THE EFFECT OF STEAMING TIME AND TEMPERATURE ON THE LONGITUDINAL PERMEABILITY OF BLACK WALNUT

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ABSTRACT

Longitudinal permeability to water of black walnut sapwood and heartwood specimen plugs was determined before and after steam treatments for 1, 2, 3, and 4 h and two temperatures (100 C and 115 C). Steaming heartwood specimens at 115 C gave three times greater increase in longitudinal permeability than steaming at 100 C. Also, steaming heartwood specimens at 115 C for 4 h gave the greatest and most significant increase (560%) in longitudinal permeability of all other steaming times (which averaged about 90% increase). However, steam treatment caused very little change in longitudinal permeability of sapwood.

Steaming at 100 C for 4 h reduced the ratio of longitudinal permeability of sapwood to heartwood from 24,000 to approximately 10,000. Steaming at 115 C for 4 h reduced this ratio to about 4,000.

Additional keywords: *Juglans nigra*, heartwood, sapwood, treatments.

INTRODUCTION

Black walnut (*Juglans nigra* L.) is a slow-drying, valuable hardwood. Although the *Dry Kiln Operator's Manual* (Rasmussen 1961) recommends approximately 2 weeks to kiln-dry 1-inch stock from green to 6% moisture content, it is quite common for some kiln operators to spend up to 4 weeks kiln-drying 1-inch stock. For thicker stock such as gunstocks, 6 months of kiln-drying has been the average time required to go from green to 6% moisture content.

Results of steaming as a means of improving wood permeability and accelerating the drying rate have been inconclusive in the past. Several reasearchers directly or indirectly found that steaming increased wood permeability (Campbell 1961; Ellwood and Ecklund 1961; Ellwood and Erickson 1962; Nicholas and Thomas 1968). On the other hand, some researchers found that steaming did not increase green wood permeability (Erickson and Crawford 1959; Forest Products Research Lab. of England 1955). And still others found that steaming increased the initial drying rate, but the advantage became less as drying temperature rose (Torgeson and Smith 1942).

The purpose of this study was to determine whether steaming improves the longitudinal permeability of black walnut. Black walnut pits do not have tori to cause pit aspiration, but the wood has abundant extractives (Cooper 1971). Although the sapwood is fairly permeable, the heartwood is very impermeable even in the longitudinal direction (Chen and Cooper 1974). This paper describes the effect of the time of steam treatment at two different temperatures on the longitudinal permeability of sapwood and heartwood of green black walnut.

EXPERIMENTAL

A fresh, green sample of black walnut was cut and stored in a freezer at –10 F in order to preserve its green condition until the time of testing.

For sapwood, 16 specimen plugs (½-inch in diameter and ½-inch-long along the grain) were tested for each steaming treatment. Because of the greater variability in permeability of heartwood, 24 specimen plugs (½-inch in diameter and ¼-inch-long along the grain) were tested for each steaming treatment. Because of the lower perme-

TABLE 1. *Average longitudinal permeability[1] of green and steamed black walnut heartwood, and changes due to steam treatment*

Green before steaming Millidarcys	CV[2]	After steaming Millidarcys	CV[2]		Average change Percent	Steaming time Hours
		Steaming at 100 C				
0.61	(164)	0.79	(182)		29.5	1
0.40	(144)	0.62	(134)		55.0	2
0.65	(168)	1.05	(210)		61.5	3
0.69	(219)	1.64	(179)		137.7	4
				Grand Ave.	70.9	
		Steaming at 115 C				
0.81	(194)	1.79	(260)		121.0	1
0.66	(101)	1.25	(121)		89.4	2
0.72	(89)	1.20	(167)		66.7	3
0.58	(120)	3.87	(147)		567.2	4
				Grand Ave.	211.1	

[1] Each permeability value is an average of 24 specimens.
[2] Coefficient of variation (%).

ability, ¼-inch-long specimens were used in heartwood. Specimen plugs among different steaming treatments were matched along the grain.

Four different steaming times (1, 2, 3, and 4 h) at two different temperatures (100 C and 115 C) were employed in this study.

The longitudinal permeability to water of each specimen plug was determined before and after the steam treatment. The general procedure and equipment used to measure the permeability of the specimens have been previously described (Chen and Cooper 1974; Comstock 1968). The only modification for this study was that a pressure of 1.1 psi. was used to measure the flow of sapwood specimens and a pressure of 30 psi. was employed for heartwood specimens. The above pressures were chosen to avoid possible turbulent flow in the sapwood and to have some measurable flow in the heartwood.

