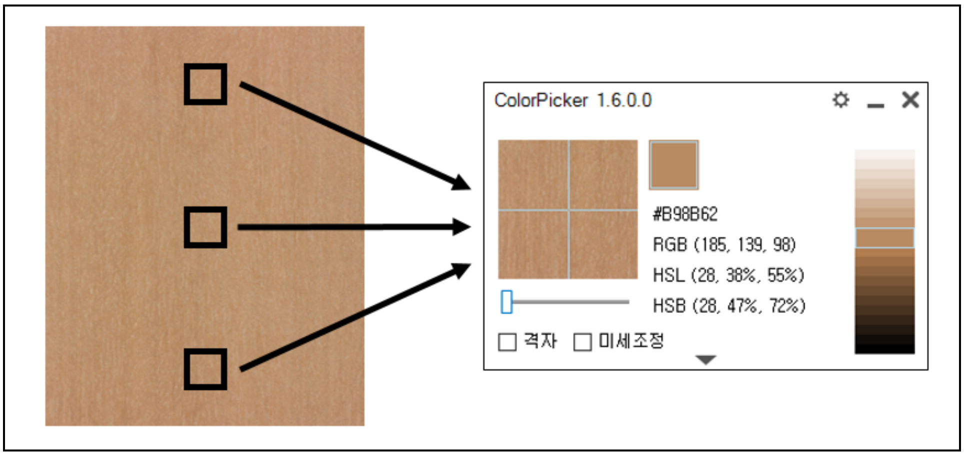

Fig. 1: RGB value extraction process from a wood sample photograph.

Statistical analysis

The relationships of color and physical properties of the hardwood were analyzed using SPSS Statistics 2.6 software (IBM, Armonk, NY, USA). To determine the degree and direction of the correlations between tree size; specific gravity; MOR; MOE; and R, G, and B values, Pearson's correlation was employed to measures both the direction and degree of relationships. The coefficient has a value between -1 and 1, and the larger is the absolute value of the coefficient, the stronger is the linear relationship (Sedgwick 2012).

Also, this study investigated the effect of physical variables of wood such as wood size, specific gravity, MOR, MOE, and color on wood color through multiple regression analysis. To estimate the regression coefficients of multiple regression analysis, ordinary least squares (OLS) was used (Mason and Perreault 1991).

In this study, physical properties of tree size, specific gravity, MOR, and MOE were independent variables, while color information of R, G, and B values was the dependent variable. Eq. 1 shows a regression estimation model to examine the relationships between hardwood color and physical properties. The regression models 1, 2, and 3 used R, G, and B as dependent variables, respectively:

$$Y_{(1,2,3)} = \alpha_0 + \beta_1 SG + \beta_2 MOR + \beta_3 MOE + \beta_4 TS + \varepsilon \qquad (5)$$

where: Y_1: R, Y_2: G, Y_3: B, SG - specific gravity, MOR - modulus of rupture, MOE - modulus of elasticity, TS - tree size, α_0 - constant (intercept term); and ε - residuals (error term).

RESULTS AND DISCUSSION

Results of Pearson's correlation analysis

Tab. 1 provides Pearson's correlation results of this study. Tree size and specific gravity had a significant negative (-) correlation at the 1% level, which indicates that the taller is the tree, the lower is the specific gravity. The size and specific gravity of trees are related closely to their growth environment. Chen et al. (2017) found that the specific gravity of pioneer subtropical wood species was lower than that of suppressed individuals. This occurs because pioneer trees need to invest in tree height growth rather than specific gravity early in their lives.

In this study, tree size had a significantly positive (+) correlation with R, G, and B values at the 1% level. It can be inferred from this that the closer are the colors of the tree to pure red, green, and blue, respectively, the taller is the tree. This relationship also can be explained by mechanism of tree growth. Tall trees do not have the energy to produce deep colors, as they have to allot much energy to height growth (Moya and Calvo-Alvarado 2012).

