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# Wood potential of Pau-mulato (*Calycophyllum spruceanum* Benth.) from natural regeneration in floodplain forest in the Brazilian Amazon

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**Abstract:**

*The use of timber forest resources has historically been a source of income and livelihood for families in lowland forests in the Brazilian Amazon. However, many of these woods are used without the knowledge of their properties. Studying the technological properties of these species is fundamental to subsidize their use and management, especially in shorter cycles of forest asset utilization. The objective of this research*

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*was to characterize the physical properties of the wood of Calycophyllum spruceanum of 12 years of age. The analysis were performed according to the radial position of the trunk (medulla-bark direction) and the traction wood and opposite wood, marked by the eccentricity of the medulla. Four trees were harvested for sampling and were furthermore analyzed. The density of the wood increased in the radial direction, with higher values closer to the bark. There were no significant differences between the two types of wood, traction and opposite, for the physical properties.*

**Keywords:** Brazilian Amazon, wood density, traction wood, opposite wood, physical properties.

## INTRODUCTION

The use of forestry timber resources available in the Amazon transcends the backward model of selective exploitation of species. Currently, the specificities of the environment and species (specific management) must be considered, recommending measures and activities that seek the sustainability of production and maintenance biological diversity. According to Miranda (2012), there are many wood-producing species about which little is known in terms of technological characteristics.

The Pau-mulato species (*Calycophyllum spruceanum* Benth.), belonging to the Rubiaceae family, is considered a pioneer species in alluvial forest successions in Peru, Brazil, Ecuador and Colombia (GÁLVEZ et al., 2020). According to Queiroz and Machado (2007), this species stands out due to its massive regeneration in lowland forest in the Amazon estuary, mainly in areas recently abandoned by cut and burn agriculture, and widely used in the construction of riverside residences, in the production of firewood, coal, carpentry and furniture industry of the region.

*C. spruceanum* wood is moderately heavy, hard, compact, of good workability and resistant to biological deterioration (SOTELO MONTES et al., 2007). With these characteristics, species of

*Calycophyllum* are commonly used in joinery for furniture manufacturing and in civil construction (SOTELO MONTES et al., 2007).

Wood, being a material of biological character, presents high variability, which can be originated from environmental, genetic factors and interactions of both. Their physical and anatomical characteristics vary between species, between individuals of the same species and within a single stem in the sense of medulla-bark and from the base to the top (MELO et al., 2014).

Among the physical properties of wood, density is the most studied and one of the most important, mainly due to its easy determination and its direct relation to other properties (BATISTA et al., 2010). In general, the higher the density, the greater the volumetric contraction and swelling, with practically a linear relationship between these properties. In addition, density is an important parameter for assessing wood quality, despite being a complex variable, resulting from the combination of several factors such as fiber size, cell wall thickness, vessel and parenchyma volume, heartwood and sapwood ratio, and arrangement of anatomical elements (SILVEIRA et al., 2013).

Another important physical characteristic is the retractability, which is related to the expansion or contraction of the wood due to the gain or loss of water. It is influenced by radial, tangential and longitudinal planes, being also possible to demonstrate the dimensional stability and indicate some wood uses. The knowledge about the properties of the raw material wood and the variation existing within it, help in its best form of use as a final product.

Therefore, considering the social, economic and ecological aspects, it is evident that C. spruceanum becomes a promising species in the context of wood production in a lowland environment and, above all, with the possibility of providing riverside families with an alternative source of income. Thus, this work aims to evaluate the usage potential, by determining the physical properties of the wood of Calycophyllum spruceanum, in floodplain forests of the Brazilian Amazon.

