Managing the Technological Potential of Eschweilera truncata A. C. Sm in the Amazon

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Abstract

Eschweilera truncata trees, known commercially by the name of Matamatá, are abundant, widely distributed throughout the forest, and characterized by important features for forest management, but are not harvested due to the scarcity of studies of the technological attributes that would reveal their potential, such as their machining and physical properties. Otherwise such studies might contribute to the inclusion of new species in the market, strengthening the sustainability of the forest ecosystems. Given this gap, the present research aimed to evaluate the performance of Matamatá wood in terms of its physical properties and behaviour under the machining process that would be used in this sector of the timber industry. The research involved a study of the tree, from which a base disk was removed in order to analyse its apparent density, density, shrinkage and anisotropy coefficient. The tradable shaft was split into logs and planks to assess the effects of machining processes. In the data analysis, we used descriptive statistics and the Tukey test. The results obtained classify Matamatá wood as high density and identify its anisotropy coefficient of 1.90, suggesting a medium to low stability. E. truncata wood performed excellently in the machining evaluation, and its results in the planer, sandpaper, drill perforation, frame in the top and lathe tests were also outstanding; in addition it presented wood material of the same quality throughout, whether heartwood or sapwood. This is an important indicator of wood yield, signifying that greater use can be made of the wood. The performance of the wood was validated via the manufacture of products such as furniture, decoration and finger-boards for musical instruments. In general, it can be concluded that the wood studied may be used in the lumber industry, because it presents similar features to those in the species already marketed and because it is plentiful all over the Amazon region.

Keywords: Matamatá; technological characterisation; machining; forest management; small diameter species

INTRODUCTION

Brazil is one of the world's largest producers and consumers of tropical forest lumber (ITTO, 2017). Native timber production is concentrated in the region comprised by the Legal Amazon, with Mato Grosso and Pará being the main loggers of native species (IBGE, 2016). However, the timber sector in the region is marked by the practice of maximum logging per unit area, the exploitation of a few species of commercial interest and a great waste of wood, both in the forest and in the industry. Forest extraction carried out without planning, intensively and selectively, has transformed areas with high stocks of wood to degraded forests, where wood is low in commercial value and difficult to transport (Moutinho et al. 2011).

The Amazon forest has very diverse timber species, but the extraction of wood in this region is not consistent with its potential, since the market is not interested in many species. Commercially valuable timber species become rare or economically extinct (RICHARDSON & PERES, 2016) and as a result of selective exploitation the number of species joining the list of protected species increases.

In this sense, the high demand for wood, combined with economic pressures for immediate results, raises the need to technologically characterise new wood species that are well distributed in the forest in order to introduce more of them to the market (TAQUES & ARRUDA, 2016).

In this context, species such as the *Eschweileragenus* of the family Lecythidaceae are seen as a promising alternative. Inventories carried out by the laboratory team of forest managers of the Instituto Nacional de Pesquisa da Amazônia – INPA – detected the high incidence of a species known as “Matamatá” throughout the state of Amazonas. Such species are not large in diameter compared to species commonly exploited in the timber sector, but have high population density. They also form a stable element in forest recomposition, that is, if they are managed, they can support and recover the stock that is harvested (REIS et al., 2014; REIS et al., 2016). Exploration of the forests is permitted provided that the instructions of SDS-AM resolution 17/13 are followed.

However, in order for a certain wood to be commercially exploited, its wood potential – that is, its limits and the conditions of use that it will meet – must be known;. Knowledge of the physical, mechanical, chemical and anatomical properties of wood, as well as its machinability, is of fundamental importance for bringing these species into the productive sector and into competition in the different sectors of the timber industry. If we know these properties we can analyse them in comparison with the characteristics of traditional woods; that is, we can assess the qualities of new woods through the interrelationships of their properties and the similarities between species (NASSUR et al., 2013).

