Ciência da Madeira ***(Brazilian Journal of Wood Science)***

6(1): 23-30, 2015
DOI: 10.12953/2177-6830/rcm.v61p23-30

Recebido: 07-07-2014 Aceito: 23-02-2015

Assessing the physical and mechanical properties of three native species from Southern Brazil

Adriano Bolgenhagen[1], Diogo José Horst[2]*, Rodolfo Reinaldo Hermes Petter[3], Oto Roberto Bormann[4]

[1]Departamento de Tecnologia Industrial, Universidade do Estado de Santa Catarina - UDESC, São Bento do Sul, SC.
[2] Engenharia de Produção, Universidade Tecnológica Federal do Paraná - UTFPR, Curitiba, PR.
[3]Engenharia de Produção, Universidade Federal do Rio Grande do Sul, Porto Alegre, PR.
[4]Departamento de Engenharia de Produção (PPGEP), Universidade do Estado de Santa Catarina - UDESC, São Bento do Sul, SC.

ABSTRACT This study aimed at asserting some physical and mechanical characteristics of three different wood species from Brazil: Bracatinga (*Mimosa scabrella* Benth.) Cedro-rosa (*Cedrela fissilis* Vell.) and Vassourão-branco (*Piptocarpha angustifolia* Dusén ex Malme). The tests done include the determination of moisture content, density, dimensional stability (swelling and shrinkage), volumetric variation, normal compression to the grain, tensile parallel to the grain, wood shearing, static bending and bonding and fixing properties (finger-joint resistance and pulling out nails and screws). In addition, some factors regarding the machinability of these materials were also evaluated. Results showed distinct peculiarities among the species, highlighting their positive performance during tests, and in most cases the obtained values were similar or even above those required by technical standards, indicating the possible application of these materials in several productive processes.

Keywords: native trees, mechanical strength, dimensional stability, wood properties.

Avaliação das propriedades físicas e mecânicas de três espécies nativas do sul do brasil

RESUMO Este estudo teve como objetivo determinar algumas características físicas e mecânicas de três espécies distintas nativas do Brasil: Bracatinga (*Mimosa scabrella* Benth.) Cedro-rosa (*Cedrela fissilis* Vell.) e Vassourão-branco (*Piptocarpha angustifolia* Dusén ex Malme). Os testes realizados incluem a determinação do conteúdo de umidade, densidade, estabilidade dimensional (inchamento e retração), variação volumétrica, compressão normal às fibras, tração paralela às fibras, cisalhamento, flexão estática, e também propriedades de colagem e fixação (resistência de emendas finger e arranque de pregos e parafusos). Além disso, alguns fatores referentes à usinabilidade destes materiais também foram avaliados. Os resultados demonstraram peculiaridades distintas entre as espécies, destacando seu desempenho positivo durante os testes, na maioria dos casos obtendo valores em conformidade ou até mesmo acima daqueles requeridos pelas normas técnicas, portanto indicando a aplicação destes materiais em diversos processos produtivos.

Palavras-chave: árvores nativas, resistência mecânica, estabilidade dimensional, propriedades das madeiras.

* Autor correspondente: diogohorst@hotmail.com

Introduction

Wood is a very competitive material used for various purposes such as pulp and paper, construction or furniture. It presents aspects, which make it economically competitive, and shows excellent ecological acceptance. When associated with modern techniques of reforestation, it allows the profitable development of industrial products.

However, with the emergence of reforestation as a way to feed the industrial need for timber, in most cases the species used are from non-conventional (exotic) origin, thereby resulting in a series of non-natural concepts to the environment.

Nowadays, the increasing globalization and the consequent expansion in international trade are causing the introduction of many exotic species – both intentionally and unintentionally – in places where there are no natural enemies, making exotic species more efficient than the native ones in the utilization of resources (THOMAS; REID, 2007). Indeed, these kinds of species are multiplying rapidly and are consequently leading to the impoverishment of the environment, the simplification of ecosystems and even the extinction of some native species (GUREVITCH; PADILLA, 2004).

