Ecological panels as an alternative for waste from mechanical processing of Amazonian species

Marcos Breno Lopes Marques[1], Claudete Catanhede do Nascimento[2] Roberto Daniel de Araujo[2]
[1] Master's Postgraduate Program in Forestry and Environmental Sciences - PPGCIFA, Federal University of Amazonas-UFAM, Manaus/AM, Brazil (+5592982020748, marcosmarques44@gmail.com)
[2]Researcher at the National Institute of Amazonian Research/INPA, Manaus/AM, Brazil

Abstract

The wood residues resulting from the operational phases in companies in the forestry market are normally considered by-products and, therefore, are discarded or reused for energy production, however, this material has a greater potential, such as the generation of new products through agglutination, which may generate a new segment in the wood industry, causing competition between products of native and planted species. This research aimed to develop agglomerated panels using residues of two tree species from the Amazon (Dinizia excelsa Ducke and Manilkara huberi (Ducke) Chevalier) and a mixture of commercial Amazonian species of high density, with the purpose of greater added value and a possible solution to reduce the negative environmental impacts of carbon emissions. The experimental design consisted of three treatments with five repetitions in each. Experimental panels were produced with a nominal density of 0.80 g/cm³, using castor oil-based resin with 10% percentages. The panels were pressed with a pressure of 10 MPa, temperature of 100ºC and with a pressing time of 10 minutes. The evaluations of the results obtained were compared with the ANSI A208.1 / 2009 standard and with the literature on agglomerated panels of tropical species. In physical properties, the panels showed compliance with the values found in the literature, however, they are outside the standard of the norm. Regarding the mechanical properties, the MOR values classify the panels in the medium to high density standard in accordance with the standard. The results of the MOE are superior to those of the existing literature, with emphasis on the perpendicular traction that presents values consistent with the literature. The machining evaluations carried out according to ASTM D 1666-11 / 2011, show a good quality in the finish. In general analysis and in compliance with the regulations, all panels have economic viability and potential for industrialization.

Keywords: chipboard panels, wood residues, tropical woods

1. INTRODUCTION

The Brazilian Amazon is one of the main tropical wood producing regions in the world and its growing stock contributes to more than 30% of the world's timber reserves [ITTO, 2014]. Despite presenting a significant amount of raw material, the activities carried out still predominantly develop in an unsustainable manner, causing an enormous waste of forest resources in all stages of the production chain, from forest exploration to industrial processing in the sawmill [Araújo, 2013].

The average yield of Brazilian sawmills is around 60 to 80% [Batista, Silva & Corteletti, 2013]. However, in the Amazon region, the processing of native wood reaches a loss of 59% [Hummel *et al*., 2010], which causes an increase in the final price of the product and the volume of waste generated in saw dust and edge planks [Biasi & da Rocha, 2007].

Among the most explored native species we can mention the *Manilkara huberi* (Ducke) Chevalier (Maçaranduba) and *Dinizia excelsa* Ducke (Angelim Vermelho), sought mainly due to the multiple uses of their woods. In a study developed by [Melo *et al*., 2012], it was found that one log of *Manilkara huberi* (Ducke) Chevalier (2.90 m³) yields approximately 45% (1.30 m³) and the other 55% is waste, with 18.24 % of these residues (0.29 m³) being characterized as sawdust. While [Stragliotto, 2019] when studying the yield of sawn wood for export of the Dinizia *excelsa Ducke* species, a use of 40.18% with 59.82% of residues was observed.

This low yield can generate an increase in wood consumption, leading to a shortage of this raw material in the future. The yield in the processing or splitting of logs in the sawmill is an important issue that has an intrinsic relationship with sustainability in the use of forest resources, since the level of use of the raw material directly influences the area of explored forest necessary to meet the demand for wood [Iwakiri, 1990].

The necessary knowledge to solve these problems involves the characterization of the productive performance of these industries, the factors that generate waste, the volume and type of existing waste and the seasonality of its generation, in addition to the possible uses that can be given to this material [Brand *et al.,* 2002]. In addition, the prognosis of the stock and yield of the raw material processed at the sawmill is of paramount importance for businessmen in the forestry sector, enabling improvement in production planning, optimization and control [Iwakiri, 1990].

According to [Quirino, 2004], waste can be used energetically to produce heat, steam or electricity in thermoelectric plants. Another use is in the form of solid fuel, such as charcoal. Carbonization and combustion have been identified as alternatives to reduce waste from the timber industries, however, they generate impacts on the environment through the release of gases and derivatives [Fontes, 1994].

