Núcleo de Meio Ambiente
Universidade Federal do Pará
Rua Augusto Corrêa, 01, Guamá
Belém, Pará, Brasil
https://periodicos.ufpa.br/index.php/agroecossistemas

USE OF *Euterpe oleracea* (Mart.) STEMS AS BEAMS IN RURAL AMAZON COMMUNITIES

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ABSTRACT: Due to the availability of *açaí* berry stems in rural Amazon communities, we aimed to evaluate the use of these stems as beams. Adaptations on the equipment and standards were realized to test green and air dry stems. Although stiffness was different, the strength of green and dry stems did not differ. Thinner stems have greater moduli of rupture and elasticity, however, thicker stems support higher loads. The loss of the central zone on dry stems affected more significantly strength than stiffness. The stems are indicated for light constructions, of lower structural demand, such as buildings covered with straw or fiber cement tile.

KEYWORDS: *Açaí* berry palm tree, Static bending, Residue.

UTILIZAÇÃO DE ESTIPES DE *Euterpe oleracea* (Mart.) COMO VIGAS EM COMUNIDADE RURAIS DA AMAZÔNIA

RESUMO: Devido à disponibilidade de estipes de açaizeiro em comunidades rurais Amazônicas, objetivou-se avaliar o uso destes caules como vigas. Adaptações do equipamento e de normas foram realizadas para ensaiar estipes na flexão estática tanto verdes como secos ao ar. Embora a rigidez tenha sido diferente, estipes verdes e secos apresentaram a mesma resistência. Caules mais finos possuem maiores módulos de ruptura e elasticidade, mas os de maiores diâmetros são os que suportam maior carga. A perda da porção central nos caules secos afetou em maior grau a resistência, e em menor a rigidez. Os estipes são indicados para construções leves, de menor exigência estrutural, como construções com cobertura de palha ou telha de fibrocimento.

PALAVRAS-CHAVE: Açaizeiro, Flexão estática, Resíduos.

Recebido em: 2019-10-05
Avaliado em: 2020-07-09
Aceito em: 2020-07-15

UTILIZACIÓN DE TALLOS DE *Euterpe oleracea* (Mart.) COMO VIGAS EN COMUNIDADES RURALES AMAZÓNICAS

RESUMEN: Debido a la disponibilidad de tallos del *naidí* en comunidades rurales Amazónicas, el objetivo fue evaluar el uso de estos tallos como vigas. Adaptaciones del equipamiento y de normas fueron realizadas para ensayar los tallos en flexión estática en las condiciones verde y seco al aire. Aunque la rigidez haya sido diferente, tallos verdes y secos presentaran la misma resistencia. Tallos delgados tienen mayores módulos de ruptura y elasticidad, sin embargo, los tallos gruesos soportan cargas más altas. La pérdida de la porción central en los tallos secos afectó en mayor grado la elasticidad y en menor la resistencia. Los tallos de *naidí* son indicados para construcciones ligeras, de menor exigencia estructural, como las cubiertas con paja o teja de fibrocemento.

PALABRAS CLAVES: Palma *naidí*, Flexión estática, Residuo.

There is in Brazil a great diversity of native palm trees, and in the Amazon, they represent one of the families of greatest socioeconomic and environmental importance (SANTOS et al., 2017; VIANA et al., 2014).

The açaí berry palm tree (*Euterpe oleracea* Mart.) is an example of an Amazonian palm that has several uses, however, the palm heart and the fruit have greater economic and social importance in the lives of the populations of this region, especially in the states of Pará and Amapá (YOKOMIZO et al., 2012).

Açaí groves, native or cultivated, are usually managed so that there is an increase in fruit productivity through thinning of excess stems, thus, the producer maintains 3 to 5 stems per individual (QUEIROZ; MOCHIUTTI, 2012). Since the number of stems can reach 25 per clump, the elimination of stems can lead to a large generation of waste (KANG et al., 2012; QUEIROZ; MOCHIUTTI, 2012) which is currently underused.