The higher is the specific gravity of wood, the more positive are the correlations to MOR and MOE. The specific gravity is related to the amount of wood substance; therefore, as the specific gravity increases, the mechanical properties of the wood increase (Armstrong et al. 1984, Zhang 1994). On the other hand, specific gravity, MOR, and MOE showed negative (-) correlations with R, G, and B, respectively, which indicates that the darker is each red, green, and blue color of the wood, the higher are the specific gravity, MOR, and MOE. Additionally, when taking into account the absolute value of the coefficient, R, G, and B values were most affected by specific gravity.

A previous study of 10 Amazonian hardwood species showed that wood with high specific gravity was darker and had more red pigment compared to that with low specific gravity (Sousa et al. 2020), and our results are in agreement with this finding. This effect suggests the possibility of predicting the physical properties of wood simply from R, G, and B values derived from a photograph of the wood sample displayed on a monitor.

Tab 1: Results of Pearson's correlation analysis.

	TS	SG	MOR	MOE	R	G	B
TS	1	-0.264**	-0.016	0.09	0.141**	0.122*	0.134**
SG		1	0.832**	0.786**	-0.644**	-0.669**	-0.673**
MOR			1	0.897**	-0.557**	-0.575**	-0.579**
MOE				1	-0.464**	-0.484**	-0.487**
R					1	0.966**	0.910**
G						1	0.968**
B							1

*Note: TS - tree size, SP - specific gravity, MOR - modulus of rupture, MOE - modulus of elasticity, ** $P < 0.001$.*

Results of multiple regression analysis

Tab. 2 shows the results of multiple regression analysis in this study. Since the F-values of all multiple regression models were within the significance level of 1%, the estimated regression results are statistically significant. In a regression model, when the variables are independent, the model's explanatory power (R^2) increases. If the characteristics of the independent variables are similar, the variance of the estimator increases. This problem is called multicollinearity and is evaluated through the VIF (Variance Inflation Factor). Generally, when the VIF is 10 or higher, multicollinearity is high. Since the VIF of all multiple regression models in this study was less than 10. The independent variables did not make a multicollinearity problem.

Based on adjusted R^2, Models 1, 2, and 3 had explanatory power of 42.4%, 46.2%, and 46.6%, respectively. Tree size (β_1), specific gravity (β_2), and MOR (β_3) were significant in the positive (+) direction at the 1% level in all models. On the other hand, MOE (β_4) was significant in the negative (-) direction at the 1% level in all models.

These results suggest that increases in tree size, specific gravity, and MOR and decreases in MOE increase the R, G, and B values. In conclusion, the results of this study suggest that the color of the wood is related closely to its height, specific gravity, and physical properties. In particular, it suggests that the specific gravity of wood is related closely to its color.

This study suggests the possibility of predicting the physical properties of wood simply with R, G, and B values extracted from wood sample photographs displayed on a monitor without directly analyzing the wood. This process is expected to be useful not only for wood scientists, but also for exporters and importers of wood.

Tab. 2: Results of multiple regression analysis.

	$Y = \alpha_0 + \beta_1 SG + \beta_2 MOR + \beta_3 MOE + \beta_4 TS + \varepsilon$								
	Model 1			Model 2			Model 3		
Variables	Coeff.	t-stat.	VIF	Coeff.	t-stat.	VIF	Coeff.	t-stat.	VIF
α_0	287.858	34.195		261.614	32.103		211.52	29.838	
TS	-0.38	-2.162**	1.279	-0.533	-3.127**	1.279	-0.406	-2.742**	1.279
SG	-162.357	-8.369**	4.225	-176.78	-9.413**	4.225	-152.481	-9.333**	4.225
MOR	-0.438	-3.193**	7.034	-0.424	-3.195**	7.034	-0.379	-3.281**	7.034
MOE	4.328	3.885**	5.71	4.571	4.239**	5.71	3.933	4.193**	5.71

*Note: TS - tree size, SG - specific gravity, MOR - modulus of rupture, MOE - modulus of elasticity, α_0 - constant (intercept term); and ε - residuals (error term), ** $P<0.001$.*

CONCLUSIONS

As a result of applying Pearson's correlation and multiple regression analyses to investigate relationships between various physical data and color data of wood, color information (R, G, and B) of wood samples was most affected by specific gravity, indicating that the color and specific gravity of wood are related closely. In addition, the physical properties of wood could be inferred from the R, G, and B values of wood sample photographs displayed on a monitor.