Despite all the advances in the use of technology to manufacture higher value-added products, there is still little or no technical-scientific information on the best combinations of production factors when we use machines to achieve a surface quality that adapts material to various purposes. Within these process variables, our ignorance about the influence of the surface quality of wood, derived from its physical and anatomical properties, stands out and needs to be remedied (PINHEIRO et al., 2017). These properties are allied to the other factors that influence the process of material removal via machining. The timber sector urgently needs more research leading to technological improvements, the rationalisation of the use of raw materials, greater efficiency and better use of native wood if it is to seek new markets, both national and international.

The increasing difficulties in obtaining native wood, coupled with the lack of policies that allow for the sustainable and rational exploration of tropical forests, at a time when wood is in great demand for and economic pressure is exerted for immediate results, justify the development of this research. Its aim was to evaluate the possible use of *Eschweilera truncata* wood to produce goods of had high added value.

MATERIAL AND METHODS

The wood used in this study came from the Experimental Tropical Forestry Station of the Instituto Nacional de Pesquisas da Amazônia (E.E.S.T./INPA), located in the municipality of Presidente Figueiredo, in the north of Brazil. A tree of the species *Eschweilera truncata* with a diameter at breast height (DBH) of 50 cm was selected and examined according to the procedures established for forest management.

A base disk with a thickness of 5 cm was removed to obtain tree body-specimens properly oriented with respect to the anatomical features so as to determine the physical properties and make an anatomical analysis (see Figure 1). The tests were adapted according to the procedures of ABNT NBR 7190:1997 and NBR 11941:2003.

The samples were weighed on a 0.01g precision scale, their dimensions measured with callipers and submerged in water to determine the volume using the liquid displacement method and oven dried at 103 ± 2°C to weight, in order to calculate the density, apparent density, basic density, dimensional stability and anisotropy coefficient.

The apparent density at 12% (ρ), basic density (ρbas), retractability ($R_{(t,r)}$) and anisotropy coefficient (CA) were calculated using Equations 1, 2, 3 and 4. The retractability test was performed next on these specimens, and the radial and tangential directions were measured.

$$\rho_{12} = \frac{M_{12}}{V_{12}} \qquad \text{(Equation 1)}$$

$$\rho_{b} = \frac{M_{s}}{V_{sat}} \qquad \text{(Equation 2)}$$

$$R_{(t,r)} = \frac{D_{sat} - D_{s}}{D_{sat}} * 100 \qquad \text{(Equation 3)}$$

$$CA = \frac{R_{t}}{R_{r}} \qquad \text{(Equation 4)}$$

where ρ12= bulk density (g / cm³); M12= mass at 12% humidity (g); V12= volume at 12% humidity (cm³); ρbas= basic density (g / cm³); Ms= dry mass (g); Vu= saturated volume (cm³); R= maximum linear contraction coefficient (%); Dsat= dimension in saturated conditions (mm); Ds= dimension after oven drying (mm); t= tangential direction; r= radial direction, CA= anisotropy coefficient.

Specimens prepared for the anatomical analysis were oriented in turn in the tangential, radial and longitudinal directions in the dimensions 1.5 x 2.0 x 3 cm, respectively, containing part of the sapwood and heartwood in the same sample. The anatomy of the samples was described using the comparison method (confrontation), supporting the method of botany collection - Xiloteca / COTI / INPA, where mainly the sensory and macroscopic anatomical features are observed. The structures were analysed with the aid of a 10 x magnification magnifying glass and through image analysis using a stereoscope equipped with a digital camera and computer with Pixel Pro 2.1 image analysis software.

The machining tests were performed following the guidelines of ASTM D1666 - 11, with adaptations regarding the sample size. Twelve samples containing heartwood and sapwood were selected in the same piece to analyse the behaviour of the wood in both regions. The following paragraphs describe the tests performed.