Aware of the use of these stems by traditional communities in the composition of housing structures, warehouses, decks and bridges (QUARESMA SOUSA et al., 2009), the present study aimed at evaluating the mechanical properties in the static bending of the entire stem of *Euterpe oleracea*, in the green and air-dried states.

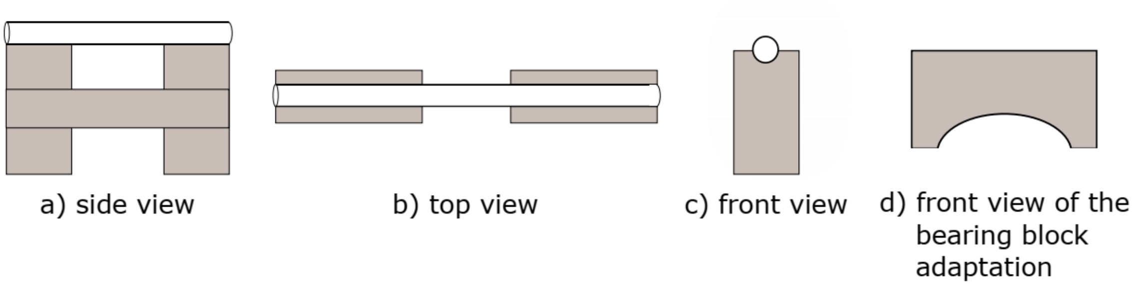
In the surrounding area of the city of Santarém – PA (Brazil), after identification on-site by Prof. Dr. João Thiago Rodrigues de Sousa, 26 stems of *E. oleracea* were collected out of the center of the clumps in order to obtain straighter stems, being one sample per clump. The cut was made at 30 cm from the ground and the stems were sectioned again for specimens lengthening 1.80 m. The stems were taken to the Wood Technology Laboratory, at the Federal University of the Western Pará (UFOPA), where they were included in the wood collection placed in the laboratory itself.

The mechanical tests were carried out on green stems and at 12% moisture content (air dry). While the green ones were tested as soon as they arrived at the laboratory, the rest were placed in an acclimatization room at 25 ºC and 65% air relative humidity, until they reached a hygroscopic balance at 12% moisture content (MC). Initially, 13 stems were used for green treatment and the rest for dry treatment. However, four stems were discarded from the last treatment, as they were not in perfect condition.

The static bending tests carried out through a universal testing machine (EMIC with a capacity of 300 kN) underwent a technical adaptation, so that these could be used as supports for the round shape of the stems. Wooden pieces were made with a 5 cm concavity at the upper end, 25 cm x 15 cm x 80 cm (Figure 1a, 1b and 1c), replacing the original test supports. At the top, another rectangular piece of 25 x 20 cm was added, with a concavity (Figure 1d) so that it would fit with the cylindrical body of the stem and, thus, the bearing block should apply load to a flat surface.

For the calculation of the rupture and elasticity moduli, the Brazilian standard NBR7190 (ABNT, 1997) was adopted. The second moment of area was also adapted for the circular section. After the tests, the samples were included in the wood collection of UFOPA.

Figure 1. View of the parts for the technical adaptation.



Statistical analysis was performed using the software R (R DEVELOPMENT CORE TEAM, 2019), the values were submitted to the T test after confirmation of normality of data and homogeneity of variances by the Shapiro-Wilk and Bartlett tests, respectively. In addition, the variables studied were subjected to Pearson's correlation test. All tests were performed at the significance level of 5%.

The mean values of modulus of rupture did not differ between the two treatments evaluated (Table 1). The modulus of elasticity was different when the stems were in a green and dry state, the latter being stiffer than the former. Both in strength and stiffness the highest coefficients of variation were found in green stems.

Table 1. Strength and Stiffness on static bending, and diameter of the stems in air-dry and green conditions

	Strength (MPa)		Stiffness (GPa)		Diameter (mm)	
	Air-dry	Green	Air-dry	Green	Air-dry	Green
Mean	32.87 ns	36.21 ns	7.09 *	4.14 *	93 ns	109.00 ns
Stand. Dev.	10.27	12.18	2.75	2.03	18.44	24.75
Max	43.51	60.63	10.11	8.02	118.0	151.00
Min	16.04	21.93	2.43	1.21	65.00	73.00
CV (%)	31.23	33.64	38.79	49.06	19.83	22.71

* : the means are significantly different, ns: non-significant, Stand. Dev.: Standard Deviation, CV (%): Coefficient of Variation
Source: The Authors.

