SORPTION AND SHRINKAGE STUDIES OF SIX ARGENTINE WOODS

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(Received March 1983)

ABSTRACT

Sorption isotherms and shrinkage values were measured for six valuable Argentine wood species. Fiber saturation points were calculated. Tangential shrinkage ranged from 3.1 to 8.5% and radial shrinkage from 2.2 to 6.4%.

Keywords: Parana pine, *Cedro misionera,* Peterebi, *Quebracho colorado, Quebracho blanco, Algarrobo blanco,* sorption isotherms, adsorption, desorption, shrinkage.

INTRODUCTION

Argentina is the major per capita consumer of forest products in Latin America, although natural timber stands, comprised of some 500 tree species, occupy less than 10% of the total land area of 2.8 million square kilmeters. Argentina's forest products industry depends primarily on plantation grown and imported woods. This reliance on other than native species is due, in part, to a lack of knowledge of the basic properties of the native species.

A serious problem of some Argentine woods is dimensional instability of both workpieces and building elements during their use. This occurs after drying and is thought to be caused by improper drying schedules and/or unsuitable drying techniques. If these are the causes, a better understanding of the relationship between relative humidity and equilibrium moisture content (EMC) would be useful in alleviating this problem. This study was designed to determine shrinkage from swollen to oven-dry conditions for six native Argentine woods: Parana pine (*Araucaria angustifola* (Bert.) O.K.), Cedro misionero (*Cedrala tubiflora* (Bert.), peterebi (*Cordia trichotoma* (Vell.) Arrab.), Quebracho colorado santiagueno (*Schinopsis quebracho-colorado* (Gris.) Engl.), Quebracho blanco (*Aspidosperma quebracho-blanco* Schlecht.), and Algarrobo blanco (*Prosopis alba* Gris.). These species are economically important in Argentina and are also the most representative of the country's major natural regions: (a) the *Selva Misionera* (*Misiones Forest*), and (b) the *Parque Chaqueno* (*Chaco Woodlands*).