## MATERIAL AND METHODS

### Sample collection and preparation

The trees were collected in a lowland forest in the Amazon estuary, in the municipality of Mazagão, Amapá state (00° 14' 35" S and 51° 22' 59" W), in a affluent of the Amazon River called Igarapé Bispo, an area located in an experimental field of Embrapa Amapá. The climate of the region is of the Ami type, super humid equatorial, according to the Köppen classification. The minimum average temperature is 23 °C and the maximum average is 38 °C, with an average relative humidity of 80%. The annual rainfall varies around 2,500 mm (GAZEL FILHO et al., 2008). The soil is classified as Haplic Gleissoil. The predominant vegetation in the region is the Alluvial Dense Rainforest, also known as lowland forest (IBGE, 2012).

Four *C. spruceanum* trees of twelve years of age were cut down (Table 1), from which disks of 5 centimeters of thickness were removed at a height of 1.30 m from the ground (DAC), for making the bodies-of-proof. This material was prepared and sent to the Laboratory of Innovation, Science and Technology of Forest Products at the State University of Pará (LICTM), campus VI Paragominas. The demarcation and preparation of the bodies-of-proof was carried out in the central portion of the disk, in the direction from the largest to the smallest radius (bark-bark), to later verify the presence of traction and opposite wood, since all the trees presented a medulla eccentricity.

**Table 1. Dendrometrical characteristics of the *Calycophyllum spruceanum* individuals.**

| Tree | DAC (cm) | Comercial height (m) | Total height (m) |
|---|---|---|---|
| 1 | 22.28 | 11.0 | 20.0 |
| 2 | 24.51 | 10.4 | 17.5 |
| 3 | 19.73 | 9.3 | 17.3 |
| 4 | 19.41 | 12.16 | 17.2 |

### Characterization of the physical properties of wood

To determine the basic density and retractability (longitudinal, radial, tangential and volumetric contractions) of the wood, bodies-of-proof were removed from the discs at 0%, 33% and 100% in the medulla-bark direction of each tree. Thus, making a total of 24 bodies-of-proof, six per tree (three in the major radius, and three in the minor radius), for analysis in accordance with the standard procedures of ABNT 7190 Norm. The anisotropic factor was also obtained, calculated by the relationship between tangential and radial contractions. Subsequently, the bodies-of-proof were saturated by treatment in a system with a glass container and the aid of a vacuum pump for 52 hours. To determine the retractability values, the dimensions were measured in the three cutting planes, in the saturated state with the aid of a universal analog caliper, and after drying in an oven, related to the dimensions of the bodies-of-proof in the anhydrous condition.

For basic density, volume was determined using the water immersion method. After the saturation period, all samples were dried in an oven at 103 ± 2 °C for 24h, with measurements being made every 2 hours until constant mass was reached. A scale with precision of 0.01 g and a mathematical formula of the relationship between saturated volume and dry mass were used.

### Data analysis

For the results analysis, the mean values, standard deviation and coefficient of variation were calculated using the software Microsoft Excel 2016.

Analysis of variance (ANOVA) was also carried out in order to test whether the variations in physical properties were significant as a function of the radial position and the reaction and opposite wood. It was followed by F test at 5% probability of error, and for the multiple comparison of averages the Scott-Knott test was used at 5% significance level, when the F test presented significance. All statistical analyzes were performed using the Statistica 7.0 software (STATSOFT, 2012).

## RESULTS AND DISCUSSION

### Physical properties

Considering the radial position, only the basic density was significant at 95% probability. For the comparison between driftwood and opposite wood, the values obtained in the analysis were not significant (Table 2).

**Table 2. Summary of analysis of variance of basic density (pbas), tangential contraction (εt), radial contraction(εr), volumetric contraction (Δv) and anisotropy coefficient (FA) of the radial position and the traction and the opposite wood of the species C. spruceanum.**

| Variation source | DF | Mean-square | | | | |
|---|---|---|---|---|---|---|
| | | ρbas | εt | εr | Δv | FA |
| **Radial position** | 2 | 0.0520* | 3.3070$^{ns}$ | 0.1165$^{ns}$ | 3.6580$^{ns}$ | 0.0118$^{ns}$ |
| **Wood** | 1 | 0.0018$^{ns}$ | 1.2421$^{ns}$ | 1.3442$^{ns}$ | 4.3861$^{ns}$ | 0.0009$^{ns}$ |
| **Radial position*Wood** | 2 | 0.0000$^{ns}$ | 1.2532$^{ns}$ | 0.0487$^{ns}$ | 0.7773$^{ns}$ | 0.0081$^{ns}$ |
| **Error** | 18 | 0.0009 | 1.8282 | 0.6006 | 2.7171 | 0.0394 |
| **Total adjusted** | 23 | | | | | |

DF: degrees of freedom; *: significant at 5% by the F test ; ns: non-significant at 5% by the F test.