The stems of açaí palm trees, in both MC, presented a high coefficient of variation in strength and stiffness. The heterogeneity of the thickness of the peripheral zone of the stem can be a cause of these great variations observed, since it is much more resistant than the central portion (BALBONI et al., 2019). As this stiffer and stronger material is located in the portion where greater stresses are generated in bending, small variations in the thickness of this layer result in great variations in strength and stiffness of the stem.

In general, lignocellulosic materials have superior mechanical properties when dry, due to the greater density and rigidity of the cell walls, as well as the increase in the percentage of woody material, caused by water loss and wood shrinkage (KRETSCHMANN, 2008).

As a parameter, when green, *Carya illinoinensis* wood showed 50.73 MPa of resistance to static bending, at 12% MC , this value reached 82.96 MPa, 63.53% more resistant (STANGERLIN et al., 2010). However, in the açaí palm tree the opposite was observed, where the green stem was about 10.16% more resistant.

The açaí palm tree is a monocot, and unlike timber species, it does not present secondary xylem (JURA-MORAWIEC et al., 2015). However, its mechanical behavior is similar to those of same density woods in parallel compression (BALBONI et al., 2019).

After the tests, it was noted that the central portion of some stems was deteriorated in its entire length, as reported in the literature (BALBONI et al., 2019). In most cases, before the stems were dry, the center had already rotted because of its own moisture content, even though they were in an acclimatization room with a 12% equilibrium MC.

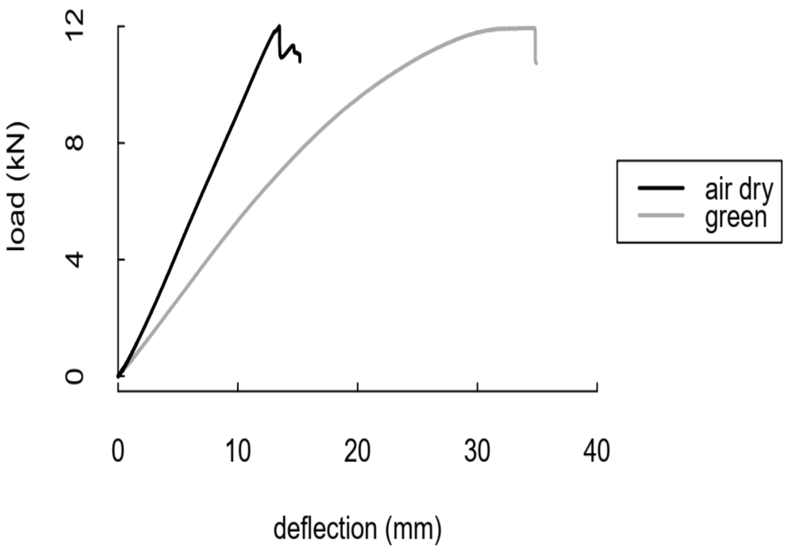
Although the central portion of the stem is much less strong and stiff (BALBONI et al., 2019), its presence in the green stems helps keeping the upper peripheral zone away from the lower peripheral zone as load is applied. The absence of the central portion in dry stems makes these stems more sensitive to cutting force, resulting in greater fragility, even though the material itself is most likely more resistant in the dry state.

As a result, the dry stem has practically no plastic behavior, breaking soon after exceeding the elastic limit, while in green state it is observed not only a lesser modulus of elasticity, but also a great deflection in the plastic behavior (Figure 2).

Palm stems are quite flexible, so the behavior reported in green stems was expected. Small diameters combined with low values of modulus of elasticity, are probably responsible for this high flexibility observed, which keeps them standing even after strong winds or rather hurricanes, as commonly seen in the international media.