ACKNOWLEDGMENTS

This research was supported by the Basic Science Research Program administered through the National Research Foundation of Korea (NRF), funded by the Ministry of Education (NRF-2019R1I1A3A02059471) and under the framework of an international cooperation program managed by the NRF of Korea (NRF-2020K2A9A2A08000181). The authors express their thanks to the "The Business Startup Incubator Support Program" supported by the Ministry of Education and National Research Foundation of Korea.

REFERENCES

1. Armstrong, J., Skaar, C., DeZeeuw, C., 1984: The effect of specific gravity on several mechanical properties of some world woods. Wood Science and Technology 18(2): 137-146.
2. Bigsby, H., Rai, C., Ozanne, L., 2013: Determining consumer preference for furniture timber. Journal of Forest Products Business Research 2(2): 1-20.
3. Chen, L., Xiang, W., Wu, H., Lei, P., Zhang, S., Ouyang, S., Deng, X., Fang, X., 2017: Tree growth traits and social status affect the wood density of pioneer species in secondary subtropical forest. Ecology and Evolution 7(14): 5366-5377.
4. Hidayat, W., Qi, Y., Jang, J., Park, B., Banuwa, I. S., Febrianto, F., Kim, N., 2017: Color change and consumer preferences towards color of heat-treated Korean white pine and royal paulownia woods. Journal of the Korean Wood Science and Technology 45(2): 213-222.
5. Hong, S.C., Hwang, S.W., Lee, W.H., 2012: Present condition of domestic wooden playground. Journal of the Korea Furniture Society 23(2): 207-213.
6. Jo, H.K., Seo, J.E., 2021: The characteristics of post-corona era and the furniture preference of university students. Journal of the Korean Housing Association 32(1): 91-98.
7. Kotradyova, V., Vavrinsky, E., Kalinakova, B., Petro, D., Jansakova, K., Boles, M., Svobodova, H., 2019: Wood and its impact on humans and environment quality in health care facilities. International Journal of Environmental Research and Public Health 16(3496): 1-20.
8. Mason, C.H., Perreault Jr, W.D., 1991: Collinearity, power, and interpretation of multiple regression analysis. Journal of marketing research 28(3): 268-280.
9. Meier, E., 2015: Wood! Identifying and using hundreds of woods worldwide. The wood database, 272 pp.
10. Moya, R., Calvo-Alvarado, J., 2012: Variation of wood color parameters of Tectona grandis and its relationship with physical environmental factors. Annals of Forest Science 69(8): 947-959.
11. Sedgwick, P., 2012: Pearson's correlation coefficient. BMJ 345: e4483.
12. Sousa, W.C.S., Barbosa, L.J., Soares, A.A.V., Goulart, S.L., Protásio, T.P., 2020: Wood colorimetry for the characterization of amazonian tree species: A subsidy for a more efficient classification. Cerne 25(1): 451-462.
13. Yazaki, Y., 2015: Wood colors and their coloring matters: a review. Natural Product Communications 10(3): 505-512.
14. Zhang, S.Y., 1994: Mechanical properties in relation to specific gravity in 342 Chinese woods. Wood and fiber science 26(4): 512-526.

EUN-SUK JANG, CHUN-WON KANG*
JEONBUK NATIONAL UNIVERSITY
INSTITUTE OF HUMAN ECOLOGY, COLLEGE OF HUMAN ECOLOGY
DEPARTMENT OF HOUSING ENVIRONMENTAL DESIGN AND RESEARCH
567, BAEKJE-DAERO, DEOKJIN-GU 54896
JEONJU-SI, JEOLLABUK-DO
REPUBLIC OF KOREA
*Corresponding author: kcwon@jbnu.ac.kr