TECHNICAL NOTE: PROPERTIES OF WOOD FROM FROST-TOLERANT EUCALYPTUS PLANTED IN BRAZIL

*E. C. Lengowski**

Adjunct Professor
Faculty of Forestry Engineering
Federal University of Mato Grosso
Avenue Fernando Corrêa da Costa
Mato Grosso 18068 600, Brazil
E-mail: elainelengowski@gmail.com

E. A. Bonfatti Júnior

PhD Student in Forestry Engineering
Department of Forestry Engineering and Technology
Federal University of Paraná
Avenue Prefeito Lothário Meissner
Paraná 80210 170, Brazil
E-mail: bonfattieraldo@gmail.com

B. Vatras

Engineering Student
University of Contestado
Avenue Roberto Ehlke
Santa Catarina, 89460 010, Brazil
E-mail: brunavatras1995@gmail.com

P. B. Moreira Neto

Engineering Student
University of Contestado
Avenue Roberto Ehlke
Santa Catarina 89460 010, Brazil
E-mail: pedromoreira016@gmail.com

J. M. R. Barros

Master Student in Forestry Science
Faculty of Forestry Engineering
Federal University of Mato Grosso
Avenue Fernando Corrêa da Costa
Mato Grosso 18068 600, Brazil
E-mail: jeinna17@gmail.com

S. Nisgoski

Associated Professor
Department of Forestry Engineering and Technology
Federal University of Paraná
Avenue Prefeito Lothário Meissner
Paraná 80210 170, Brazil
E-mail: silnis@yahoo.com

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* Corresponding author

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Abstract. The study of the technological characteristics of wood is of great importance as it provides information that may help to direct its best use. It is also useful in forest breeding programs and in the choice of which species to plant. Traditionally, the most planted tree in Brazil is the hybrid *Eucalyptus grandis* × *Eucalyptus urophylla*. The planting of *Eucalyptus* in Brazilian cold regions has intensified in recent years, and this and other species of the genus have also been used for this. Wood basic density, fiber dimensions, chemical composition, and higher heating value (HHV) of *Eucalyptus benthamii*, *Eucalyptus dunnii*, and *Eucalyptus saligna*, all species with a tolerance to frost, were analyzed. Basic densities, all greater than 460 kg/m^3, were not significantly different among species. *E. dunnii* had the longest fiber (0.98 mm), the highest holocellulose content, and the lowest lignin content, showing its potential for pulping. *E. benthamii* and *E. saligna* together have higher lignin content with greater HHV, and so are more indicated for energy. Total extractive and ash content were high, but there were no significant differences among the species.

Keywords: Hardwood, wood chemistry, fiber, wood basic density.

INTRODUCTION

Because of its climatic conditions, genetic breeding, and forestry research, Brazil has high productivity for *Eucalyptus* and *Pinus*, as measured by the volume of wood produced per area per year. The southern region of Brazil has the largest planted area of *Pinus*, which is adapted to the temperate climate. However, each year the plantations of *Eucalyptus* have been increasing in this region; in 2006, about 18% of plantations in the southern region were *Eucalyptus*, and in 2018, this genus reached 34% (IBÁ 2019).

The interest in *Eucalyptus* comes from its shorter cutting cycle, 6-7 yr, when compared with *Pinus*, 10-12 yr. Its wood is very versatile and can be used for the production of pulp and paper, energy, sawn wood, and wood panels. To increase the *Eucalyptus* plantation in the southern region, the main challenge was to find frost-tolerant species.

Frosts cause two types of stress: cooling, in which the temperature is cold enough to cause injuries to the plant but not cold enough to freeze it, and the freezing itself, which causes further injuries to the plant (Taiz et al 2014). The mechanisms to prevent the formation of ice crystals in the cells define the tolerance capacity of a species in a cold climate, and these mechanisms have genetic and environmental characteristics (Larcher 2003).