Intending the use of stems as beams, it is important to note that, both in green and air-dry states, the stems with the smallest diameters were the ones with the highest strength and stiffness values (Figure 3A and 3B).

Figure 2. Load deflection curves for stem samples with approximately 112 mm diameter.



Source: The Authors.

The thinner stems are found mainly in denser forests, as they need to compete for light with the plants around them. These stems need to compensate for their small diameters, with greater moduli of rupture and elasticity. Stems with greater moduli of rupture also showed greater moduli of elasticity (Figure 3C).

Although thinner stems are more efficient, thick stems have the highest load capacity values (Figure 3D). As in cylindrical parts, the second moment of area is influenced by the diameter to the fourth power, small increases in diameter result in outstanding improvement in the load capacity. That is, when it is necessary to support structures with greater loads without worrying about the weight of the structure, the larger diameter stems must be considered. However, when a lighter structure is required, less thick stems should be used.

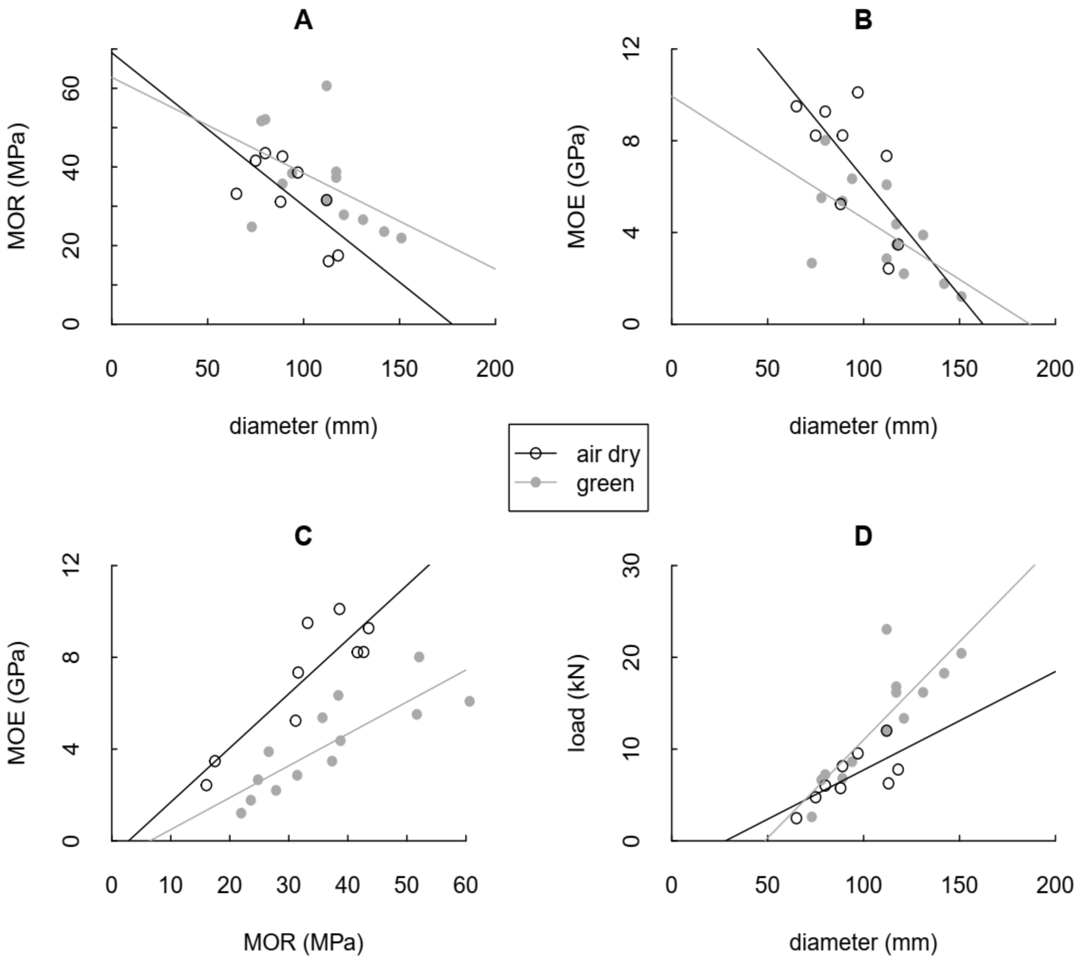
The relationship among all variables were significant (Table 2), with the exception of the relation between strength and diameter in the green state, which showed some discrepant points (Figure 3A), however, a larger sample study would probably have displayed a significant relation. Thus, it was noted that the smaller diameter stems present greater stiffness in both treatments, due to their negative correlation, as well as greater strength, in the case of air-dried stems.