The condition of developing countries in the pursuit of sustainability, particularly those with mega biodiversity, mainly depends on their ability to protect ecosystems, economies and public health (RODRIGUES, 2003). Unluckily, an invasion of exotic species among plants, animals and microorganisms brings a significant and unprecedented threat to the resources of these countries (PIMENTEL et al., 2005).

Brazil is a well-known exporter of pulp, lumber, panels, frames and furniture, but mainly exports products built from exotic varieties, such as pines and eucalyptus. Among the native species most commonly used for export, it is possible to highlight Jatobá, Ipê and Cumaru. In this context, there is the possibility of using other native species for diverse applications. However, most of their physical and mechanical properties remain unknown.

Bracatinga (*Mimosa scabrella* Benth.) is a native tree from Brazil, typically found among sub-forests. It has been exploited for several purposes, emphasizing its good lumber – used for furniture production and construction – and its wastes, which are an attractive alternative energy source. In addition, this species adapts quickly to degraded areas (EMBRAPA, 1988; BARTOSZECK et al., 2004; LORENZI, 2008).

Bracatinga reaches 4-18 m in height (up to 29 m when adult) and its trunk is usually straight, with diameters varying between 30 and 40 cm. The bark has a thickness of around 20 mm, presenting brown color when young and from brownish-gray up to dark-brown when it reaches maturity (ANGELI; STAPE, 2003, NAPPO et al., 2004, MACHADO et al., 2006).

Cedro-rosa (*Cedrela fissilis* Vell.) spreads itself across the national territory – from Rio Grande do Sul as far as Minas Gerais, sometimes extending to the North –, besides being present in other countries of South America, such as Bolivia, Peru, Argentina and Paraguay. One of its main peculiarities is its pink color tone; the wood has excellent quality and is being used for several purposes, such as the production of frames and floors (MATTOS, 1980; PINHEIRO et al., 1990).

Cedro-rosa tree reaches 10-25 m in height (up to 40 m when adult) and 40-80 cm in diameter. Its trunk is cylindrical and slightly twisted, presenting a grayish-brown bark with typical longitudinal fissures. The bark is 40 mm thick and it is internally red (XAVIER et al., 2003; LORENZI, 2008).

Vassourão-branco (*Piptocarpha angustifolia* Dusén ex Malme.) occurs naturally in the southern states of Brazil, especially in Minas Gerais, São Paulo, Santa Catarina and Rio

Grande do Sul. This species usually grows in clearings and coppices, characterized by secondary vegetation. In general, its wood is used for construction, chipboards and plywood, and it is recommended for the production of pulp and paper, as well as animal forage (CARVALHO, 2003).

This species reaches 5-15 m in height (30 m when adult) and its trunk is almost straight, with cylindrical section diameter between 30 to 40 cm, presenting a smooth and whitish bark, which can reach up to 20 mm in thickness (MAINERI; CHIMELO, 1971, LORENZI, 2008).

The knowledge of the characteristics of different kinds of wood allows their rational use. In this sense, this work aimed at ascertaining some physical and mechanical properties of three native woods from Brazil: *Mimosa scabrella* Benth., *Cedrela fissilis* Vell. and *Piptocarpha angustifolia* Dusén ex Malme. Additionally, other factors conducive to their machinability were also evaluated.

Material and Methods

Physical and mechanical tests were performed at the Laboratory of Wood and Furniture Technology from the National Service of Industrial Learning (SENAI), an institute certified by The National Institute of Metrology Quality and Technology (INMETRO), and at the Laboratory of Industrial Technology from the University of Santa Catarina State (UDESC).

The criterion used for the selection of the size of the samples followed the requisites of the Brazilian Association of Technical Standard (ABNT) NBR-7190 (1997). All materials previously selected for testing presented no flaws such as knots or rots, and tests were carried out inside a conditioned environment with an average temperature maintained at 20°C and relative humidity around 70%.

For the tests, twenty planks of each species were bought from local markets in São Bento do Sul (located in the northeast of Santa Catarina State) and this material was originally purchased in saturated conditions and in small batches, measuring approximately 4 $x10^{-2}$ m^3 with a thickness of 27 mm.

