Ecodesign in the use of the Amazonian Peãozinho wood for making an eco-efficient product

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Abstract

In the midst of the current logging scenario and the growing concerns and actions in favor of preserving the environment, research related to the insertion of new tree species in the market and about the design of products with low environmental impact are of paramount importance for the development of forest management and product design activities. Thus, The holistic view, which includes everything from the extraction of the raw material to the final disposal of the product, guided this research in order to show the technological potential of the species Micrandopsis scleroxylon W. Rodr. through machining and validation processes by making an eco-efficient product. The methodology adopted was: survey of the demand, designing of the concept, definition of the function, generation and materialization of alternatives, tests and refinements and presentation of the final solution. The results obtained in the process of machining the wooden material of the species were excellent throughout the process. It is believed that the approach inherent to small diameter trees, for the benefit of forest management, provides the understanding that it is possible to make use of them in the manufacture of the most varied wooden artifacts. Contributing to further research on Little Known Species.

Keywords: Amazonian wood; Ecodesign; Eco-efficient product; Forest management; *Micrandopsis scleroxylon* W. Rodr

1. INTRODUCTION

Among the many activities of the productive sector in the northern region, logging in the Amazon can be considered as one of the most important. Due to the many researches carried out addressing this issue, it is assumed that the true potential of this activity has not been emphasized in the regional context (SILVA E NASCIMENTO, 2016). It is important to note that, given the diversity of tree species, the current number explored is still small. This is worrisome because the still demanding consumer market opts for species considered as traditional, but due to unbridled exploitation it has resulted in a decrease in the frequency of species such as Mahogany, Jacarandá and others.

In the midst of the current logging scenario in parallel with the growing concerns and actions in favor of preserving the environment, research related to the insertion of new tree species in the market and about the design of products with low environmental impact are of paramount importance for the correct development of forest management and product design from wood. In this way, the holistic view that comprises from the extraction of raw material to the final disposal of the product guided this research that aimed to show the technological potential of the species *Micrandopsis scleroxylon* W. Rodr. with the popular name "Peãozinho" through machining and validation processes by making eco-efficient products. This work proposes to generate information about small diameter trees in order to subsidize the Forest Management, with the objective of stimulating its use in artifacts.

1.1 Sustainability, Ecodesign and Eco-efficient Products

Sustainability has been widespread recently, but it is not applicable to all cases in the same way, as it is not a set of universal rules, since for each problem a different solution needs to be developed. With the growing need for countries to find ways to enhance the growth of their economies without causing negative impacts on the environment, the term sustainability emerged in the 1980s. (NORO et al. 2012).

Within this panorama is Ecodesign, where projects are developed with a view to the environment, a way to generate products that cause less or no environmental impact, if possible. Venzke (2002,) proposes that "the main objective of Ecodesign is the creation of eco-efficient products, without compromising its costs, quality and time constraints for manufacturing". Thus, it is necessary to adopt some practices during the design of a product, namely:

1. Material recovery, where the materials used are closer to their natural state;
2. Projects focused on simplicity, where the shapes of the products enable less energy expenditure and do not require as many human resources to make them, in addition to enhancing the assembly / disassembly factor, durability and easy use of the products all without compromising the aesthetic value of the product;
3. Reduction of raw materials at the source, where it aims to reduce waste in the act of extracting raw material and reduce materials throughout the product's service life, aiming at reducing environmental impacts;
4. Recovery and reuse of waste, this is a necessary process for the entire life of the product since a certain amount of waste is generated throughout it;
5. Uses of forms of sustainable energy and renewable materials, use of renewable resources where the rate of renewal is sufficient for their full use;

6. Products with greater durability, it is not the best option for companies aiming at profitability, since products like this do not require immediate manufacture / obtaining a substitute, the choice is up to the designer and the manufacturer;
7. Packaging recovery, whether by turning the primary packaging into a display or giving a new use to the tertiary packaging, the important thing is that it can be recycled or reused;

All of these practices aim to meet the needs of Ecodesign in the development of products that meet the objectives of eco-efficiency, as they are closely related to its fundamentals. Which are: sustainable use of water, electricity and other renewable resources; reduction, reuse and recycling of materials; introduction of alternative forms of energy generation; introduction of projects that promote the durability of consumed and manufactured products; introduction of practices that contribute to environmental efficiency in conjunction with financial savings; internal and external dissemination of environmental awareness (SEBRAE, 2014). As for the term eco-efficiency, it is a management strategy that combines environmental and economic performance.