It is noted that the values for basic density increased gradually in the medulla-bark sense, and variations also were verified in several other studies of native species such as *Inga alba* (Sw.) Willd .; *Anadenanthera peregrina* (L.) Speg. and *Schizolobium parahyba* Wood. (VALENTE et al., 2013; MELO et al., 2018). As for tangential, radial, volumetric and anisotropic factor contraction values, they did not differ between positions (Table 3).

According to Sette Júnior et al. (2012) such increase in the wood density is due to changes in the exchange rate meristem, in which, as the formation of the adult wood occurs, the thickness of the fiber wall increases and the frequency and number of vessels decreases. Therefore, meeting the mechanic-physiological factors derived from the tree development process, causing this variation to occur in the medulla-bark direction.

**Table 3. Variation of the physical properties of *C. spruceanum* wood in lowland forests in the Amazon estuary . ρbas: basic density; εt: tangential contraction; εr: radial contraction; ∆v: volumetric contraction; FA: anisotropic factor.**

| Postion | ρbas ($g.cm^{-3}$) | $\varepsilon_t$ (%) | $\varepsilon_r$ (%) | ∆v | FA |
|---|---|---|---|---|---|
| 0% | 0.58±0.02 c | 7.18±0.99 a | 4.30±0.62 a | 11.72±1.39 a | 1.44±0.07 a |
| 33% | 0.65±0.04 b | 8.13±1.52 a | 4.11±1.08 a | 12.43±1.98 a | 1.41±0.14a |
| 100% | 0.74±0.03 a | 8.44±1.03 a | 4.44±0.67 a | 13.07±1.18 a | 1.49±0.28 a |
| **Average** | 0.66 | 7.92 | 4.28 | 12.40 | 1.44 |

Averages followed by equal letters in the column do not differ statistically by the Scott-Knott test at 5% of significance.

The general average value of basic density obtained for the *C. spruceanum* wood was 0.66 $g.cm^{-3}$, being classified as moderately heavy wood, corresponding to the basic density above 0.56 $g.cm^{-3}$ according to IBAMA (2018). Close density results were found for some Amazonian species of commercial value (Table 4).

**Table 4. Similar densities of some Amazonian tree species of commercial value.**

| Species | Density ($g.cm^{-3}$) | Bibliography |
|---|---|---|
| *Parkia paraensis* | 0.56 | Silveira et al. (2013) |
| *Clarisia racemosa* | 0.66 | Silveira et al. (2013) |
| *Hevea brasiliensis* | 0.65 | Najil et al. (2011) |
| *Calycophyllum spruceanum* | 0.66 | Present work (2018) |

Araújo et al. (2016), studying the physical properties as a function of the diameter and base-top position of the wood of *Calycophyllum spruceanum*, obtained an average basic density of 0.65 $g.cm^{-3}$. Sotelo Montes et al. (2007), found for the wood of this species in the Peruvian Amazon, a basic density of 0.76 and 0.71 ($g.cm^{-3}$), respectively. This increase may be mainly related to age, diameters, forestry treatments and different sites., This may also be due to the presence of juvenile wood that is more pronounced in the wood of young trees, which is characterized by a lower density in either the marrow-bark or base direction-top (MELO et al., 2014; BONDUELLE, 2015; MOORE; COWN, 2017).

