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Evaluation of the Basic Properties for the Korean Major Domestic Wood Species III. Korean Pine (*Pinus koraiensis*) in Jinan-gun, Jeollabuk-do

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ABSTRACT

Wood has different cellular compositions and characteristics depending on the species, and even within the same species, the characteristics vary depending on the growth region. Therefore, in order to use wood effectively, it is essential to understand its properties and the appropriate applications for each species. Korean pine has been widely used for landscaping, fruit trees, and as a construction material both historically and in the present, and it has been a major conifer species planted nationwide since the 1960s. In this study, the anatomical properties (length and width of tracheids, cell wall thickness), physical properties (specific gravity and shrinkage), mechanical properties (bending strength, longitudinal compressive strength, longitudinal tensile strength, shear strength, hardness), and chemical composition (ash, extractives, lignin, sugars) of Korean pine which was produced in Jinan, Jeollabuk-do were evaluated. The results showed that Korean pine is classified as a low specific gravity wood, with relatively low strength, and its chemical composition exhibited trends similar to those of typical conifer species.

Keywords: Korean pine, anatomical property, physical property, mechanical property, chemical composition

1. INTRODUCTION

Wood has the advantage of being an environmentally friendly material that is naturally produced through photosynthesis, but it also has unique properties such as non-uniformity and anisotropy due to its composition of various cells, which requires care when processing or utilizing it (Chong and Park, 2008). In particular, considering that each tree species has different properties, and even within the same tree species, variations in properties occur depending on the growth region and age of the tree, wood properties per tree species and its appropriate utilization and application should be appropriately understood for efficient utilization of wood (Park *et al*.,

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2024a). Park *et al.* (2024a, 2024b) reported the evaluation results [i.e., anatomical property (length and width of the main constituent cells, and cell wall thickness), physical property (specific gravity and shrinkage), mechanical property (bending strength, longitudinal compressive strength, longitudinal tensile strength, shear strength, and hardness), and chemical composition (ash, extractives, lignin, and sugars)] of Korean red pine (*Pinus densiflora*) from Pyeongchang, Gangwon-do, Korea and tulip tree (*Liriodendron tulipifera*) from Gangjin, Jeollanam-do, Korea, as basic properties, in order to establish a database on wood properties of major Korean wood species. This study evaluated the basic properties of Korean pine (*Pinus koraiensis*) produced in Jinan-gun, Jeollabuk-do, which is the third target after the aforementioned tree species, and presented the results.

Korean pine is an evergreen coniferous tree species distributed in the elevation range of 100–1,900 m throughout the Korea, with an average height of 30 m, and a diameter of 1.0 m (Kim *et al*., 2007). In the scientific name of the Korean pine, the specific epithet ‘koraiensis’ denotes ‘Korea’ indicating that this species is native to the Korean peninsula. It has long been regarded as one of the principal tree species naturally distributed across the region since ancient times (Bae *et al*., 2012). Korean pine was planted in royal palaces and used for landscaping, and several historical records indicate that it was planted and managed from the Silla Dynasty to the Joseon Dynasty (Bae *et al*., 2012). Additionally, pine nuts, the fruit of Korean pine, were a common food for ordinary people and were one of the tributes sent to China (Bae *et al*., 2012). In more modern times, as a main economic tree species in the Korea, 440,000 ha of Korean pine have been planted since the 1960s, and even currently, the Korean pine forest area covers 210,000 ha, which accounts for approximately 3.3% of the entire forest areas, making it one of the most representative artificial forests in the Korea. Representative Korean pine forests include national forests, including ‘Pungcheon-ri Korean pine forest’ in Hongcheon, Gangwon-do, ‘Gapyeong Korean pine forest’ in Gyeonggi-do, and ‘Chuncheon Korean pine forest’ in Gangwon-do, and natural forests, such as ‘Gwongeumseong Fortress Korean pine forest’ in Sokcho, Gangwon-do, ‘Inner Seorak Korean pine forest’ in Inje, Gangwon-do, and ‘Bukdae Korean pine forest’ in Odaesan, Hongcheon, Gangwon-do.