In this way, the main objectives of eco-efficiency boil down to: reducing the consumption of resources, reducing the impact on nature and providing customers with higher quality products and services. Turning consumer goods into eco-efficient products consists, first of all, of doing the Life Cycle Analysis (LCA) of the same (FIGURE 01). According to SEBRAE (2014), "LCA is the assessment of the environmental impacts associated with the production, consumption and disposal of a product, summarized in 5 steps".

Figure 1. Life Cycle Analysis. Source: SEBRAE (2014).

"Bad design" or bad projects are very easy to find in everyday life, they are inadequate conceptions that cause accidents and even misuse, thus, developing a product with eyes focused only on one stage of its life cycle or for just one of its users among the various people who will interact with it throughout its existence, an inappropriate product will result in some of these phases or for some of these people (BARBOSA FILHO, 2009). Therefore, it is worth emphasizing the need to have a holistic view of the process, from obtaining raw materials to final product disposal.

1.2 Forest Management, Amazon and Small diameter trees

The vast and heterogeneous Amazonian forest has several tree species that can be sold. But there is legislation that aims to direct logging to the best yield through sustainable forest management. For that, the legislation has regulations regarding the minimum diameter for cutting, as well as there are authors proposing a maximum diameter, aiming at the conservation of the forest. According to Cunha et al (2002, p. 02) “the minimum cut diameter is regulated by specific legislation. IBAMA established that the DBH > 45 cm should be the minimum cut diameter”.

However, the forest presents the occurrence of several species of trees of small diameter that can substitute for the widely explored species. These trees come under the definition of "LKS". Also according to Cunha et al (2002, p. 02) "the market that is conservative continues to put pressure on a few species with a high level of demand, while others are rarely acceptable." There is a considerable amount of trees not yet explored called "little known species" (LKS), "undesirable" or "exploration not necessary". They are generally not accepted by the market due to lack of knowledge about the technological potential of the species.

According to INPA / LEAM records in the municipality of Itacoatiara, there is a company that has about 60 species in its exploration chain. This is possible through advances in research, which show results in terms of machining quality, physical and mechanical properties of small diameter wood species. Thus, it can be said that LKS's work as a management option and have potential for exploration since they have a base area (m^2 / ha), frequency (%) and abundance (n / ha). For a species to be exploited, according to the assumptions of the forest inventory, it must meet these three factors.

Little Known Species - LKS, the Peãozinho (*Micrandopsis scleroxylon* W. Rodr) belongs to one of the largest families of dicots, having a worldwide distribution (FIGURE 02). It is an Amazonian tree with a small diameter, frequent in the dry land forests of the municipality of Manaus-AM. The difference between heartwood and sapwood is quite noticeable since it presents heartwood in a dark brown color in contrast to the sapwood that varies between yellow or light cream (BARROS, 2016).

As for the use of sapwood, there is some fear on the part of the lumber companies and producers of wood artifacts, since it presents physical and mechanical properties inferior to the heartwood in some cases. And it is worth pointing out that the darker the wood, the greater the desire for consumption. But the studies that have been carried out prove that lighter colored woods can be inserted in the logging market in addition to identifying in certain species the similarity of physical and mechanical properties between heartwood and sapwood (KLITZKE et al. 2008; PEREIRA et al. 2013). Barros (2016, p. 76) states that "low performance is not only due to equipment or wood with internal defects, but also due to the difference in wooden material".

Peãozinho (Micrandopsis scleroxylon W. Rodr) has a distinct wooden material, that is, with well-defined heartwood and sapwood and a significant amount of sapwood (FIGURE 02). Visually, the difference between heartwood and sapwood is very large, but when it comes to density, statistically speaking, sapwood and heartwood are the same, all trees of this species have high density wood, ranging from 0.82 to 0.97 g / cm³, between sapwood and heartwood, therefore, more resistant, thus allowing the use of all the wooden material of the tree in the manufacture of products with high added value and which require a fine finish in addition to being able to be used in marquetry techniques. It is also important to emphasize that this species presents good results in terms of machining, with technological characteristics of quality.

Figure 2. Cross-sectional view of the wood and basic density of the heartwood. Source: Barros, 2016.

2. MATERIALS AND METHODS

Among the various methodologies proposed for product development, the methodology proposed by Barbosa Filho (2009) was adopted, which consists of surveying the demand, building the concept, making the functional definition, generating the alternatives, materializing them, carrying out tests and refinements and present the final solution.