Wood and Fiber Science, 16(4), 1984, pp. 575–582

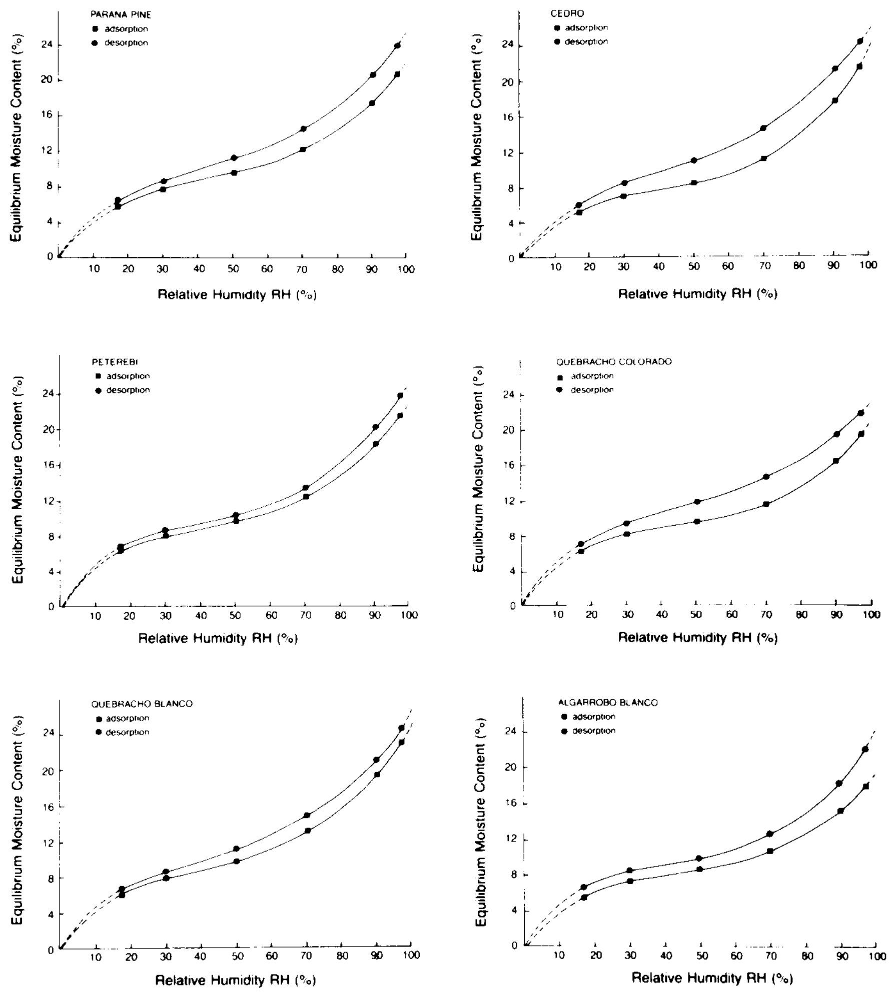

FIG. 1. Sorption curves for the six species studied. All measurements made at 20 C.

LITERATURE REVIEW

Since dimensional changes of wood in service are so important in processing, both shrinkage and swelling have been extensively studied by a number of researchers. Nearn (1955) studied the effect of water-soluble extractives on the volumetric shrinkage and EMC of eleven tropical and domestic woods. He found that the presence of extractives was responsible for a lower fiber saturation point and increased dimensional stability.

Wangard and Granados (1967) found that extractives depress the sigmoid sorption isotherm at relative humidities above 60 to 70%. They used nine tropical woods with extractive contents ranging from 3 to 17%. Before extraction, the desorption FSP ranged from 20.5 to 32.8%, while after neutral solvent extraction, the desorption FSP increased to between 30.4 and 38.0%.

Volumetric shrinkage-moisture content curves for twelve species were measured

TABLE 1. *EMC and hysteresis coefficients for six Argentine woods measured at 20 C.*

Species	Relative humidity (%)						Average hysteresis coefficient
	17	30	50	70	90	97	
Parana pine							
Adsorption	6.2	7.9	10.2	14.7	17.6	20.9	
Desorption	6.6	8.5	11.9	16.4	21.1	24.1	
Hysteresis coefficient	0.94	0.93	0.86	0.90	0.83	0.87	0.89
Cedro misionera							
Adsorption	6.1	7.3	9.7	14.5	17.8	21.5	
Desorption	6.1	8.5	12.0	16.9	21.4	24.2	
Hysteresis coefficient	1.00	0.86	0.81	0.86	0.83	0.89	0.88
Peterebi							
Adsorption	6.5	8.0	10.5	15.4	18.6	21.7	
Desorption	7.0	8.6	11.8	16.5	20.7	24.1	
Hysteresis coefficient	0.93	0.93	0.89	0.93	0.90	0.90	0.90
Quebracho colorado							
Adsorption	7.0	8.3	10.8	14.7	16.7	19.6	
Desorption	7.0	9.7	13.6	17.8	19.6	20.7	
Hysteresis coefficient	1.00	0.86	0.79	0.83	0.85	0.95	0.88
Quebracho blanco							
Adsorption	6.2	7.3	10.8	16.0	19.5	23.0	
Desorption	6.7	8.6	12.2	17.3	21.3	24.8	
Hysteresis coefficient	0.93	0.85	0.89	0.92	0.92	0.93	0.93
Algarrobo blanco							
Adsorption	5.6	7.5	9.8	13.1	15.5	18.0	
Desorption	6.7	8.6	12.2	17.3	21.3	24.8	
Hysteresis coefficient	0.78	0.93	0.99	0.94	0.93	0.82	0.90

by Higgins (1957). He noted considerable differences in total volumetric shrinkage between species. He studied four North American softwoods and eight tropical hardwoods and found significant differences in EMC values among the twelve species. Six species had FSP values of 15 to 20%. These species were primarily foreign hardwoods with high extractive contents. Five of the foreign woods were found to have good dimensional stability as indicated by their relatively flat hysteresis loops.

Spalt (1957) studied sixteen North American and tropical woods and found a wide range of fiber sturation points. These ranged from 19.8 to 30.5% in adsorption and 21.8 to 33.6% in desorption. He attributed the wide spread in FSP to greatly differing extractive contents.