The planks were opened on boards with the use of a band saw, reaching the final dimensions of 50 x 50 x 27 mm, and dried in a laboratory pilot-scale kiln maintained at 50 $^oC \pm 3$ for 24h until they reached a moisture content between 12 and 15%.

It is important to highlight that, when testing native specimens, some care must be taken because the cutting of their wood is restricted by law, so for research purposes the samples in this study were purchased in places where forest management occurs.

The determination of the physical properties was performed following the American Society for Testing and Materials regulations, and the tests determined the moisture content D-4442 (ASTM, 2007) and density D-2555 (ASTM, 2011).

Tests of dimensional stability (swelling and shrinkage) were performed according to the American Wood Protection Association regulations (AWPA, 2014).

Evaluations of mechanical properties were performed with the use of a universal essay machine model DL–5000–10000 (EMIC®), and these tests were performed following the requisites of the National Institute of Standardization of Chile NCH-973 (INN, 1999), NCH-975 (INN, 1999), NCH-976 (INN, 1999) and NCH-987 (INN, 1986).

The feed rate velocities adopted during tests were: normal compression to grain 15 mm/min, tensile parallel to grain 50 mm/min and wood shearing 12 mm/min.

Tests of finger-joint resistance were performed following the D5572-95 (ASTM, 2005) standard for tests, and the samples received an adhesive application using catalyzed glue classification D4 (Franklin®).

The test of pulling out screws and nails was performed following the NHC-979 (INN, 1999) regulation. This norm recommends that to determine the maximum resistance value, it is necessary to start from the minimum force value obtained during the initial test. Thus, during the tests, PHS FL 3.5 x 25 mm and PHS 4.5 x 50 mm screws and 25mm nails (CISER®) were used.

Results and Discussion

Compared to Bracatinga, Cedro-rosa and Vassourão-branco presented lower volumetric variations. It is important to emphasize that, according to Pfeil (2003) the dimensional stability of wood can vary depending on several criteria, generally varying an average of 10% in the tangential direction, 5% in the axial direction and 0.5% in the radial direction. This parameter confirms the positive results obtained in this study, as shown in Table 1.

The dimensional stability of Bracatinga was classified as medium/high, whereas Cedro-rosa and Vassourão-branco presented medium/low stability, according to the standard values cited by ABNT NBR-7190 (ABNT, 1997).

The volumetric variation of Bracatinga was classified as medium, whereas Cedro-rosa and Vassourão-branco presented lower volumetric changes. In their study of the dimensional stability of different Tropical Pines, Trianoski et al., (2013) found similar values regarding those reported in this research.

It is important to note that, during testing, the species presented different behavior and some common particular characteristics were noted between them. For example, during the drying procedures, the samples of Vassourão-branco and Cedro-Rosa showed a few cracks and slight curling, which can be fixed easily, thus presenting a behavior similar to pines, in accordance to a study conducted by Calegari et al. (2007).

Table 1. Evaluation of the physical properties of the tested specimens.
Tabela 1. Avaliação das propriedades físicas das amostras testadas.

Physical properties	Sample	Direction			Standard Deviation
		Tangential	Radial	Axial	
Moisture (%)	A	10.67	-	-	0.892
	B	10.16	-	-	1.745
	C	10.87	-	-	0.850
Density (g/cm^3)	A	0.60	-	-	0.008
	B	0.46	-	-	0.013
	C	0.52	-	-	0.012
Swelling* (%)	A	11.1	5.0	0.6	-
	B	8.5	4.0	0.4	-
	C	9.6	5.4	0.5	-
Shrinkage* (%)	A	12.6	5.2	0.9	-
	B	7.6	3.2	0.3	-
	C	10.0	4.6	0.4	-
Volumetric variation (%)	A	5.6	-	-	-
	B	4.1	-	-	-
	C	4.5	-	-	-

A (Bracatinga), B (Cedro-Rosa), C (Vassourão-branco), (α=5%).