After identifying all the problems involving small diameter trees and making eco-efficient products, the wood species *Micrandopsis scleroxylon* W. Rodr. was taken as the object of study in this research, with the trade name “peãozinho”.

The study area where the tree was collected is located in the municipality of Manaus, at the Experimental Station of Tropical Silviculture of the National Institute for Research in the Amazon (EEST / INPA) - Nucleus ZF-2, at km 23 of the ZF-2 road Agricultural District of the Manaus Free Trade Zone Superintendence (SUFRAMA), with access at km 50, M/E of the BR-174 Highway, Manaus - Boa Vista. The selection of this species was based on the forest inventory carried out in 1 hectare, where it was decided to collect trees of species with diameters less than 40 cm and that had a greater occurrence in the study area.

The trees of the species were split into four equal logs and processed on boards to be kiln dried at 12% humidity (FIGURE 03). A selection of some pieces of the species *Micrandopsis scleroxylon* W. Rodr. Was made, namely: two boards with the presence of heartwood and sapwood that were processed at the

Laboratory of Engineering and Wood Artifacts - LEAM / INPA where the machining tests were carried out.

Figure 3. Board with the presence of heartwood and auburn.

Taking into account the practices inherent to Ecodesign and the fundamentals of eco-efficiency in addition to the principles for the design of consumer goods (IIDA, 2005), a table of requirements and design parameters was developed in order to guide the generation of alternatives (TABLE 01).

Table 1. of Requirements List and Design Parameters

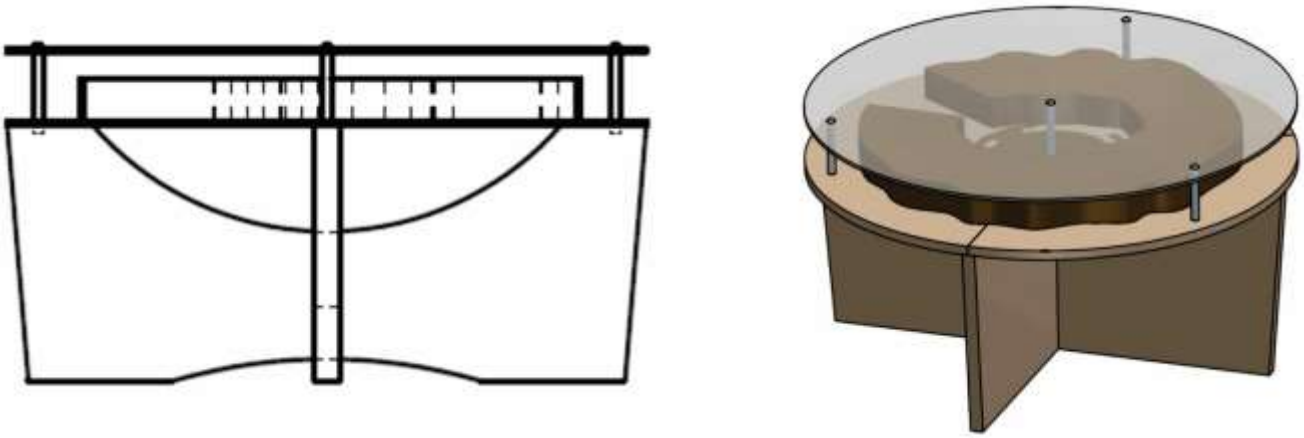
Requirements	Parameters
USAGE	
Ergonomics	Optimal adaptation between the product design and the user regarding its limits.
Simple and intuitive usage	The product must be easily understood, without relying on specialized knowledge.
Anthropometry	Adequate dimensional relationship between product and user
FORM	
Practicality	More geometric shapes applying modularity.

Style	Generate alternatives with a certain aesthetic appeal seeking to further enhance the product. Ex: Use the Marquetry technique.
Reduction of energy expenditure	The alternatives must avoid unnecessary oversizing, which leads to higher energy costs.
Ease during the production process	Use as little labor and tools as possible.

From the selection of the two boards of *Micrandopsis scleroxylon* W. Rodr. and based on the list of requirements and design parameters, the first sketches were conceived. Among the various artifacts that could be designed, we chose to produce a coffee table, as it is a medium-sized product. Unlike SWO (Small Wooden Objects), the coffee table brings more value to the raw material used.