According to Guler et al. (2007) and Valente et al. (2013) transverse and volumetric contractions are affected by density and anatomical characteristics, that is, the closer to the bark the greater the specific mass and the proportion of wood that tends to be more dimensionally stable, thus justifying the greater contractions near the bark.

The average values of volumetric, tangential, radial and anisotropic contraction were 12.40%, 7.92%, 4.28%, and 1.44, respectively. There was a crescent increase in volumetric, tangential and radial contraction in the radial direction. This can be attributed to the increase in specific mass in the same direction, an expected ratio due to the magnitude of the dimensional variation, being normally greater in the wood of higher density, since the greater amount of wood material per unit volume.

As seen in Table 3, the total average data obtained for wood contraction of *C. spruceanum* presented to be very close to the values obtained by Andrade (2016) in an experimental planting area, observing 11.39%, 6.79%, 4.59% and 1.49 for volumetric, tangential, radial and anisotropic contraction, respectively.

The variation coefficients obtained for the contraction results were quite low, demonstrating greater homogeneity of the wood of the species studied, which favors its use in applications that require greater dimensional stability. This is consistent with the literature, as Oliveira et al. (2010) state that lower values of standard deviation and coefficient of variation presupposes greater uniformity of the woody tissue.

As for radial contraction, it appears that the values observed for *C. spruceanum* were close to those obtained by Araújo et al. (2016) in studies with the same species in estuarine floodplain areas, which was 5.09%. As well as approaching average values for other native species such as *Cedrela fissilis* 5.37% (Motta et al. 2014); *Hymenolobium petraeum* 4.10% and *Carapa guianensis* 4.30% (IPT, 2013).

Regarding tangential contraction, the value observed in this study is in accordance with the results obtained by Sotelo Montes et al. (2007) who obtained mean data of tangential contraction of 7.50%, for the same species of 36 months of age in the Peruvian Amazon.

When analyzing the volumetric contraction, it is noted that the result obtained for *C. spruceanum* is in agreement with other results observed for other species of potential use. For example, Lobão et al. (2011), studying a group of timber forest species, observed volumetric contraction for the species Paricá - *Schizolobium parahyba* var. amazonicum (12.07%), Ipê - *Handroanthus* sp. (12.53%) (EVANGELISTA; COSTA, 2017) and Cambará - *Erisma uncinatum* Warm. (12.50%) (IPT, 2017). It is worth mentioning that woods with low high volume contractions are considered dimensionally excellent, i.e., they have few defects during the drying process, facilitating in many aspects their industrial use.

This assumption is evidenced when comparing the volumetric contraction of commercial woods such as *Manilkara huberi* (17.6%), *Calophyllum brasiliense* (16.9%), *Goupia glabra* (16.1%) and *Bowdichia* sp. (15.1%) (ZENID, 2009). It was observed that *C. spruceanum* presents lower volumetric contraction (12.40%), thus pointing out that its wood has less volumetric changes with the water outlet, and may replace the use of these species when considering the aspect of their dimensional stability (ARAÚJO et al., 2016).

Regarding the anisotropic factor of *C. spruceanum* wood, the average values found in the different radial positions did not differ statistically, as shown in Table 3. It is clear that the value obtained near the medulla was higher (1.44) in relation to the central position (1.41), followed by an increase closer to the bark (1.49), with the general average of 1.44.

This classification is considered of extreme importance in the study of contractions, because the greater this factor, the greater the tendency to splitting and warping of the wood during the dimensional changes caused by the hygroscopic variation, thus determining the quality of the wood, with FA values varying between 1.5 and 2.5 (MIRANDA et al., 2012). The results demonstrate that the *C. spruceanum* wood is dimensionally stable and less prone to defects, since the lower the ratio present in the anisotropic factor, the lower the tendency to crack and warp the piece of wood during the dimensional movements caused by the variation of humidity. This variation is inferred as a well-known behavior, when the wood is intended to be used in the manufacture of floors, frames and doors (GONÇALVES et al., 2009; OLIVEIRA et al., 2010).