On the other hand, the wood from Bracatinga showed a greater resistance during drying, in most cases resulting in curling and warping, therefore presenting enormous difficulty to repair. It is important to lay emphasis on the fact that, by taking certain precautions – such as adopting a suitable drying program – most of these problems could be avoided. Table 2 shows the results of the mechanical properties analyzed.

Generally, the species presented positive machinability during testing, each one with its own peculiarities. For example, the wood from Bracatinga showed a natural tendency to crack, especially during the process of thickness reduction. In addition, some precautions must be taken during the process of saw cutting, because Bracatinga has a moderately hard wood, presenting several knots, which can easily disrupt the cut.

Table 2. Evaluation of the mechanical properties of the tested samples.
Tabela 2. Avaliação das propriedades mecânicas das amostras testadas.

Mechanical Properties	Sample	Average Values* Deformation/Tension	Force Max. (kgf)	Standard Deviation
Compression Normal to Grain (mm)	A	1.45	9988	0.278
	B	1.51	10017	0.731
	C	2.38	9990	1.285
Wood Shearing (kgf)	A	832.3	-	218.2
	B	967.8	-	337.3
	C	956.2	-	191.7
Tensile Parallel to Grain (MPa)	A	92.47	474.00	39.071
	B	25.36	203.10	5.502
	C	74.56	382.20	17.714
Static Bending (MPa)	A	291.20	220.50	25.499
	B	181.30	133.90	18.677
	C	366.34	255.68	44.686

A (Bracatinga), B (Cedro-Rosa), C (Vassourão-branco), *modulus of elasticity, (α=5%).

Table 3. Evaluation of bonding and fixing properties of the tested specimens.
Tabela 3. Avaliação das propriedades de colagem e fixação das amostras testadas.

Bonding and Fixing Properties	Sample	Direction			Standard Deviation
		Radial	Tangential	Axial	
Pulling out Nails* (kgf) (13 x 15 mm)	A	52.72	72.19	29.43	8.974
	B	29.16	51.83	46.32	3.154
	C	37.43	43.39	32.10	11.197
Pulling out Screws* (kgf) (PHS PAN 4.5 x 50 mm)	A	165.60	137.80	164.59	20.821
	B	184.70	155.80	161.80	41.360
	C	137.70	190.90	136.50	18.988
Pulling out Screws* (kgf) (PHS PAN 3.5 x 25 mm)	A	137.80	164.90	118.20	44.483
	B	100.90	95.04	82.42	13.575
	C	111.20	126.60	114.90	10.434
Finger Joint Resistance (kgf/cm^2)	A	311.90	-	-	69.353
	B	218.50	-	-	59.507
	C	293.20	-	-	56.947

A (Bracatinga), B (Cedro-Rosa), C (Vassourão-branco), *directions (radial, tangential, axial), (α=5%).

It is important to highlight that Bracatinga also presented a high tendency to chipping, especially when used in processes involving routers and milling.

Vassourão-branco was classified as a medium density wood, exhibiting positive machinability during several processes such as during thickness reduction, drilling, sanding and straightening. However, during the process of cutting with the use of a band saw, some precautions must be taken, especially when working with very high feed speeds. Table 3 shows the bonding and fixing properties of the species.

Cedro-rosa was classified as a low density wood and presented positive machinability. During tests, it acquired a great finish as a result from the process of sanding, but it should always be machined towards the normal direction of the fibers, otherwise the wood may exhibit a harsh aspect,

thus raising wood splinters. The results from the finger joint resistance test showed that, most of the times, the obtained values remained above those established by the standard determined by D-5572 (ASTM, 1995), which is of 140.6 kgf/cm^2.

Indeed, still regarding the finger-joint resistance test, Bracatinga wood presented an average value of 122%, Cedro-rosa 56% and Vassourão-branco 109% above the standard. Additionally, Bracatinga evidenced a result 30% higher in comparison to Cedro-rosa and this last one reached a result 6% higher than Vassourão-Branco.

It is important to emphasize that the samples used in this study are part of native specimens with no adequate control of their genetics. This feature may result in some biological differences among them, therefore influencing on the determination of their physical and mechanical properties. Besides, other factors such as the age of the trees or the environment where they were planted may contribute differently to the properties of the tested specimens.