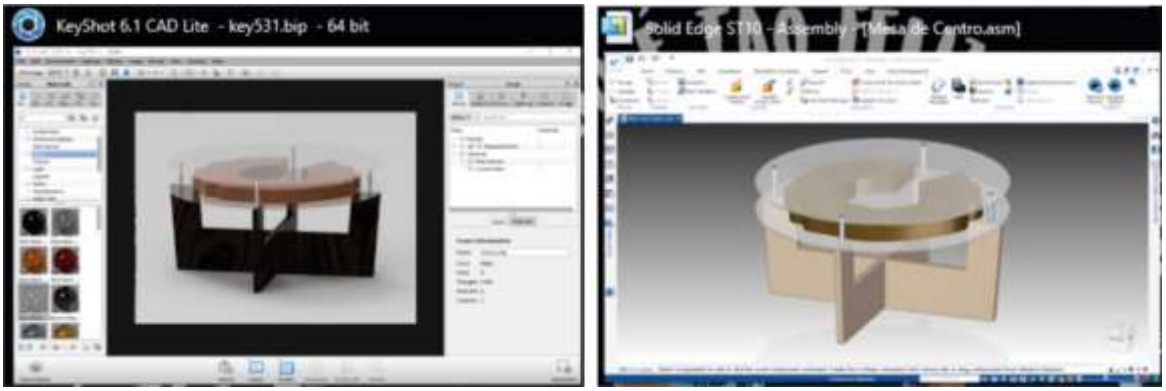
After perfecting the alternatives via a quick sketch, they had their virtual prototypes modeled using the Solid Edge software (FIGURE 04), the selection was made based on the requirements and design parameters and the one that most met the criteria was modeled in the software Solid Edge CAD and rendered in the KeyShot software.

Figure 4. Initial alternative to the coffee table.



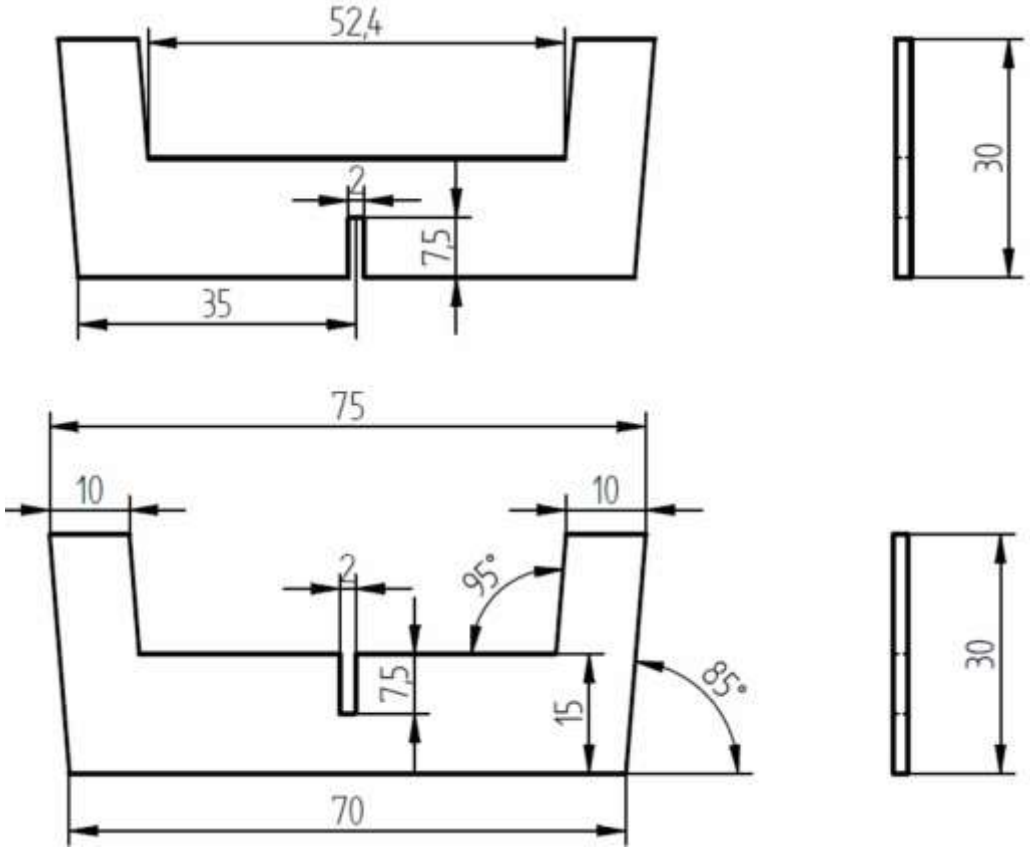
These softwares were used seeking the following objectives: 3D visualization of the generated alternative, creation of a virtual prototype instead of a physical prototype for not using raw materials and energy expenditure, analysis of the assembly and disassembly relationships, nexus between the elements and generation of technical details of the coffee table for later production of the physical prototype (FIGURE 05).