The use of residues for production in products with higher added value is a possible solution, not only to reduce the negative environmental impacts resulting from the emission of gases, but also to generate work and income [Rivela *et al*., 2006]. Thus, the objective of this work was to develop agglomerated panels using residues from two commonly used Amazonian tree species and a mixture of commercial high-density Amazonian species to enable the use of solid waste for panel production.

3. MATERIAL AND METHODS

3.1 Characterization of the study area and waste collection

The study was carried out at Instituto Nacional de Pesquisas da Amazônia (INPA) in partnership with the company Mil Madeiras Preciosas Ltda., linked to the Precious Wood Amazon (PWA) group, located in the municipality of Itacoatiara about 227 km from the city of Manaus- AM (02° 43'S and 58° 31'-58° 57'O) [26].

The material from this study was obtained through a donation from the company linked to the project, where mechanical processing residues from the split of the logs identified as Massaranduba and Angelim Vermelho were donated.

The donated residues were transformed into chips, making wooden fillets for grinding in a mechanical grinder in a 60 mesh size. Later, with the crushed material, it was packed in a plastic bag for its accommodation.

3.2 Botanical identification

From the samples obtained in item 3.1, specimens oriented in the tangential and radial directions were made to be identified in the wood identification laboratory - LAIM of the Coordination of Technology and Innovation - COTEI of the National Institute for Research in the Amazon - INPA. The identifications were made based on the ABNT procedures and by comparing the samples cataloged in the xylotheque of this course coordination office.

3.3 Moisture content and bulk density

This property was determined by double weighing, weighing the residues on a precision scale after collection, and then they were placed in the oven at 105°C until they acquired a constant weight, to obtain the last weight for the calculation of humidity.–

The apparent density was determined by the stoichiometric method with wood moisture of 12%, being carried out in the Laboratory of Engineering and Wood Artifacts (LEAM), using digital caliper and precision scale.

3.4 Determination of ash and silica

The ash determination was carried out following the ASTM D1102-84 [ASTM, 2007] standard with 1 g of sawdust (60 mesh) and platinum crucibles with the use of a muffle furnace, with the quantification of silica performed according to [Vogel, 1981].

3.5 Fabrication of the panels

The methodology used for the production of the panels was in accordance with the specifications of NBR 14810-1 [ABNT, 2013] for medium density particle boards with adaptations. The desired formatting of the panels to be developed consisted of dimensions 400X400X15 (mm) with a density of 0.80g/cm3. The volume of matter to be used in production was calculated using the density equation.

The resin used in the manufacture was IMPERVEG AGT 1315 donated by the company IMPERVEG Polímeros Indústria e Comércio Ltda, with a composition based on vegetable polyurethane (originated from castor oil), formulated by the cold mixture of a prepolymer and a polyol. The applied experimental design produced three panels using 1632g of wood and 288g of resin, with 15 specimens removed from each panel for the tests. The panels were produced at the Physical-Chemical Testing Laboratory of the Faculty of Technology of Universidade Federal do Amazonas (UFAM), and the work carried out by [Lima, 2012], [da Silva *et al*., 2013] and [Silva, 2019] were adopted as methodological references.

3.6 Manufacture of panels

At first, the wood particles were weighed on a digital scale to separate the components the day before the preparation of the panels, which were accommodated in individual plastic packages. On the day the plates were made, the prepolymer and polyol components were weighed on a digital scale.

Then, the resins were mixed with the wood particles for a period of 10 minutes until the material was homogenized. Subsequently, this material was placed in a mold and compacted manually, being promptly placed in a hot press at a temperature of approximately 100°C, pressure of 10 MPa for 10 min.

After the pressing process, the plates were allowed to cure for 72 hours, where they received finishes and were cut for tests according to figure 1. Five specimens were removed from each plate with the following dimensions: 50X50 (mm) for the swelling and absorption tests (basic density), 50X200 (mm) for the elasticity module test and 50X80 (mm) for the rupture module being calculated through these also the perpendicular tensile strength.