The genus *Eucalyptus* includes more than 700 species, almost all originating from Australia (Angiosperm Phylogeny Group III 2009), and it became an economically important crop around the world because of its useful wood and leaves. Some species have already proven to be frost tolerant, such as *Eucalyptus acmenoides*, *Eucalyptus benthamii*, *Eucalyptus botryoides*, *Eucalyptus carnea*, *Eucalyptus cinerea*, *Eucalyptus crebra*, *Eucalyptus deanei*, *Eucalyptus dunnii*, *Eucalyptus ficifolia*, *Eucalyptus globulus* subsp. *globulus*, *E. globulus* subsp. *maidenii*, *Eucalyptus grandis*, *Eucalyptus maculata*, *Eucalyptus microcorys*, *Eucalyptus muelleriana*, *Eucalyptus paniculata*, *Eucalyptus propinqua*, *Eucalyptus resinifera*, *Eucalyptus robusta*, *Eucalyptus saligna*, *Eucalyptus smithii*, *Eucalyptus tereticornis*, *Eucalyptus tindaliae*, and *Eucalyptus viminalis* (Flores et al 2016).

In recent years, the planting of *Eucalyptus* in the southern region of Brazil has intensified because species adapted to cold weather were found, but little is known about their wood quality. Therefore, this research is aimed at analyzing the wood characteristics of three frost-tolerant *Eucalyptus* species, which are exhibiting high productivity in terms of wood volume in Brazilian regions with frosts incidence. These informations will indicate best uses for each species, support breeding programs, and help with decision-making on which species to plant in colder regions.

MATERIALS AND METHODS

Wood Species and Sampling

The *Eucalyptus* species studied were *E. benthamii*, *E. dunnii*, and *E. saligna*. The studied trees came from a 6-yr-old experimental plantation in Canoinhas, Santa Catarina, Brazil. The climate in the region is the Cfb type according to Köppen's climate classification, without a defined dry season, with fresh summers, and frequent frosts in June, July, and August. Average temperature is 17.0°C, and average annual rainfall is between 1600 and 1900 mm (Alvares et al 2013). The three species are adapted to cold climates with frosts, and in that region, they had productivity greater than 40 m^3 ha^{-1} yr^{-1}, whereas the Brazilian average productivity for *Eucalyptus* is 36 m^3 ha^{-1} yr^{-1} (Bonfatti Júnior and Lengowski 2017).

From each species, we randomly selected three trees which we felled and then removed discs at 0%, 25%, 50%, 75%, and 100% of the commercial stem height. These discs were chopped and mixed to form a composite sample from each tree. In total, three samples of wood chips per species were produced and used for the subsequent analyses.

Wood Characterization

The wood basic density was determined by the maximum moisture content method according to ABNT NBR 11941:2003 (ABNT 2003) using wood chips with five replications per tree. For the fiber dimensions, small fragments were removed from the wood chips for maceration. From the macerated tissue, we measured the length, width, and wall fraction of 100 fibers/species using an optical microscope and following the guidelines of the International Association of Wood Anatomists (IAWA 1989).

The composite samples from each tree were reduced to sawdust separately to determine the chemical composition and the high heating value, also in five replications per tree. We determined the total extractive content, the total lignin by the sum of soluble and insoluble lignin content, the inorganic ash content, and the holocellulose content, all following the Technical Association of the Pulp and Paper Industry (TAPPI) test method guidelines (TAPPI 2020). The determination of the higher heating value (HHV) was made according to ASTM E7194-87 (ASTM 2004).

Statistical Analysis

We performed the Grubbs test for outliers, Shapiro–Wilk test for data normality, Levene test for homogeneity of variance and analysis of variance, and the Tukey test at 5% of significance.

RESULTS AND DISCUSSION

Table 1 shows the results of the analyses.