Figure 5. Interface of the KeyShot and Solid Edge software.



Taking into account the design process, in the alternative generation stage, we sought to work with the valorization of the raw material through the application of concepts such as modularity and application of meaning. The alternative carries with it the meaning of an appeal for the use of small diameter trees to replace those of larger diameter and commercial value, which are less and less frequent due to logging.
The geometric shape of the proposed alternative included two main advantages: ease of production and reproduction and the use of few machines for its manufacture. The shapes are simple, attractive and functional, easily reproducible (FIGURE 06).

Figure 6. Partial technical details of the alternative.



The boards of *Micrandopsis scleroxylon* W. Rodr. were processed and the generated parts were sized based on the technical details of the coffee table for the production of the physical prototype. As shown in Figure 07, they were first sawed on the circular saw (A / B) and later processed on the trowel (C) and then on the thicker (D).

Figure 7. Processing of Peãozinho pieces.

As it is a small diameter tree, the wooden pieces needed to be glued by pressing with the help of clamps after being processed. It was sought to glue following the order sapwood/heartwood and not heartwood/heartwood or sapwood/sapwood both because of the principles of marquetry and because of the visualization of colors resulting from such a combination. Specific glue was used to glue wooden joints. The pieces remained pressed for about 24 hours. All markings for directing the band saw cut were made on the piece after 24 hours of pressing for gluing (FIGURE 08).

Figure 8. (A) Pressing the parts and (B/C) marking of them for cutting.

The physical prototype of the coffee table was completed without requiring many machines during the process. The assembly and disassembly test was carried out according to the 3D virtual prototype. The machines used during the manufacturing process were: Circular Saw, Band Saw, Straightener, Thicknesser, Circular Sander, Orbital Sander and Drill. The mechanical processing residues generated were classified and transformed into a product.

3. RESULTS

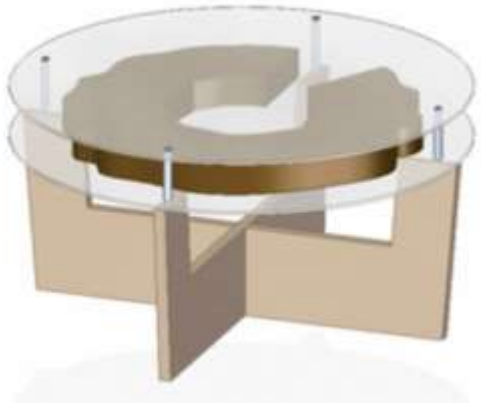
The physical prototype of the product was successfully completed and tests for validation were carried out. Tests like assembly and disassembly and simulation in an environment. When performing the Life Cycle Analysis (LCA) of the product we have the following (FIGURE 09):

Figure 9. Life Cycle Analysis of the coffee table.

1. Extraction of raw material: as previously explained in the methodology, the wood was collected in the study area of the National Institute for Research in the Amazon. Because of its frequency in the vicinity of the city of Manaus / AM (and in other locations in the state and the Amazon), there are no expensive costs for extraction and processing of wood.
2. Manufacturing: as it presents more geometric shapes and is easy to manufacture in addition to having technical details, it is a product that can be easily reproduced by third parties without the need to use many machines and labor.
3. Distribution to the reseller market: regarding logistics, we see that through modularity and ease of assembly and disassembly, the product does not occupy much space when prepared for transport. In this way facilitating both the reseller market and the consumer market, since transport is in all stages, from extraction to final disposal.
4. Use: the use of the coffee table does not generate harmful impacts or energy costs in this stage, its main function being only decorative. It is worth mentioning the use of cleaning products and finishing touches like waxes or varnishes or sealers, these activities being carried out over long periods of time.
5. Final disposal: what can interfere with the disposal of the proposed coffee table is precisely the styles and fashion patterns introduced by the retail market. It is worth pointing out that solid wood products have a long service life, especially when the wood is medium to high density. As an alternative to disposal, the coffee table in question has three forms of use that alter its aesthetic perception. It can be used as the initial idea: two pieces of wood (base), two glass discs, stainless steel spacers and hollow wood disc; it can still be used only as: two pieces of wood, two glass discs and stainless steel spacers; or only: two pieces of wood, a glass disk and fasteners. The important thing is that all parts can be reused or recycled, as is the case with the two base parts. At the end of the product's service life, they can be reconfigured for transformation into a new product, for example: marquetry pieces