Planing - performed on a thicknesser planer (blades at 45º and with a 2 mm cut) and a performer (with a 1 mm cut); the defects found were barbs, fuzzy/crushed grain and wood burns.

Sanding - performed using a hand sander that allowed sanding with grit sizes of 80, 180, 280 and 360 (commercial specifications); the defects found were surface scratching and fluffy grain.

Lateral tear - performed in a horizontal drill that has a manual feed, using 8mm twist drill and 15mm cutter; the defects found were barbs, fuzzy / crushed grain and wood burns.

Drilling – using a vertical drill with 11.5, 10,8, and 6 mm diameter high speed steel bits. The holes were spaced 25 mm apart; the defects found were those of fuzzy grain, grain pullout and wood burns.

Nail Piercing - 18 x 24 [2 1/4 x 10] nails (commercial specification) were used. The nails were hammered into the ends of the specimens, at a distance of 10 mm from the edge and 20 mm from each other; In this test the evaluation considered only whether the nails were accepted.

Top frame - made with a 2 mm deep roulette; the defects found were those of raised, torn and fluffy grain.

Lathe - the parts were turned following a pattern of use of the same tool until the contour was very close to that described in the standard; the defects found were of fuzzy grain, plucked grain and wrinkled surface.

After the tests, the pieces were subjectively evaluated by four appraisers, who were technicians from the wood industry segment of the Instituto Nacional de Pesquisa da Amazônia – INPA e LEAM, following the criteria of grades (Table 1) in the behaviour of wood, indicating the presence or No defects. The ASTM D-1666-11 standard served as an evaluation parameter of the results obtained. The results of the tests were evaluated visually and tactfully, mindful of the sensitivity of the observers, who compared the pieces with the photographs used in this standard. Subsequently, the evaluations were analysed and the wood classification for each test was obtained by averaging the grades of the evaluators.

Table 1 - Notes applied to the part-evaluations in the machining tests

Mark	Evaluation	Defect
1	Excellent	No defects
2	Good	Presence of less than 50% of defects
3	Regular	Presence of 50% of defects
4	Poor	Presence of more than 50% of defects
5	Unacceptable	Presence of 100% of defects

The data were analysed using descriptive statistics (mean, standard deviation and coefficient of variation) and an Analysis of Variance (ANOVA).

With the data obtained on the properties and the products, a comparative analysis was made of species that are currently sold in the market. This phase consulted a database of the Wood Artifact Engineering - LEAM laboratory of 100 Amazonian tree species, regarding basic density, tangential contraction, radial contraction, anisotropy and machining.

RESULTS AND DISCUSSION

Macroscopic anatomical features

According to the general characteristics, *Eschweilera truncata* (Lecythidaceae) wood has a rough dark brown outer bark and an inner light yellow to brown colour; its heartwood s a different shade of brown, well differentiated from light to greyish sapwood, right grain, fine texture, and a noticeable smell of fibrous liber (see Figure 1).

In the macroscopic description, sinuous thin lines were observed, suggesting the presence of a contrasted parenchyma. A few small to medium pores, solitary and grouped, were apparent to the naked eye; they were obstructed by tilose. Numerous very thin rays at the top were visible under a magnifying glass, while marked uniformity in width and spacing on the radial face was visible to the naked eye. Small, sparse spinal macules and small scattered secretory channels could be seen (refer to Figure 1A).