According to Tsoumis (1991), many features may vary within the plant, during the life of the plant and between individuals of the same species. Furthermore, branches and other parts of the trunk tend to present lower densities in comparison to the marrow stem (HOADLEY, 2000).

The knowledge of the hygroscopic properties of wood is an excellent criterion for its selection and safe use, since it has direct influence on the wood properties. Accordingly, it is important to know these properties in order to make a better choice of the material for a specific application.

Conclusions

All specimens tested showed adequate properties during the determination of moisture content, density, dimensional stability (swelling and shrinkage), volumetric variation, normal compression to the grain, tensile parallel to the grain, wood shearing, static bending, bonding and fixing properties (finger joint resistance and pulling out nails and screws). In most cases, the obtained values were above those required by the technical standards, thus proving the possible use of these kinds of wood in several applications such as construction or furniture.

The tests reinforced the existence of distinct peculiarities among the specimens, thus showing that these native trees present physical and mechanical properties equal or even superior to those obtained from exotic specimens, which are currently the most commonly used in wood processes of transformation in Brazil.

References

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). **D4442–07**: Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials, 6 pages, 2007.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). **D2555–06**: Standard Practice for Establishing Clear Wood Strength Values, 18 pages, 2011.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). **D5572–95**: Standard Specification for Adhesives Used for Finger Joints in Nonstructural Lumber Products, 17 pages, 2005.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS (ABNT). **NBR–7190**: Projetos de estruturas de madeira, 107 páginas, 1997.

AMERICAN WOOD PROTECTION ASSOCIATION (AWPA). Book of Standards: American Wood Protection Association, 670p, 2014.

ANGELI, A.; STAPE, J. L. ***Mimosa scabrella*** **(Bracatinga)**. Instituto de Pesquisas e Estudos Florestais IPEF-LCF/ESALQ/USP: Piracicaba, SP, 2003.

BARTOSZECK, A.C. de P. e S.; MACHADO, S. do A.; FIGUEIREDO FILHO, A.; OLIVEIRA, E.B. Dinâmica da Relação Hipsométrica em Função da Idade, do Sítio e da Densidade Inicial de Povoamentos de Bracatinga da Região

Metropolitana de Curitiba, PR. **R. Árvore**, Viçosa-MG, v. 28, n.4, p. 517-533, 2004.

CALEGARI, L.; STANGERLIN, D. M.; SANTINI, E. J.; HASELEIN, C. R.; LONGHI, S. J.; DO CARMO, P. I. O.; DA SILVA FILHO, L. C. P.; GATTO, D. A. Monitoring Moisture Content in *Pinus elliottii* sp. Engelm. and *Eucalyptus grandis* sp. W. Hill ex Maiden WOODS, Under Different Drying Temperatures, Through the Ultrasound. **Ciência Florestal**, v. 17, n. 4, p. 399-408, 2007.

CARVALHO, P. E. R. **Espécies Arbóreas Brasileiras:** Embrapa Florestas, Colombo, PR, 1039p, 2003.

EMBRAPA. **Manual técnico da Bracatinga (*Mimosa scabrella* Benth)**. Centro Nacional de Pesquisa de Florestas (EMBRAPA-CNPF). Documentos, 70p. v. 20. Curitiba, PR, 1988.

GUREVITCH, J.; PADILLA, D. K. **Are invasive species a major cause of extinctions?** Trends in Ecology and Evoloution, v. 19, n. 9, 470-474, 2004.

HOADLEY, R. B. **Understanding Wood**: A Craftsman's Guide to Wood Technology. Taunton Press Inc. 2nd Edition, 2000.

INSTITUTO NACIONAL DE NORMALIZACIÓN (INN) CHILE **NCH–979**: Madera – Determinación de las propriedades mecânicas – Ensayo de extracción de clavo, 7p, 1999.