Later, Stamm (1962, 1964) and Skaar (1972) provided comprehensive discussions of dimensional changes. More recently, Spalt (1979) reviewed the state-of-the-art of water vapor sorption by high-extractive woods. He stated that woods with a high extractive content exhibit lower EMC and shrinkage at room tem-

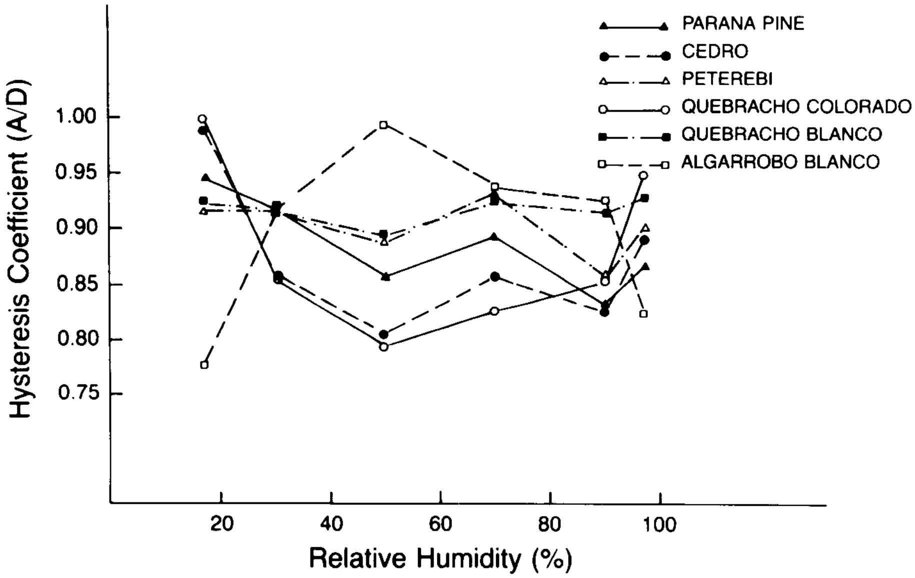

FIG. 2. Adsorption/desorption ratios for the six Argentine species.

perature but higher shrinkage and collapse during the elevated conditions experienced during kiln drying.

MATERIALS AND METHODS

Sample preparation

The specimens used in this study were taken from air-dry wood samples obtained from the National University of Santiago del Estero, Argentina. The history of these samples prior to their arrival in the United States is unknown.

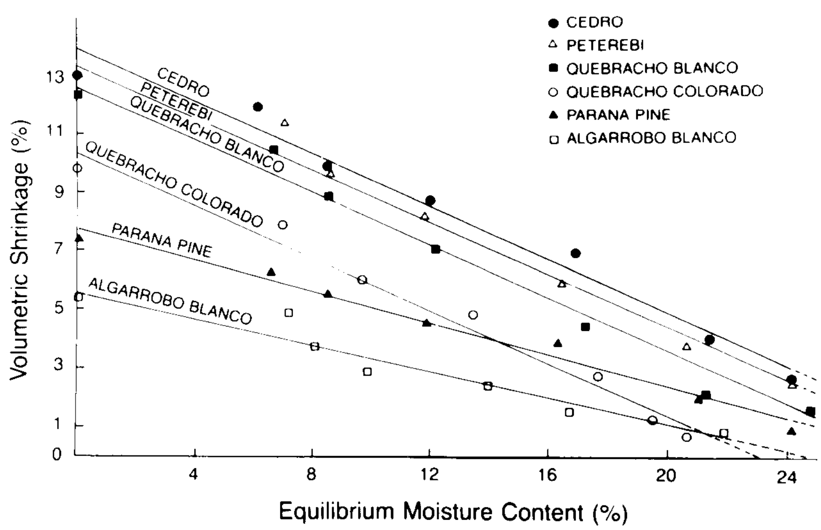

FIG. 3. Volumetric shrinkage curves.