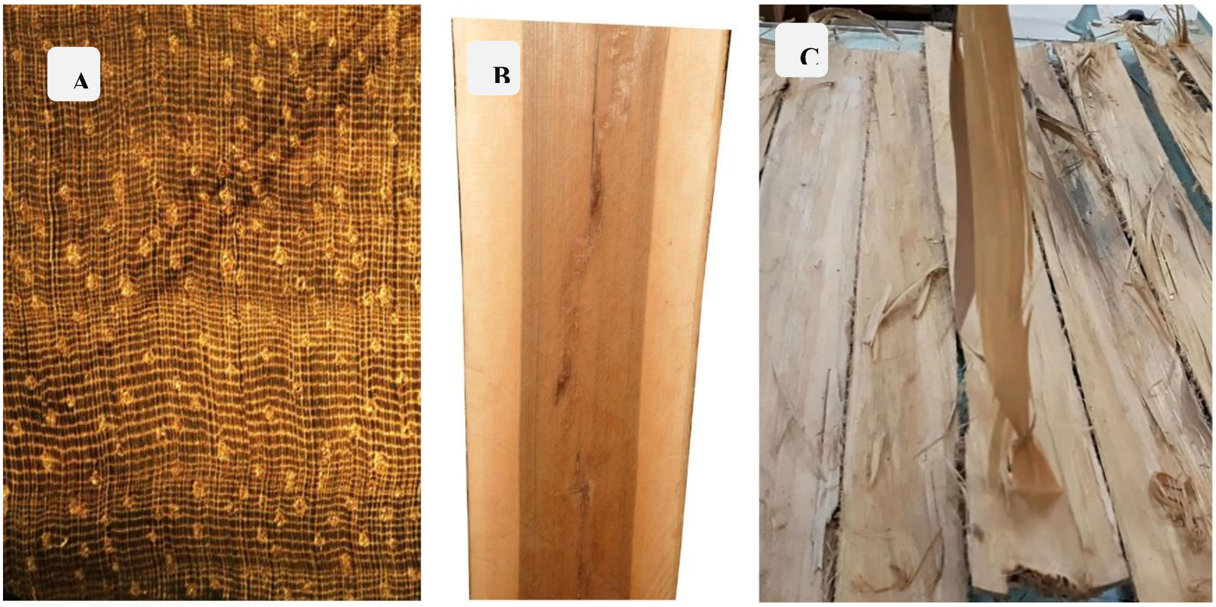

Figure 1- (A) Transversal plane macrophotography (10X); (B) Heartwood and sapwood; (C) Fibrous liber

E. truncata wood has straight grain, of a type of grain which is appreciated for its greater mechanical strength, easy deployment and minimum number of undesirable deformations when dried. From a decorative point of view, the tangential and radial surfaces of the wood are quite regular in appearance and with no special ornamental shapes. Texture is another very important feature, in that woods with a fine texture receive a great finish. As is characteristic of Lecytidacea, *E. truncata* in their fibrous free structure present fibre which is widely used in upholstery, basket making and other products that make use of wood fibres.

Mori et al. (2001) mention that the genus *Eschweilera* is considered the largest of the Lecythidaceae, with approximately 100 species, and also the most complex in terms of identification; however, all present similar characteristics, a fact that the present study confirms.

The type and texture of the grain in the workability tests are essential parameters for identifying whether the wood will perform well or poorly in the machining process. According to Mady (2000), the straight grain wood facilitates drying, unfolding, and surface finishing processes and increases mechanical resistance.

Regarding the texture, it may be recalled that wood, when it presents a fine texture, can obtain excellent results in the finishing process. Burger & Richter (1991) classify textures as coarse, medium or thin according to the distribution and percentage of the anatomical elements in the wood; these criteria were adopted to predict whether or not wood will take a good finish.

Physical properties of wood

Table 1 shows the average values of the basic and apparent densities of *Eschweilera truncata wood*, as well as its dimensional stability and anisotropy coefficient. According to the classification proposed by Melo et al. (1990), the wood of this species has high density. The result of comparing basic and apparent density (12%) with that of other native species of the Amazon region shows that the values are close to those found in the studies by Moutinho et al. (2011), Barros (2016) and Nascimento et al. (2017 and 2018), who obtain basic density readings that range from 0.80 to 0.95 g / cm³ for six different species of Matamatá. With regard to apparent density, IPT – the Instituto de Pesquisas Tecnológicas (2009) records values similar to those obtained for species such as Red Angelim (1.09 g / cm³), Goiabão (0.93 g / cm³) and Itaúba (0.960 g / cm³) at the same moisture content of 12%.