INSTITUTO NACIONAL DE NORMALIZACIÓN (INN) CHILE **NCH–973**: Madera – Determinación de las propriedades mecânicas – Ensayo de compresión paralela, 9p, 1999.

INSTITUTO NACIONAL DE NORMALIZACIÓN (INN) CHILE. **NCH–975**: Madera Determinación de las propriedades mecânicas – Ensayo de tracción perpendicular as fibras, 7p, 1999.

INSTITUTO NACIONAL DE NORMALIZACIÓN (INN) CHILE. **NCH–976**: Madera Determinación de las propriedades mecânicas – Ensayo de cizalle paralelo a las fibras, 8p, 1999.

INSTITUTO NACIONAL DE NORMALIZACIÓN (INN) CHILE. **NCH–987**: Madera Determinación de las propriedades mecânicas – Ensayo de flexión estática, 9p, 1986.

LORENZI, H. **Árvores Brasileiras:** manual de identificação e cultivo de plantas arbóreas nativas do Brasil, Instituto Plantarum, vol.1, 5.ed. Nova Odessa, SP, 2008.

MAINIERI, C.; CHIMELO, J.P. **Fichas de Características das madeiras brasileiras**. IPT – Instituto de Pesquisas Tecnológicas, 2 ed. São Paulo, SP, 1971.

MATTOS, J. R. **Contribuição ao estudo do cedro** – *Cedrela fissilis* Vell. Instituto de Pesquisas de recursos Naturais Renováveis "IPRNR - AP", 1980. 54p. Publicação n. 4. Porto Alegre, RS, 1980.

MACHADO, S. do A.; BARTOSZECK, A.C de P. e S.; FIGUEIREDO FILHO, A.; OLIVEIRA, E.B. Dinâmica da Distribuição Diamétrica de Bracatingais na Região Metropolitana de Curitiba. **Revista Árvore**, Viçosa-MG, v. 30, n. 5, p. 759-768, 2006.

NAPPO, M.E.; GRIFFITH, J.J.; MARTINS, S.V.; MARCO JUNIOR, P.; SOUZA, A.L; OLIVEIRA FILHO, A.T. Dinâmica da Estrutura Fitossociológica da Regeneração Natural em Sub-bosque de *Mimosa Scabrella Bentham* em Área Minerada, em Poços de Caldas, MG. **Revista Árvore**, Viçosa-MG, v. 28, n. 6, p. 811-829, 2004.

PIMENTEL, D.; ZUNIGA, R.; Morrison, D. Update on the environmental and economic costs associated with alien-invasive species in the United States. **Ecological Economics**, v. 52, n. 3, p. 273–288, 2005.

PINHEIRO, A. L.; MARAGON, L. C.; PAIVA, G. L. R. M. Características fenológicas do cedro (*Cedrela fissilis* Vell.) em Viçosa, Minas Gerais. **Boletim de Pesquisa Florestal**, Curitiba, PR. v. 21, p. 21-26, 1990.

PFEIL, W. **Estruturas de madeira**. 6 ed. Rio de Janeiro, RJ: Livros Técnicos e Científicos, 2003.

RODRIGUES, M. T. BIODIVERSIDADE: DO PLANEJAMENTO À AÇÃO. Cienc. Cult. v. 55, n. 3, 2003.

TRIANOSKI, R.; DE MATOS, J. L. M.; IWAKIRI, S.; PRATA, J. G. Avaliação da Estabilidade Dimensional de Espécies de *Pinus* Tropicais. Floresta e Ambiente, v. 20, n. 3, p. 398-406, 2013.

THOMAS, M. B.; REID, A. M. Are exotic natural enemies an effective way of controlling invasive plants? Trends in Ecology and Evolution, v. 22, n. 9, p. 447-453, 2007.

TSOUMIS, G. **Science and Technology of Wood: Structure, Properties, Utilization**. Van Nostrand Reinhold, New York, 1991.

XAVIER, A.; SANTOS, G.A.; WENDLING, I.; OLIVEIRA, M.L. Propagação Vegetativa de Cedro-rosa por Miniestaquia. **Revista Árvore**, v. 27, n. 2, p. 139-143, 2003.