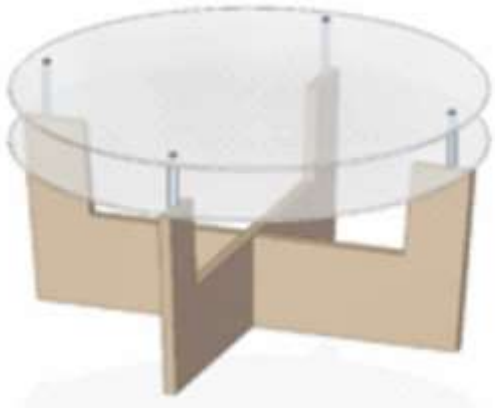
As for item 5 of the Life Cycle Analysis of the coffee table, we have the following: regarding the alternatives of use aiming at the late final disposal of the product the first alternative is to use the coffee table as it was designed. Featuring a total of nine pieces, of them being two base pieces, two glass discs (top), one hollow wooden disc and four stainless steel spacers, as shown in FIGURE 10. The hollow wood disk falls within the scope of the use of forest residues, which has not been addressed in depth during the development of this research.

Figure 10. Alternative 01 for using the coffee table.



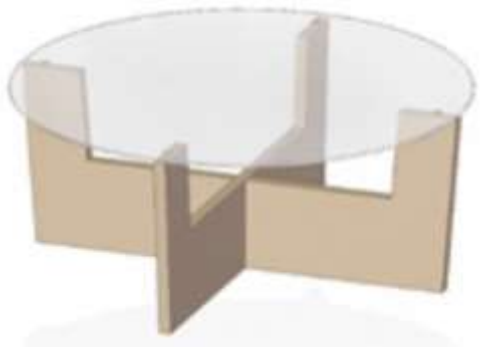
The second alternative of using the coffee table does not use the wooden disk, thus reducing the total weight of the product, in addition to other things such as transportation and labor to obtain and prepare the hollow wooden disk (FIGURE 11).

Figure 11. Alternative 02 for using the coffee table.



In the third alternative of using the coffee table, the pieces are reduced even more, leaving only the two base pieces, the glass disc and the fasteners (FIGURE 12).

Figure 12. Alternative 03 for using the coffee table.



For each of the alternatives for using the coffee table aiming at its late final disposal, validation was performed through the physical prototype as in figure 13. Which indicated the possible uses of the coffee table in the face of the constantly changing market trends.

Figure 13. Assembly test to validate alternative 03 of use.

Through Life Cycle Analysis - LCA and exposure of the alternatives for using the coffee table, we have that the product meets the requirements and parameters established in the methodology regarding the use and the form of the same. As for the tests carried out in relation to the use of the product, all obtained a positive result, since the product is easy to assemble and disassemble in the following aspects:

1. Base: the base consists of two pieces of wood assembled by means of fitting only without requiring connection elements such as nails, screws or fasteners.
2. Glass: glass is easy to obtain and handle, in addition to easy assembly with the base by means of stainless steel spacers.
3. Wood disk: item of a purely decorative character (in terms of using the product in question) is obtained from the reuse of hollow tree pieces discarded in sawmill yards or the like. No need for fasteners for its union with the other parts of the table.

In addition to its ease of assembly and disassembly, the coffee table does not present any complexity in its manufacturing process, since its technical details allow for easy reading and reproduction.