As a wood, Korean pine is a representative conifer species that has been frequently employed as a construction material in the past, alongside Korean red pine trees, which can be found in the literature (Lee and Bae, 2021; Son *et al*., 2011). In addition, due to its widespread use from the past to the present, there have been numerous studies on wood species identification for structural members and sawn lumber (Hwang *et al*., 2020; Park *et al*., 2017b; Yang *et al*., 2015, 2017, 2019a, 2019b; Yoo *et al*., 2022). Recent research has also focused on grading classifications of sawn lumber, as well as adhesive properties and joints for CLT manufacturing, to further the application of Korean pine in modern wood structures (Pang et al., 2011a, 2011b, 2017; Park *et al*., 2017a). Additionally, several studies have been published analyzing the color change, moisture adsorption, and combustion properties induced various wood modifications, including heat treatment, acetylation treatment, and flame-retardant treatment, to facilitate the use of Korean pine as an interior material (Chang *et al*., 2012; Cho *et al*., 2015; Choi, 2011; Chung *et al*., 2016; Hidayat *et al*., 2017; Hwang *et al*., 2014; Kim *et al*., 2020; Lee and Lee, 2018; Lee *et al*., 2015a, 2015b; Lim *et al*., 2014; Park *et al*., 2012a, 2012b; Ra *et al*., 2012). Furthermore, several studies have been reported the antibacterial and anti-inflammatory effects of Korean pine essential oil (Jang *et al*., 2012; Lee *et al*., 2014; Yeon *et al*., 2019).

2. MATERIALS and METHODS

2.1. Target species

This study selected and utilized 40 Korean pine logs with a small-end diameter of 300 mm or more from Mountain 1 (N35.68°, E127.45°), Baekam-ri, Baekun-myeon, Jinan-gun, Jeollabuk-do, the Korea (Fig. 1). The average age of the logs used in this experiment was approximately 37 years.

2.2. Evaluation of basic properties

This study analyzed the basic properties, i.e., the anatomical property (length and width of tracheids, and cell wall thickness), physical property (specific gravity and shrinkage), mechanical property (bending strength, longitudinal compressive strength, longitudinal tensile strength, shear strength, hardness) and chemical composition (ash, extractives, lignin, sugars), of the published tree species, Korean pine. Each item was evaluated using the same method as in the previous study (Park *et al*., 2024a). In most cases, the specifications of KS or ASTM were referenced as shown in Table 1, but as for the evaluation of anatomical properties without standardized specifications, the experimental methods were determined by referring to previous studies (Kim *et al*., 2024; Lee and Bae, 2021; Lee *et al*., 2021a, 2021b, 2021c; Nam and Kim, 2021). The evaluation methods for each property are described in detail by Park *et al.* (2024c). In consideration of the non-uniformity and anisotropy of the wood, the specimens used for the evaluation were sawn from heartwood without juvenile wood in the form of edge grain with annual rings parallel to the edges as shown in Fig. 2.

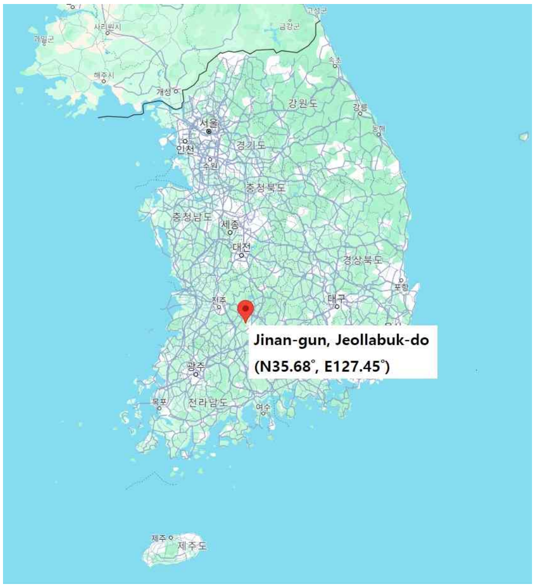


Fig. 1. Korean pine production site.

3. RESULTS and DISCUSSION

3.1. Anatomical property

As a result of the evaluation of the anatomical properties of Korean pine, the length of the tracheids was 2.36 mm in the early wood, and 3.12 mm in the late wood; the width of the tracheids of the early wood was 44.83 μm in the radial direction, and 31.62 μm in the tangential direction, and the width of the tracheids of the late wood was 20.88 μm in the radial direction, and 29.92 μm in the tangential direction. The cell wall thickness of tracheids was measured to be 2.74 μm in the early wood, and 4.73 μm in the late wood.

Fig. 3 is an optical microscope image of three sections to confirm the cell structure of Korean pine.

3.2. Physical property

As a result of evaluating the specific gravity and shrinkage of Korean pine, the specific gravity was 0.380 in green condition, 0.399 in air-dried condition, and 0.421 in oven-dried condition. The total shrinkage per direction was 0.49% in the longitudinal direction, 2.24% in the radial direction, and 7.19% in the tangential direction, and the total volumetric shrinkage was 9.70%.