Table 1 -Descriptive measures of the physical properties of *Eschweilera truncata wood.*

	ρ12% g / cm³)	ρbas (g/cm³)	Rt (%)	Rr (%)	CA
Average	1.01	0.77	8.39	4.93	1.90
DP	0.11	0.04	1.04	1.94	0.67
CV %	11	5	12	39	35

ρbas: basic specific mass; Rt: tangential contraction; Rr: radial contraction; CA: anisotropy coefficient; SD: standard deviation; CV: coefficient of variation.

The wood of this species is classified as having medium stability according to the classification of Galvão and Jankowsky (1984, because it has an anisotropy coefficient of 1.90. Given these data, it can be said that the wood should not present serious problems as sawn wood, provided that the process of unfolding is conducted according to the recommended techniques.

The values determined in this study are consistent with others obtained for hardwood, by several authors such as IPT (2003) analyzing wood from Cupiuba, Cedrorana, Goiabão, Jacareuba, Pau Roxo, Tauary; and Angelim presenting anisotropy ranging from 1.55% to 1.90%. Barros (2016), when he studied the species of Ingá-Vermelha, Peãozinho, Matamata, Breu-vermelho, Murici, Abiurana with anisotropy found values from 1.60% to 2.10%. INPA (1991), among the woods that make up the Amazon Wood Catalog, lists woods such as *Eschweilera odora* (1.55%), *Hymenaea courbaril* (1.88%) and *Pilhecellobium incuriali* (1.90%).

The retractability difference between tangential and radial directions is a major cause of wood defects that occur during the drying process. These defects are generated by the manifestation of anisotropy, where the higher the value, the higher the probability of defects occurring in wood that may make its use unfeasible (OLIVEIRA et al. 2010).

Machining Process

The data collected and analysed suggest that *E. truncata* wood behaved similarly in all tests for heartwood and sapwood, showing the same quality of woody material throughout. This means that both can be used for the same purposes, increasing the wood yield. Barros (2016) mentions that no sapwood is currently used by sawmills, thus reducing wood yield. Therefore, woods that have similar characteristics provide increased yield because they are used in their entirety and consequently help to improve sustainable forest management. They reduce the number of individuals that must be felled to meet the volume desired. In short, this proposal causes less wood waste in industries, helping to make the activity more sustainable. With this in mind, Table 2 arranges the evaluations assigned to each test, in both heartwood and sapwood. It is noteworthy that the lateral tear test was divided into 2 parts (using drill and cutter) because different evaluations were received, one rated excellent and the other good. Figure 2 shows the results of machining tests on wood.

Table 2- Test results of *E. truncata* woodworking.

Test	Core	Sapwood	ASTM D1666 - 11 Rating
Planing	Excellent	Excellent	No defects
Sanding	Excellent	Excellent	No defects
Drilling	Excellent	Excellent	No defects
Nail Drilling	Poor	Poor	Presence of more than 50% of defects
Side Tear (Cutter)	Excellent	Excellent	No defects
Side Tear (Drill)	Good	Good	Presence of less than 50% of defects
Top frame	Excellent	Excellent	No defects
Lathe	Excellent	Excellent	No defects