TABLE 2. *Fiber saturation point valves (%) derived from sorption curves and shrinkage data.*

Species	Sorption curves[1]			Shrinkage data[2]			
	A	D	Mean	T	R	V	Mean
Parana pine	22.0	25.5	23.8	27.0	34.0	29.5	30.2
Cedro misionera	24.5	26.0	25.3	30.0	21.8	30.8	27.5
Peterebi	23.0	26.0	24.5	28.7	31.7	29.6	30.0
Quebracho colorado	21.0	23.5	22.3	21.3	25.7	22.8	23.3
Quebracho blanco	25.5	27.0	26.3	27.3	26.7	27.1	27.0
Algarrobo blanco	19.5	24.5	22.0	24.6	25.2	24.9	24.9

[1] A and D represent values derived from adsorption and desorption curves, respectively.
[2] T, R, and V represent values derived from shrinkage measurements.

Several specimens approximately 1 cm × 1 cm × 1 cm were cut from each of the original samples. Care was taken to prepare samples with true radial and tangential surfaces. A minimum of six replicates of each species was selected at random for use. One series of samples was used for the adsorption cycle, while another series was used for the desorption cycle. All samples were oven-dried prior to conditioning. The desorption samples were then water-saturated under vacuum.

Sample conditioning

Six different constant RH conditions (17, 30, 50, 70, 90, and 97%) were used. The humidity chambers consisted of small desiccators containing aqueous glycerol solutions. The desiccator technique was selected for being simple, rapid, economical, and fairly accurate. Glycerol was chosen because its aqueous solutions are known to be relatively temperature insensitive and can be used over a wide range of RH conditions (National Research Council 1928). The chambers were kept at 20 ± 1 C. Measurements were taken at each humidity level after equilibrium was attained. Weights were measured on an analytical balance, while dimensions were measured using a dial gauge micrometer. Moisture content was expressed on an oven-dry weight basis, while shrinkage values are based on swollen conditions.

RESULTS AND DISCUSSION

Sorption isotherms for each species were drawn as smooth curves through the experimental points (Fig. 1). The general shape of the isotherms is similar to that shown by other published curves for wood and cellulose.

From the sorption curves it is evident that *Quebracho colorado* and *Algarrobo blanco* have the lowest EMC values at 97%. These values were 20.7 and 21.9% for desorption and 19.6 and 18.0% for adsorption for each species.

These species are known to have high tannin contents—30 to 35% for *Quebracho colorado* and 10 to 12% for *Algarrobo blanco* (Tortelli 1956). It appears logical therefore to attribute their correspondingly low EMC values at 97% RH to the displacement of void volume by extraneous materials. This effect has been long recognized (Nearn 1955; Higgins 1957; Stamm 1964).

Extrapolation of the isotherms to 100% RH resulted in the fiber saturation point moisture contents given in Table 2. Adsorption FSP values ranged from 19.5 to 25.5%, while desorption values ranged from 23.5 to 27.0%. Mean values for the six species are 22.6% for adsorption and 25.4% for desorption. These are somewhat

TABLE 3. *Tangential (T) and radial (R) shrinkage (%) as functions of humidity.*

Species		Relative humidity (%)						
		0	17	30	50	70	90	97
Parana pine	T	4.4	3.6	3.3	2.5	2.0	1.0	0.3
	R	2.9	2.6	2.2	1.9	1.8	1.0	0.7
	T/R	1.52	1.38	1.50	1.32	1.11	1.00	0.43
Cedro misionera	T	6.8	6.2	5.1	4.4	3.4	1.9	1.1
	R	6.4	5.8	4.7	4.3	3.5	2.1	1.4
	T/R	1.06	1.07	1.09	1.02	0.97	0.90	0.79
Peterebi	T	8.5	7.2	6.3	5.7	3.6	2.2	1.6
	R	4.1	4.0	3.4	2.5	2.2	1.5	0.9
	T/R	2.07	1.80	1.86	2.28	1.64	1.47	1.78
Quebracho colorado	T	6.0	4.8	3.7	2.9	1.3	0.3	0.2
	R	3.6	3.2	2.2	1.8	1.4	1.0	0.4
	T/R	1.67	1.50	1.68	1.61	0.93	0.30	0.50
Quebracho blanco	T	8.2	7.0	5.7	4.8	2.9	1.4	1.3
	R	4.4	3.4	3.1	2.2	1.6	0.7	0.3
	T/R	1.86	2.06	1.84	2.18	1.81	2.00	4.33
Algarrobo blanco	T	3.1	2.9	2.2	1.6	1.2	0.9	0.7
	R	2.2	1.8	1.4	1.2	1.2	0.6	0.2
	T/R	1.41	1.61	1.57	1.33	1.00	1.5	3.5

lower than those reported by Stamm (1964) of 26% for hardwoods and 27% for softwoods.