Compared to other materials, such as bamboo stems (*Bambusa vulgaris vittata)*, the açaí palm tree had three times less strength (DA MOTA et al., 2017). As for stiffness, the species was also inferior, in both MC, considering the stiffness of 11.25 GPa of the bamboo. In contrast, bamboo is hollow and has knots with a diaphragm, which is a solid area with fibrovascular bundles (GHAVAMI; MARINHO, 2005).

Such distinctions may have allowed more strength and stiffness to the bamboo stem compared to the açaí. Batista et al. (2018), studying the mechanical properties of slats removed from the peripheral zone of the açaí palm tree stem, found a modulus of rupture in static bending of 105.77 MPa, showing that the peripheral zone has twice the strength of the entire stem.

This is, therefore, an interesting way of using the stem, which optimizes its mechanical properties, but due to the limitations of dimensions, it is necessary to join small pieces, through adhesives, to form larger pieces. Thus, more in-depth studies are needed for panels made with the peripheral zone of the stem, such as its properties in static bending, resistance in the glue line and workability.

Figure 3. Linear Regression of the variables assessed in the green and air-dry conditions



MOE: Modulus of Elasticity, MOR: Modulus of Rupture
Source: The Authors.

Table 2. Pearson's correlation coefficient and p-value (in parentheses) of the relationships evaluated.

relationship	Air-dry	Green
MOE x diameter	-0.6859 (0.0413)	-0.6494 (0.0163)
MOR x diameter	-0.6986 (0.0362)	-0.4953 (0.0852)
MOR x MOE	0.8819 (0.0016)	0.8352 (0.0003)
Load x diameter	0.7099 (0.0321)	0.8552 (0.0001)

MOE: Modulus of Elasticity, MOR: Modulus of Rupture
Source: The Authors

Although the stems of açaí are less strong and stiff than those of bamboo and woods used for structures, they can be used as beams in rustic buildings. Due to lesser stiffness, the stems present greater deformation when used in the green state. However, as in both the green and dry state the resistance is very similar, they can be used regardless of their state.

Açaí palm tree stems are a source of raw material of great supply for traditional Amazonian riverside communities, the similarities of strength in the states of MC also make them a ready-to-use raw material. The low properties in static bending when compared to other common raw materials in the region are not so problematic taking into account that virtually all roofs are made of notably light materials, such as straw and fiber cement tiles. When building heavier structures, either thicker stems should be used or tightening the columns closer together, that is, reducing the gap in between supports in bending.

As a way to dispose of the residues from the management of the açaí groves and to reduce the costs with rural constructions, the excess stocks of the açaí groves can be used by the riverside communities for use in simple constructions.

Further studies should be carried out to evaluate the use of the stem peripheral zones in the form of slats for the manufacture of glued panels, as it would be a way of adding value to the açai palm tree residues and diversifying the income source for the producer.

REFERENCES

Associação Brasileira de Normas Técnicas. NBR -7190: Projetos e Estruturas de Madeira, 1997.

BALBONI, B.M.; SOUSA, J.T.R. de; FERREIRA, M. A.; RODRIGUES, R.A. de; MACEDO, A. B. Residue of açaí berry (*Euterpe oleracea*) management as a source of lignocellulosic material. **European Journal of wood and wood product**s, 1-8, 2019. Disponível em: https://doi.org/10.1007/s00107-019-01417-8.