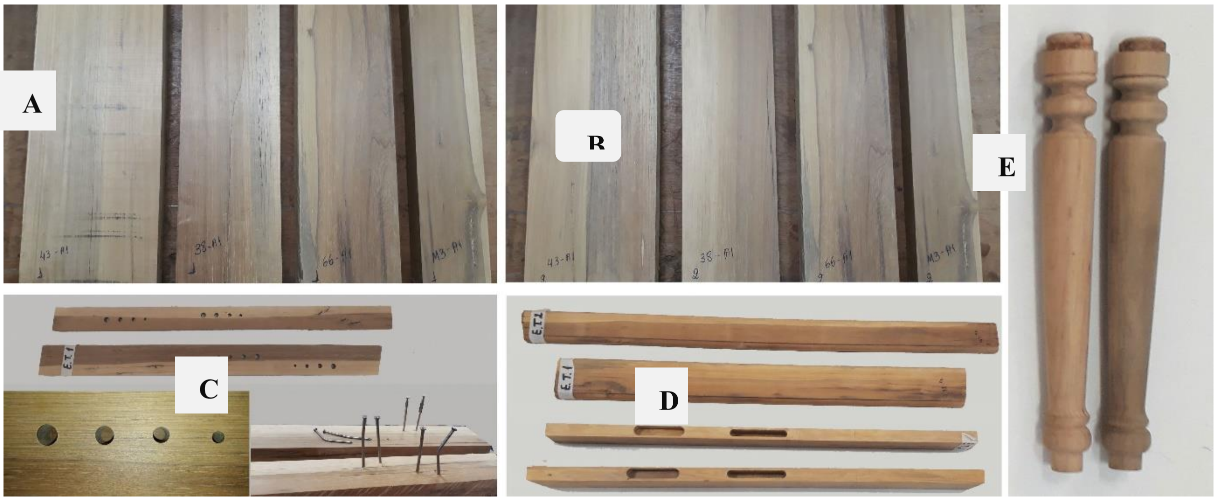

Figure 2- (A) Planing; (B) sanding; (C) Drill and nail drilling; (D) Side Tear and Top Frame; (E) Lathe.

There are no studies to compare with the present survey that demonstrate the behaviour of wood from Matamata with respect to machining processes. However, the survey results (ρbas = 0.77; CA: 1.9; Machining: excellent-good-bad) are similar to those presented by known Amazonian species, as shown in Table 3.

Table 3 - Density data, anisotropy coefficient and machining tests (planer, lathe, drilling, nailing and sanding) of timber species of commercial interest.

Species	Basic density	C.A.	Planer	Lathe	Drilling	Nailing	Sandpaper
Dinizia excelsa Ducke	0.83	1.77	Good	Excellent	Good	Poor	Good
Goupia glabra Aubl.	0.71	1.9	Good	Excellent	Excellent	Poor	Excellent
Pouteriapachycarpa Pires	0.73	1.81	Excellent	Excellent	Excellent	Poor	Excellent
Dipteryxodorata Aubl.	0.97	1.57	Regular	Good	Poor	Poor	Good
Peltogyne subsessilis WA	0.74	1.86	Regular	Excellent	Excellent	Poor	Excellent
Tabebuia serratifolia (Vahl)	0.87	1.48	Regular	Excellent	Excellent	Regular	Good
*Hymenaea courbaril*L.	0.80	1.88	Good	Regular	Good	Good	Good
Astroniumlecointei Ducke	0.81	1.91	Good	Excellent	Excellent	Regular	Excellent
Manilkara huberi (Ducke)	0.83	1.68	Regular	Good	Good	Poor	Good

CA: anisotropy coefficient

These woods are generally employed in construction and shipbuilding; they are also widely used in the manufacture of higher value-added products, such as floors, doors, furniture and ceilings, among others; decorative blades and milled objects. From these attributions and associations with the other characteristics studied, the suitability of *E. truncata* wood for similar applications can be affirmed.

The main defects in the milling, cutting and drilling processes are linked to variations in wood properties, the condition of cutting machines and tools, and machine operator training (PINHEIRO, 2017).

Product Manufacturing

The range of information obtained from the basic research on the species of *E. truncata* allowed the team to make use of applied research. Indeed, this showed that knowledge of the technological properties of wood linked to the machining process, using targeted cutting and proper machinery/tools is essential for raising productivity and the quality of products. As a way of applying the research, products were made using the woods after the machining processes.