The basic density which is the most important characteristic to evaluate the wood quality was not significantly different among the studied species. Furthermore, their values are within the typical range of *Eucalyptus* wood produced in Brazil, which are between 465 and 510 Kg/m^3 (Gomide et al 2005). Normally, fast-growing trees have reduced basic density, which make them unsuitable for some uses (Bonfatti Júnior et al 2019). However, our three species showed satisfactory densities, higher than 460 Kg/m^3.

Table 1. Results of the analyzes of three *Eucalyptus* wood species.

Property	*Eucalyptus benthamii*	*Eucalyptus dunnii*	*Eucalyptus saligna*
Basic density (Kg/m^3)	480 A (3.2)	489 A (10.4)	465 A (8.0)
Fiber length (mm)	0.94 B (8.2)	0.98 A (7.8)	0.94 B (7.3)
Fiber width (μm)	16.1 A (14.7)	14.7 B (16.9)	15.1 B (18.7)
Wall fraction (%)	41 C (24.7)	61 A (21.3)	56 B (29.9)
Total extractives (%)	3.72 A (19.8)	3.23 A (22.3)	3.14 A (33.2)
Total lignin (%)	27.6 A (4.3)	23.6 B (5.5)	27.9 A (3.3)
Holocellulose (%)	68.7 B (2.4)	73.2 A (2.4)	69.0 B (2.4)
Ash (%)	0.66 A (14.9)	0.70 A (14.4)	0.61 A (17.8)
Higher heating value (MJ/Kg)	18.3 A (0.59)	17.8 B (0.33)	17.9 AB (0.22)

Values with different letters for the same property indicate a statistically significant difference between species by the Tukey test at 5% of significance. Values in parenthesis are coefficient of variation in percentage.

Hardwood fiber length may vary from 0.5 to 2 mm, and in the case of *Eucalyptus* fibers is around 1 mm. The studied species showed little variability in fiber length, with *E. dunnii* being statistically higher. Fibers were wider in *E. benthamii*. Although the fiber wall fraction is a parameter directly related to basic density (Paulino and Lima 2018), in our samples, the wall fraction was different in the three species even though the basic densities were not statistically different.

To produce pulp, lignin is removed by chemicals to cause the fibers to separate. The lignin content directly affects the process, in that high lignin content makes the pulping difficult. Based on its chemical composition, the species *E. dunnii* is more suitable for pulping because it has less lignin and more holocellulose. In addition, its longer fibers are also favorable for paper production. The species *E. benthamii* and *E. saligna* showed no statistical differences between their hemicellulose and lignin contents.

Species with higher lignin contents make better fuel, as the lignin has HHVs than other cell wall constituents (Novaes et al 2010). Our results do not clearly show this however, perhaps because the differences in % lignin are small (Table 1). Although the species *E. benthamii* and *E. saligna* gave HHV larger than *E. dunnii*, their values are still slightly below those of *Eucalyptus* wood produced in the Brazilian state of Minas Gerais, the main producer of wood for energy, with HHVs greater than 19 MJ/Kg (Carneiro et al 2014).

For low molecular weight compounds, total extractives, and ash, no significant differences were found among species. High total extractives and ash are undesirable characteristics both for pulping and for the use of wood as fuel, and all three species showed higher values than the wood of the hybrid *E. grandis* × *Eucalyptus urophylla*, which is the most widely planted eucalyptus in the Brazilian forestry sector. Its wood has an extractive content of only 2.63% and an ash content of only 0.21% (Vivian et al 2017).

CONCLUSIONS

The three species studied showed equal basic densities and minimal differences in fiber dimensions, properties of which are within the values expected for *Eucalyptus* wood. The chemical composition analysis showed *E. dunnii* wood to be more suitable for pulping. *E. benthamii* and *E. saligna* have higher lignin content and a corresponding greater HHV, so they are suitable for energy production.

The species studied showed high contents of total extractives and ash, and these characteristics pose utilization challenges, so it is important that genetic breeding programs seek to reduce these in the next generation of frost-tolerant *Eucalyptus* for Brazil.

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