BATISTA, A.S.; BRAGA, A. B. de; SOUSA, J.T.R. de; GARCIA, J.N.; BALBONI, B.M. Potencial do resíduo do manejo do açaizeiro como substituto do bambu. In: Encontro Brasileiro em Madeiras e em Estruturas de Madeira, 16, Congresso Latino-americano de Estruturas de Madeira, 3., 2018, São Carlos. **Anais**... São Carlos: Escola de Engenharia de São Carlos-USP, 2018. p.6.

DA MOTA, I. O. de.; PEREIRA, M. A. de; DAMACENA, P. C.; SANTOS, L. C. B. dos. Estudo das propriedades físicas e mecânicas do bambu brasileiro (*Bambusa vulgaris vittata)* para aplicação na construção de sistemas hidráulicos alternativos de distribuição de água à baixa pressão. **Revista de Estudos Ambientais**, v. 19, n. 1, p. 18-26, 2017.

GHAVAMI, K.; MARINHO, A. B. Propriedades físicas e mecânicas do colmo inteiro do bambu da espécie do bambu da espécie *Guadua angustifolia*. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 9, n. 1, p. 107-114, 2005.

KANG, J.; THAKALI, K. M.; XIE, C.; KONDO, M.; TONG,Y.; OU, B.; JENSEN, G.; MEDINA, M. B.; SCHAUSS, A. G.; WU, X. Bioactivities of açaí (Euterpe precatoria Mart.) fruit pulp, superior antioxidant and anti-inflammatory properties to *Euterpe oleracea* Mart. **Food Chemistry**, v. 133, n. 3, p. 671-677, 2012.

KRETSCHMANN DE. The influence of juvenile wood content on shear parallel, compression, and tension perpendicular to grain strength and mode I fracture toughness of loblolly pine at various ring orientation. **Forest Products Journal,** 58(7-8): 89-96, 2008.

QUARESMA DE SOUSA, J.; DA SILVA HOLANDA, B.; DE SOUSA LEÃO, K.; FREIRES, A., DIAS MENDES, R. Utilização dos Métodos da Bioconstrução para Implantação de Aviário Agroecológico. **Revista Brasileira de Agroecologia**, [S.l.], v. 4, n. 2, dec. 2009.

QUEIROZ, J.A.L. de; MOCHIUTTI, S. Guia prático de manejo de açaizais para produção de frutos. Macapá: Embrapa Amapá, 2012. 24p. (Embrapa Amapá. Doc., 26).

R Development Core Team. R: A language and environment for statistical computing. Vienna, R Foundation for Statistical Computing. 2019.

SANTOS, M. de F. G. dos; ALVES, R. E.; BRITO, E. S. de; SILVA, S. M. de; SILVEIRA, M. R. S. da. Quality characteristis of fruits and oils of palms native to the brazilian amazon. **Revista Brasileira de Fruticultura**, v. 39, n. spe, 2017.

STANGERLIN, D. M.; MELO, R. R.; GATTO, D. A.; CADEMARTORI, P. H.G. Propriedades de flexão estática da madeira de *Carya illinoinensis* em duas condições de umidade. **Revista Ciência da Madeira (Brazilian Journal of Wood Science)**, v. 1, n. 2, 2010.

JURA-MORAWIEC, J.; TULIK, M.; IQBAL, M. Lateral meristems responsible for secondary growth of the monocotyledons: a survey of the state of the art. **The Botanical Review** , v. 81, n. 2, p. 150-161, 2015.

VIANA, Á. L.; MADY, F. T. M.;CARMO, M. A.; GUIMARÃES, D. F. S. da. Pecíolo de inajá (*Maximiliana maripa* (Aubl.) Drud) como fonte de matéria prima para produção de papel na Amazônia. **Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental**, v. 18, n. 4, p. 1512-1520, 2014.

YOKOMIZO, G. K.; QUEIROZ, J. A. L. de; CAVALCANTE, E. S. da; PINHEIRO, I. N. de; SILVA, P. A. R. da; MOCHIUTTI, S. Caracterização fenotípica e genotípica de progênies de *Euterpe oleracea* coletados no Afuá-Pará nas condições do Amapá. **Cerne**, v. 18, n. 2, p. 205-213, 2012.