Table 1. Standard for the evaluation of wood properties

		Standard
Anatomical properties	Length of cell	-
	Width of cell	-
	Thickness of cell wall	-
Physical properties	Specific gravity	KS F 2198 (KSA, 2016)
	Shrinkage	KS F 2203 (KSA, 2020a)
Mechanical properties	Bending strength	KS F 2208 (KSA, 2020d)
	Compression strength	KS F 2206 (KSA, 2020b)
	Tensile strength	KS F 2207 (KSA, 2020c)
	Shear strength	KS F 2209 (KSA, 2020e)
	Hardness	KS F 2212 (KSA, 2020f)
Chemical composition	Ash	KS M ISO 18122 (KSA, 2015)
	Extractives	ASTM E 1690 (ASTM, 2021)
	Lignin	ASTM E 1758-01 (ASTM, 2020)
	Sugars	

Adapted from Park *et al.* (2024b) with CC-BY-NC.

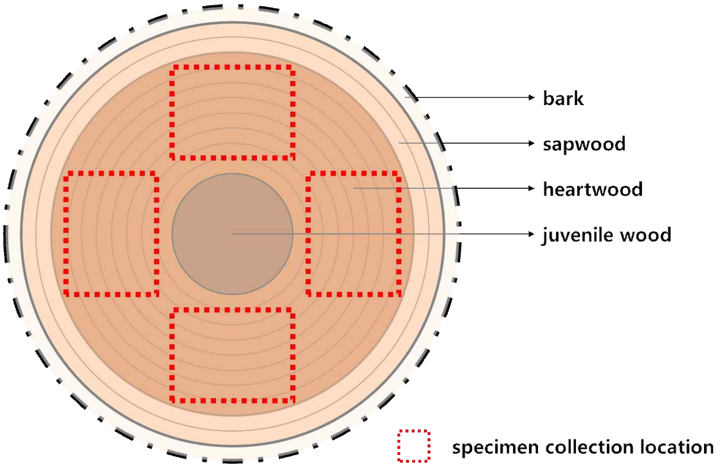
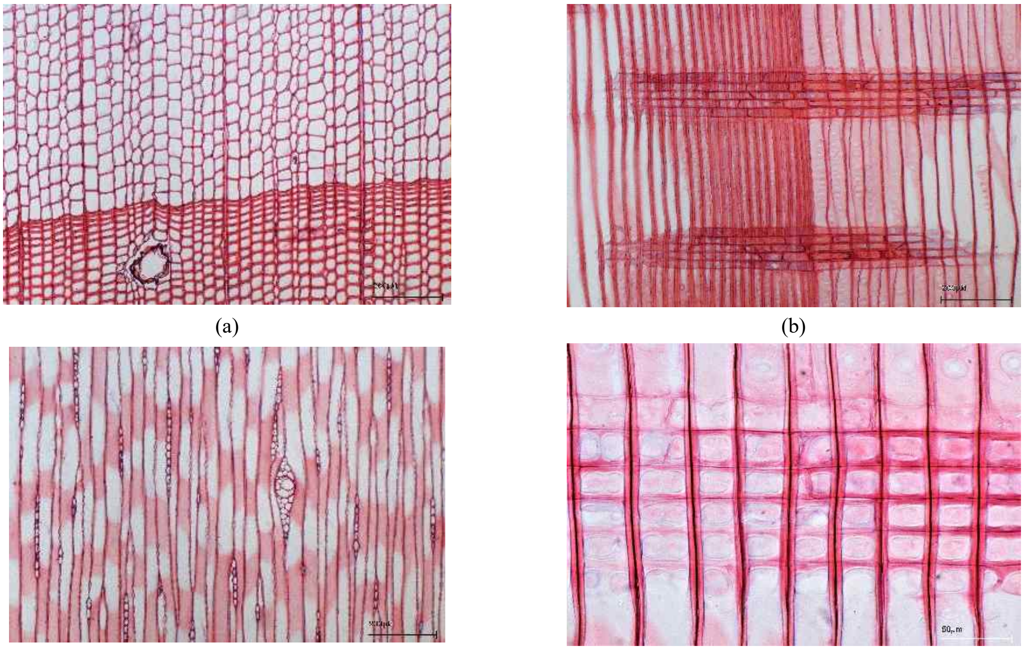


Fig. 2. Location of specimens collected from log. Adapted from Park *et al.* (2024a) with CC-BY-NC.