The steaming treatment at 100 C was conducted by placing the specimen plugs in a suspended cage above boiling water in a 1-liter beaker with the mouth of the beaker covered by a series of concentric copper rings except for a small opening at the center. The steaming treatment at 115 C was carried out in a pressure cooker.

RESULTS AND DISCUSSION

Steaming effect on heartwood permeability

Permeability values varied greatly among the 24 specimens of each treatment. For example, the permeability ranged from 0.03 to 2.81 Millidarcys before steaming and from 0.02 to 22.96 Millidarcys after 4 h of steaming at 115 C. As shown in Table 1, all the coefficients of variation (CV) are very large. However, these CV values are similar to other work on low permeability species, such as white oak, post oak, true hickory, and green ash growing on southern pine sites (Choong et al. 1974).

The effects of steaming temperature and steaming time were both found to be statistically significant at the 95% level based on the difference in permeability before and after steam treatment for heartwood. Steaming at 115 C, on the average, gave three times greater increase in longitudinal permeability than steaming at 100 C (Table 1, column 5). Steaming at 115 C also gave a greater increase in longitudinal perme-

TABLE 2. *Significant differences, by Duncan's new multiple-range test, in the effect of steaming time on longitudinal permeability of black walnut heartwood*

Steam temperature	Significantly different steaming times (HR)	Difference Millidarcys	Significant range Millidarcys
115 C	4 > 3	2.8	2.4*
	4 > 2	2.7	2.3*
	4 > 1	2.3	2.2*

*Significant at 95% level.

ability than steaming at 100 C at every steaming time (Table 1).

However, the effect of steaming time was not as apparent as the effect of steaming temperature. Duncan's new multiple-range test was employed to further analyze the data (Steel and Torrie 1960). Steam treatment at 100 C generally increased longitudinal permeability the longer the steaming time (Table 1), but these differences among steaming times at 100 C were not statistically significant. Steam treatment at 115 C for 4 h gave the greatest and most significant increase (560%) in longitudinal permeability; all other steaming times at 115 C steaming temperature caused an average increase of about 90% in permeability (Tables 1 and 2). The reason increased steaming time at 115 C did not consistently cause an increase in permeability is not known.

STEAMING EFFECT ON SAPWOOD PERMEABILITY

Contrary to heartwood, the permeability values of sapwood vary little among the 16 specimens of each treatment before and after steaming. The maximum CV is about 7%, and the majority is about 3% (Table 3).

The steam treatment caused very little change in the longitudinal permeability of sapwood. Steaming at 100 C for 1 to 4 h

TABLE 3. *Average longitudinal permeability[1] of green and steamed black walnut sapwood, and changes due to steam treatment*

Green before steaming Darcys	CV[2]	After steaming at 100 C Darcys	CV[2]		Average change Percent	Steaming time Hours
16.7	(4.4)	16.7	(4.3)		0.0	1
16.5	(2.3)	16.5	(2.4)		0.0	2
16.6	(2.6)	16.6	(2.5)		0.0	3
16.7	(3.4)	16.7	(3.4)		0.0	4
				Grand Ave.	0.0	
		After steaming at 115 C				
16.9	(3.8)	17.1	(3.6)		1.2	1
16.6	(7.2)	16.9	(5.8)		1.8	2
16.7	(3.3)	16.8	(3.4)		0.6	3
17.1	(3.2)	17.2	(3.6)		0.6	4
				Grand Ave.	1.1	

[1]Each permeability value is an average of 16 specimens.
[2]Coefficient of variation (%).

did not cause any change at all. Although steaming at 115 C caused a slight increase in permeability, the maximum increase was only about 2% (Table 3). This is approximately equal to the accuracy of the flow meter used in this test. It was felt that there was no way to increase the longitudinal permeability of sapwood because it was already at its maximum value. There were no extractive materials present within the physical structure of the wood that would reduce permeability.

In general, steaming at 100 C for 4 h reduced the ratio of longitudinal permeability of sapwood to longitudinal permeability of heartwood from 24,000 (16,700/0.69) to approximately 10,000 (16,700/1.64). Steaming at 115 C for 4 h reduced this ratio to around 4,000 (17,200/3.87).

CONCLUSIONS

The variation in longitudinal permeability, both before and after steam treatment, is very large for heartwood and very small for sapwood.

Higher temperature and longer steaming time increased longitudinal permeability in heartwood, but both higher temperature and longer steaming time failed to alter the longitudinal permeability of black walnut sapwood.

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