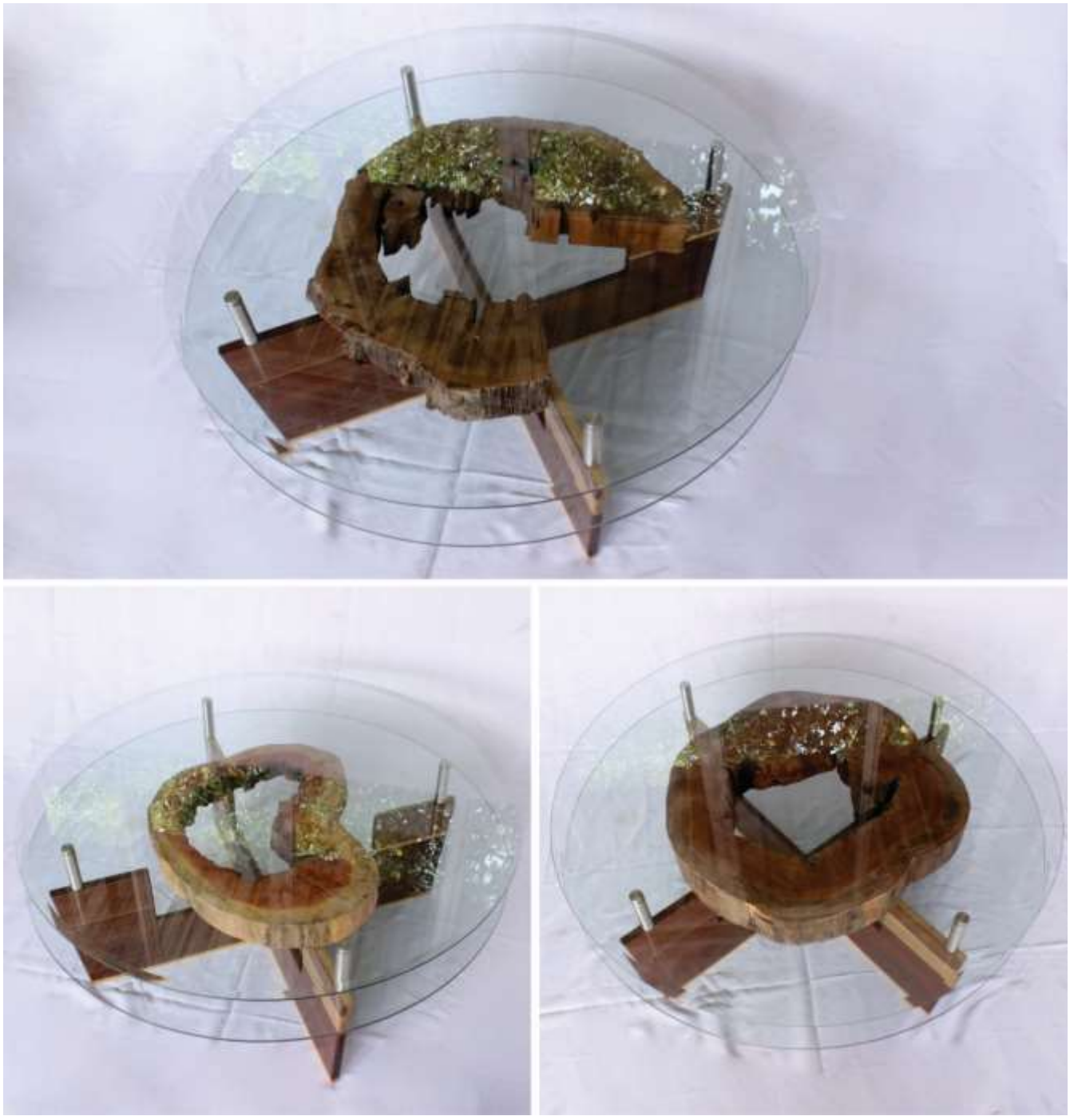
It is worth emphasizing the concept that the coffee table carries. Far from being just a product full of techniques in its execution aiming at the eco-efficient side of a manufacturing process, the coffee table called BIUNA, has its shapes inspired by the environmental cause, which is the use of wood of small diameter trees as an alternative of replacement of commercially known trees that are no longer so frequent in a larger diameter and others can no longer even be explored due to the scarcity of native tree individuals. In addition to making use of a hollow wooden disk which is easily seen being discarded as it has no commercial value for sawmills and lumber companies. At its base we have the styling of open arms

representing the support given by small diameter trees to other types of species and forest residues to be sold. Thus, we have the wooden disk hollowed out on the base, much more than just an aesthetic element, this comes to demonstrate the richness of materials that can be used even if they are forest residues.
In a single product we have the validation of the use of the Amazon wood species Peãozinho (Micrandopsis scleroxylon W. Rodr.), The application of Ecodesign practices followed by the fundamentals of eco-efficiency in the manufacture of products and the use of forest residues (FIGURE 14).

Figure 14. Biuna Coffee Table.