In these products, the wood went through the processes of thickening, planing, top moulding, drilling, turning on a lathe and gluing. For the decorative articles, pieces containing sapwood and distinct heartwood were selected from the same piece, to provide products with diversified material. The component pieces of the coffee table were detachable, giving the product greater mobility. The spectacle frames were cut 2 mm thick from the timber by blades. The products show well the contrast between heartwood and sapwood, while the details of curves, tears and perforation perfectly demonstrate the excellent finish that can be achieved with the wood and show that it can be used in the manufacture of products that require a fine finish (Figure 3).

Figure 3- Demonstration of products made with *E. truncata* wood.

To make the multifunctional coffee table (Figure 4), pieces with different designs and colours were selected to show the diversity of the wood material. The processes that the production entailed were thickening, planing, sanding, lateral tearing and drilling. The design of the product used a modular structure, combining wood with aluminium plate and glass, to form a practical and versatile piece of furniture, which could be dismantled by means of screws, allowing the furniture to be disassembled which facilitate its transport. The item can be used either as a coffee table or as a “stool or chair”.

The following processes were used to produce the above piece of furniture: thickening, planing, sanding,

Figure 4- Coffee table/bench, multifunctional furniture made of *E. truncata* wood.

lateral tearing, drill drilling and gluing. It can be seen that the wood produced excellent results in the bonding process as well. Only pieces of Matamatá wood were used in the worktop, which was glued to increase the width of the piece, while in the base (attached to the leg of the furniture) Marupá wood (*Simarouba amara*), a low density wood, which generated less friction in high density woods, was added to help the glue to bond (see Figure 5). This product was also elaborated with the use of modular structure technique; the result of the cuts made in the base of each piece of furniture allowed a new product to be made. That is, each time this item is produced, a lamp can be made out of the wood left over from its base.

Figure 5 - Coffee table, combination of Matamatá and Marupá wood with a glass top.

All the parts went through the finishing process and were sealed and varnished, to refine the finished parts. The products demonstrate the excellent result of using this wood in the machining processes, which can be replicated in the manufacture of different products.

These results, covering the physical properties, response to machining and especially the validation of manufactured products such as furniture, decorative items, fingerboards for musical instruments and spectacle-frames, strengthen the sense that wood of small diameter species has its own kind of value. It can be managed to meet different sectors of the timber industry, especially the furniture sector. This is consistent with the sole paragraph of SDS-AM resolution 17/13 that establishes that species with a minimum cut-off diameter of less than 50 cm may be commercially managed, provided that it can be shown by study that the species in question meet the technical guidelines imposed by the standard, as obtained in this research.

Knowledge of the properties of wood, as well as its machinability, creates mechanisms for the use of alternative wood species little known in the market, enabling a more sustainable exploration of the forest. Every increase in the number of exploited species reduces the exploitation of species traditionally marketed, making management more productive and yielding more wood overall (Lucas & Son Boehs, 2007).

However, the results obtained in the developed research reinforce the need to e technology to characterise other frequent species of small diameter trees to carry out sustainable management in the Amazon.

CONCLUSION

The performance of *E. truncata* wood, known as matamata, features excellent machinability; it can be used in the logging industry due to the high approval earned by its performance in thickening, sanding, drilling, moulding, horizontal drilling and lathe operations.

The results of the technological properties of wood make it possible to use matamatá wood in products with high added value. The products demonstrated the same quality of heartwood and sapwood wood material in the machining tests, suggesting that sapwood can also be used in the production sector.

On the basis of the characteristics analysed, *E. truncata* can be considered as an alternative in subsidising the timber market, since it presents similar characteristics to species which are commonly traded and is a very common species throughout the Amazon. The study shows that species of smaller diameters can be inserted in the market, given their technological potential.

The results also indicate a direction for future research: to investigate the possible use of other wood species of small diameter and high occurrence in the Amazon forest.

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