3.3. Mechanical property

As a result of measuring the mechanical properties of Korean pine, bending strength was 73.3 MPa in air-dried condition, and 33.6 MPa in green condition; longitudinal compressive strength was 38.1 MPa in air-dried condi-



(a) (b) (c) (d)

Fig. 3. Optical microscope images of each section for Korean pine (1% Safranine solution). (a) Cross section (× 10), (b) radial section (× 10), (c) tangential section (× 10), (d) radial section (× 40).

tion, and 16.0 MPa in green condition; longitudinal tensile strength was 77.1 MPa in air-dried condition, and 50.1 MPa in green condition. The shear strength in radial section was measured to be 7.4 MPa in air-dried condition, and 4.3 MPa in green condition, and the shear strength in tangential section was 8.0 MPa in air-dried condition, and 4.4 MPa in green condition. Finally, the hardness in air-dried condition was measured to be 3.6 kN in the cross section, 2.4 kN in the radial section, and 2.4 kN in the tangential section.

3.4. Chemical composition

As a result of analyzing the chemical composition of Korean pine, the ash content was at 0.27%, and the extractives content was 3.34%. The lignin content was 27.39% for acid-insoluble lignin and 1.73% for acid-soluble lignin, totaling 29.12%. The total sugars content was composed of 42.85% glucan, 20.23% XMG (xylan + mannan + galactan), and 1.15% arabinan, amounting to a total of 64.23%.

4. CONCLUSIONS

This study evaluated the anatomical, physical, and mechanical properties and chemical composition of Korean pine (Jinan-gun, Jeollabuk-do, Korea), which is a representative conifer species in the Korea, in order to establish a database of wood properties of Korean major domestic wood species (Table 2). Since diverse wood properties depend on the growth region, the properties of Korean pine produced in one region, as shown in this study, cannot represent the wood properties of the entire Korean pine tree species in the county. Therefore, it is necessary to evaluate and compare the properties of Korean pine produced in various regions, so as to derive

Table 2. Basic properties of Korean pine

Anatomical properties

Length of tracheid (n = 30)		Width of tracheid (n = 30)				Thickness of cell wall for tracheid (n = 30)	
Earlywood	Latewood	Earlywood		Latewood		Earlywood	Latewood
		R section	T section	R section	T section		
2.36 mm (0.29)*	3.12 mm (0.20)	44.83 μm (6.10)	31.62 μm (5.22)	20.88 μm (4.75)	29.92 μm (2.60)	2.74 μm (0.24)	4.73 μm (0.61)

Physical properties

Specific gravity (n = 100)			Total shrinkage (n = 100)			
Green	Air-dry	Oven-dry	Linear			Volumetric
			L direction	R direction	T direction	
0.380 (0.024)	0.399 (0.022)	0.421 (0.021)	0.49% (0.21)	2.24% (0.57)	7.19% (1.62)	9.70% (1.92)

Mechanical properties

Bending strength		Compression strength parallel to the grain		Tensile strength parallel to the grain	
Air-dry (12% MC*) (n = 25)	Green (n = 20)	Air-dry (12% MC) (n = 25)	Green (n = 28)	Air-dry (10.9% MC) (n = 16)	Green (n = 16)
73.3 MPa (7.9)	33.6 MPa (3.9)	38.1 MPa (4.9)	16.0 MPa (2.0)	77.1 MPa (11.6)	50.1 MPa (6.5)

Shear strength				Hardness		
R section		T section		C section	R section	T section
Air-dry (13% MC) (n = 15)	Green (n = 16)	Air-dry (13% MC) (n = 18)	Green (n = 16)	Air-dry (12% MC) (n = 10)	Air-dry (12% MC) (n = 10)	Air-dry (12% MC) (n = 10)
7.4 MPa (0.8)	4.3 MPa (0.4)	8.0 MPa (0.7)	4.4 MPa (0.3)	3.6 kN (0.5)	2.4 kN (0.3)	2.4 kN (0.4)

Chemical compositions

Ash (n = 6)	Extractives (n = 6)	Lignin (n = 6)		
		Acid-insoluble	Acid-soluble	Total
0.27% (0.04)	3.34% (0.34)	27.39% (0.29)	1.73% (0.24)	29.12% (0.51)

Sugars (n = 6)

Glucan	XMG**	Arabinan	Total
42.85% (0.44)	20.23% (0.07)	1.15% (0.01)	64.23% (0.37)

SD in parentheses.
n: number of specimens used in the evaluation or number of repetitions of evaluation.
R section: radial section, T section: tangential section, L direction: longitudinal direction, R direction: radial direction, T direction: tangential direction, C section: cross section, * MC: moisture content, ** XMG: xylan + mannan + galactan.

representative wood property values of the entire Korean pine trees, and the findings of this study can be utilized as a basis for such research. The following study will provide additional basic wood properties of various tree species, and regions, in order to establish a regional wood property database of Korean major domestic wood species.

CONFLICT of INTEREST

No potential conflict of interest relevant to this article was reported.

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