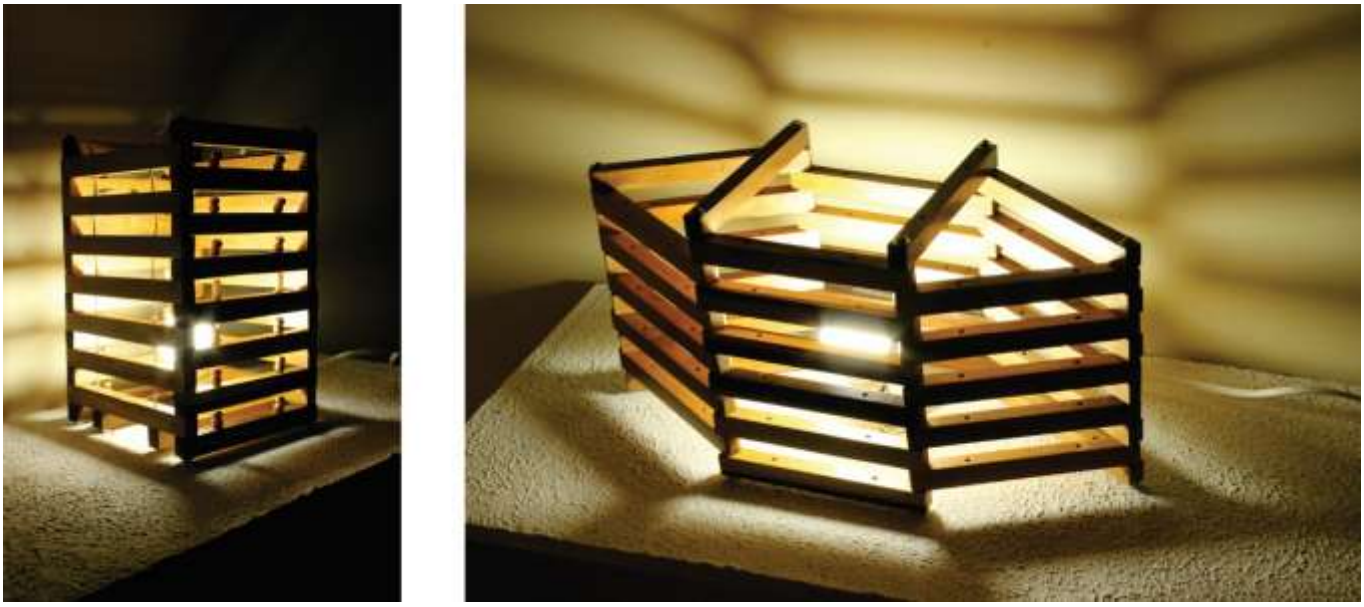
The use of forest residues was not widely addressed in the development of the research since the general objective was to show the technological potential of the species *Micrandopsis scleroxylon* W. Rodr., however the use of hollow wood discs where three discs of different tree species make up the entire BIUNA coffee table (FIGURE 15).

Figure 15. Biuna Coffee Table.



The species *Micrandopsis scleroxylon* W. Rodr (Peãozinho) showed good results in terms of machining, responding well to the use of the machines, so much so that when passing through the grinding, it presented a surface texture similar to wood pieces already sanded with sandpaper granulation above 220. The glued joints did not present a defect and the area cut for fitting was easy to execute. As for the classification of mechanical processing residues mentioned in the methodology, they were used in the manufacture of modular lamps (SILVA and NASCIMENTO, 2016). This product also met the requirements and parameters established, but it enters this article only to demonstrate the possibilities of using mechanical processing residues from the machining of the Peãozinho in the manufacture of products (FIGURE 16).

Figure 16. Lamps from a modular part.



4. CONCLUSION

The results obtained in the process of machining and finishing wooden material of the species *Micrandopsis scleroxylon* W. Rodr., Popularly known as "Peãozinho", were excellent throughout the process. In this way, meeting one of the main objectives of this research, which was to show the technological potential of such species.

It is believed that the approach inherent to small diameter trees for the benefit of forest management, even if done succinctly, provides the understanding that it is possible to use them in the manufacture of the most varied wooden artifacts. Thus contributing to more research on Little Known Species - LKSs to be carried out in order to encourage their insertion in the logging market in replacement of species considered to be traditional and which no longer have great frequency, making their use costly.

As for the manufactured product, from the Life Cycle Analysis - LCA of it, it was possible to verify the importance of having a holistic view of the product, comprising from the extraction of the raw material to the disposal of all the constituent elements of it. Thus, it is worth pointing out that the research objectives were successfully met and that they corroborate the effectiveness of using wood from small diameter trees (considered as LKSs in most cases) and the insertion of Ecodesign practices.

5. ACKNOWLEDGEMENTS

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