## Reaction and opposite woods

There was no significant difference at a 95% probability level for the interaction between the two types of wood (traction and opposite) and the radial position, for all evaluated properties (Figure 1).

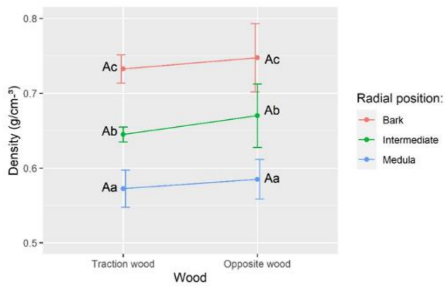


**Figure 1.** Variation of the basic density of traction and opposite wood of *C. spruceanum* as a function of the radial position, using the T Test at 95% significance level (F=0.09251, p=0.91207, α=0.95).

Even though the density between the two woods does not present significant differences, it was possible to observe that the average density in the traction wood tends to be lower than the opposite (Figure 1), both woods also with an increasing tendency in the medulla-bark sense. This pattern for wood can be associated with its distinct anatomical properties and, consequently, different densities (CHAUHAN; Walker, 2011; BOSCHETTI et al., 2015).

Ruelle et al. (2007; 2010) and McLean et al. (2012), evaluating the basic density of traction and opposite woods in native species of tropical rainforest, found that the species *Miconia fragilis*, *Virola surinamensis*, *Simarouba amara*, *Sextonia rubra*, *Virola michelii* and *Tachigali melinoni* presented greater opposite wood density than the traction wood, and in the last three species mentioned, the differences between the woods were considered statistically significant. Monteiro et al. (2010), studying the wood of *Eucalyptus* sp. and the Amazonian species *Simarouba* spp. (Marupá), respectively, found that the basic density in the radial direction has a tendency to increase in the medulla-bark direction, both for traction and opposite woods.

Traction wood can be very variable in hardwoods, as it depends on the anatomy of the wood and the content of cellulose and lignin, just as both woods (traction and opposite) can be considered different from the wood formed under normal growing conditions (VIDAURRE et al., 2013).

During the development of the tree, environmental factors and intrinsic to the species itself determine the degree of variation of the basic density in the radial and base-top directions. Therefore, the knowledge of the variations of this property in the reaction wood is important, because the density presents relevant correlation with other wood properties, and the occurrence of reaction wood influences its use in the forestry industry (VALE et al., 2010).

The retractability properties of the species show a tendency to increase the values in the direction of the medulla to an intermediate position, and follow a tendency of stabilization close to the bark in the traction wood, except for the tangential contraction that decreased in this last position. In the opposite wood, however, the tendency to increase in the medulla-bark direction is more accentuated. Despite the variations, the linear contractions of woods did not show statistically significant differences between themselves and between the radial positions (Figure 2).

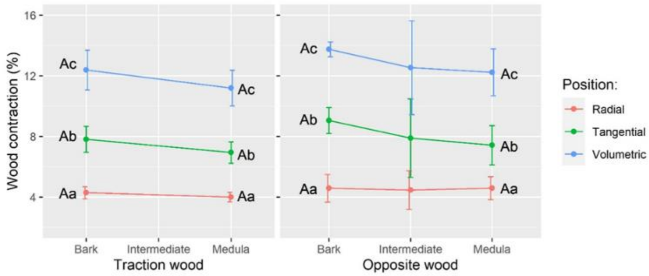


**Figure 2.** Variation of retractability of the traction and opposite woods of *C. spruceanum* as a function of the radial position, using the T Test at 95% significance level (F=0.31599, p=0.92386, α=0.95).

Monteiro et al. (2010) found in trees of the genus *Eucalyptus* that the indication of the traction wood presence is the high retractability and a high basic density when compared to normal wood. However, it is noted that the opposite wood was the one that presented the greatest contractions in the species of this study.