The magnitude of hysteresis is usually measured by the hysteresis coefficient A/D, which is defined as the ratio of EMC for adsorption to that of desorption at any given RH. Results obtained by this method are subject to variation related to the RH values at which these ratios are calculated and the limits of accuracy in interpolating moisture contents from isotherms.

The coefficients given in Table 1 were averaged in order to have a measure of the magnitude of hysteresis for each species. The mean A/D values for the species studied fall within the limits generally reported in the literature (Stamm 1964; Spalt 1957, 1958, 1979).

The two species having the high tannin content, *Quebracho colorado* and *Algarrobo blanco,* do not show exceptionally low or high hysteresis coefficients, which may be an indication that extractives have little effect on the A/D ratios. This has been suggested by Stamm (1964) for white pine (*Pinus strobus* L.) and Klinki pine (*Araucaria klinki*). When the A/D ratios are plotted as functions of RH (Fig. 2), most of the curves have the same pattern, i.e., starting high, decreasing at intermediate humidity levels, and then increasing again. *Algarrobo blanco* follows the opposite pattern, however.

Shrinkage curves

Figure 3 illustrates the relationship between volumetric shrinkage and moisture content determined in this study. These lines were fitted by least squares analyses of the data. Simple linear correlation coefficients (r) of the six species ranged from 0.96 to 0.99. The shrinkage data used to develop these curves are summarized in Table 3. Since the longitudinal dimensional changes are normally extremely small, volumetric shrinkage was approximated by adding the values for the radial and tangential percent shrinkages.

Algarrobo blanco exhibited the least volumetric change (5.3%) while *Cedro misionera* had the highest, 13.1%. It is assumed that the relatively high extractive content of *Algarrobo blanco* is responsible for the very low volumetric changes. However, *Quebracho colorado,* which is supposed to have an even higher tannin content, had a relatively high volumetric change, 9.6%. Conversely, Parana pine had a relatively low total volumetric shrinkage, 7.3% (4.4% T, 2.9 % R), and this species is not known to be rich in extraneous materials. These values do not agree with those reported by the Wood Handbook (USDA 1974) of 7.9% T, and 4.0% R. However, this is not totally unexpected, given the limited sample size available to the authors and the uncertain sample history.

It is interesting to note that the shrinkage curves for cedro, peterebi, and the two quebrachos have practically the same slope. Similarly, the lines representing Parana pine and *Algarrobo blanco* are almost parallel. The reason for this is not readily apparent. There appears to be a breakoff point between 7.7% and 10.3%. Nearn (1955) and Higgins (1957) had made similar observations. Fiber saturation points (Table 2) were also calculated based on the shrinkage data. These values are somewhat higher (1 to 7%) than those derived from the sorption curves. However, *Quebracho colorado* and *Algarrobo blanco* still have the lowest mean FSP values.

Using the data for radial and tangential shrinkage (Table 2), the T/R ratios were calculated. The values ranged from 1.07 for cedro to 2.09 for peterebi, with an average of 1.62. If the exceptionally low T/R ratio for cedro is ignored, the other five species have an average ratio of 1.73. From another standpoint, the one softwood, Parana pine, has a T/R ratio of 1.51, while the five hardwoods have a mean T/R ratio of 1.64. It was interesting to compute the T/R ratios at the various humidity levels used in this study. Neglecting the 97% RH level, the T/R ratios at the other RH levels followed the same trend as the overall T/R ratio for a species. Species that had relatively high T/R ratios, peterebi and *Quebracho blanco,* had high ratios at each RH level. Species that had low ratios had relatively low ratios at each RH level. However, in both *Cedro blanco* and *Quebracho colorado,* the T/R ratio became less than 1.00 at the higher RH levels. It would be very interesting to explore this further and see if this is real or an aberration.

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