Such facts demonstrate that many studies still need to be done aiming to identify the main factors causing the formation of reaction wood and how much they influence the variation of its properties, mainly helping the forestry activities on making decisions that guarantee the wood production of good technological quality (good performance in drying, processing, finishing and dimensional stability in use). It is also necessary to study the angle of microfibrils of wood with these characteristics in order to better understanding this behavior.

According to Ruelle et al. (2007), the tangential and radial retraction are always greater in wood under traction, except for the species *Eperua falcata*, present in the last mentioned study, which presented low values for these contractions even in high density. This suggests that the behavior of the physical properties between the traction and opposite woods may not have defined behavior and are quite variable between species (DU; YAMAMOTO, 2007; MONTEIRO et al. 2010).

As stated by Muller et al. (2014), the high volumetric contraction can make the industrial use of forest species very difficult, especially with regard to the wood drying process, considering the great possibility of defect formation. Tarmian et al. (2009) also pointed out that, in the drying of reaction wood, defects such as cracks and warping are common.

Regarding the anisotropic factor, the average data found for each wood in the radial direction also did not present any difference between them. Ruelle et al. (2007), studying ten tropical species, found that anisotropy (tangential contraction/radial contraction) is always greater in tension wood, however this only occurred significantly in only three species studied by the author.

The results obtained for the traction wood of *C. spruceanum* were 1.45 (medulla), 1.41 (intermediate), 1.44 (bark) with an overall average of 1.43, and for the opposite wood it was and 1.41 (medulla), 1.40 (intermediate), 1.52 (bark) with a general average of 1.44. The anisotropy coefficients found for the two types of wood indicate that the species has an excellent quality of use in the different radial positions, even with the presence of reaction wood, which is characterized as a defect for most tropical species.

Viadurre et al. (2013) found average values of anisotropy coefficient for traction wood of 1.12 and 1.53 for the leafy species *Acer saccharum* and *Betula pubescens*, respectively. Fernandes et al. (2018) state that the higher the differences between tangential and radial contraction, the greater the risk of making wood species for noble purposes unfeasible, such as fine furniture, window frames, boats, musical instruments, sports equipment, etc. Thus, the knowledge of this coefficient becomes useful in the study of wood, as it can indicate the best use in relation to the dimensional variation (OLIVEIRA et al., 2010).

In addition to the traction wood, the result of anisotropic factor was lower near the bark region. According to Oliveira and Silva (2003), the occurrence of less variability between tangential and radial contractions in the outermost region of the stem causes this lower anisotropy factor, which is reflected in a better wood quality.

According to Gonçalves (2013), the tendency to cracking, due to tensions, arising from the presence of traction wood, varies according to the species and between trees or clones of the same species. In general, the reaction wood has different physical and anatomical characteristics from the opposite wood.

Traction wood in tropical hardwoods may not be a significant problem from the technological point of view, as their physical properties differ slightly or nothing. However, further studies are needed with a systematic and integrated approach to its chemical and anatomical, ultrastructural characteristics and its mechanical properties, aimed at specific uses of this type of wood.

## RECOMMENDATIONS

It is recommended that further studies be carried out on the species *Calycophyllum spruceanum*, regarding its chemical, anatomical, and mechanical characteristics in order to complement the existing information and expand knowledge about this important species in the Amazon estuary. It is also important to highlight the need for integrated studies with several species, in different ecological groups, to analyze whether such variation is standard for tropical species in the Brazilian Amazon.

## CONCLUSIONS

*C. spruceanum* wood has an average density of 0.66 $g.cm^{-3}$, classified as moderately heavy at 12 years of age, with excellent dimensional stability (Anisotropic Factor = 1.44).

Density values increase in the radial medulla-bark direction and retractability (tangential, radial and volumetric) do not differ between positions.

The comparative analysis between traction and opposite woods showed that there is no significant difference in the properties of radial contraction, tangential contraction, volumetric contraction, anisotropy coefficient and basic density for the species at 12 years of age.

*Calycophyllum spruceanum* wood at 12 years of age, due to its excellent anisotropy and density, can be used in civil construction, carpentry, furniture, boats and rural structures.

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