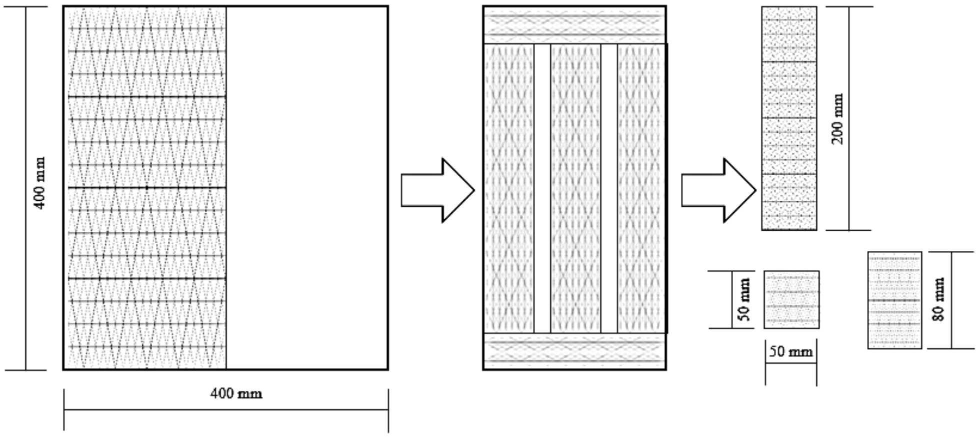

Figure 1. Squaring and cutting performed for sample removal

The apparent density of these panels was calculated according to item 3.5, and the swelling and absorption had their quantification according to NBR 14810-2 [ABNT, 2018], where it prescribes that they must be measured and weighed in 2 and 24 hours. The mechanical properties were calculated by the proposal by [Mesquita, 2013], and their evaluation was analyzed according to the ANSI A208.1 standard [CPA, 2009]. In addition, based on ASTM D 1666-11 [ASTM, 2011], tests were carried out for drilling and cracking by nails.

The drilling tests were performed with a vertical bench drill, using four helical drills of 6, 8 (high-speed steel), 10 and 12 mm in diameter with a sample perforation. The holes were drilled 20 mm apart and 10 mm from the edges. The parts were evaluated and classified according to the defects described in Table 1.

Table 1. Notes applied to part evaluations in machining tests

Note	Classification	Defects
1	Excellent	Absence of 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	Very poor	Presence of 100% of defects

Source: ASTM D-1666-11 [4].

In the nail cracking test, nails were inserted from the edges to the center of the pieces, 20 mm apart with the help of a hammer, using four types of gauge: 16X27, 14X21, 13X18 and 1x17 of the Gerdau brand. In this test, the presence of cracks or cracks was taken into account, with a classification as “accepts nails” (without cracks or in insignificant dimensions) and pieces that “do not accept nails” (with relevant cracks).

3.7 Statistical analysis

The assessment was made based on descriptive statistics (mean, standard deviation, median and quartile) in the criteria established by the standards that deal with wooden panels [ABNT, 2018]. The results of physical and mechanical properties were evaluated using the Kruskal-Wallis analysis of variance (ANOVA) (non-parametric) and the Nemenyi multiple comparison test when necessary.

4. Results and Discussion

The wood used in the production of the panels identified as *Massaranduba* (Manilkara huberi (Ducke) Chevalier), had red heartwood and light brown sapwood, with basic density ranging from 0.89 to 1.04 g / cm3, being classified as very heavy and with high natural durability. While the second red Angelim species (*Dinizia excelsa* Ducke) has reddish-brown heartwood and reddish-gray sapwood, with basic density ranging from 0.90 to 1.15 g / cm3, with the same classification as Massaranduba, with high natural durability. Both species have high commercial demand and produce a significant amount of waste around 70% per tree.

4.1 Ash and silica content

In the chemical analysis performed, an average ash content of 0.24% was found for both species (Table 2). In an individual panorama, the species *Manilkara huberi* (Ducke) Chevalier presented a value lower than that found by [Nobre *et al*., 2014], equivalent to 0.33%. When we compare the species *Dinizia excelsa* Ducke, it presented a value higher than that found by [Fortes, 2018], which expressed a value of approximately 0.18% and approximate to the value found by [Araújo, 2019] of 0.23%.

In a study developed by [Santana & Okino, 2007] where the ash content of 36 Amazonian woods was evaluated, there is a variation of this percentage from 0.2% to 2.3% based on the density of the wood. Other researchers, such as [Aquino, 2003] and [Numazawa, 1986], found values ranging from 0.43 to 1.76%. This variation can be related to the environmental conditions under which the tree grows [Fengel, 1989] and can also be influenced by its location and also by the discourse by [Collet, 1956], that the ash content after carbonization depends on the amount of inorganic compounds present in the wood.

Species	*Dinizia excelsa* Ducke			*Manilkara huberi* (Ducke) Chevalier	
	Ash Content		Silica content	Ash Content	Silica content
Samples	1	0.25	0.06	0.26	0.09
	2	0.22	0.07	0.22	0.10
Average	0.24		0.07	0.24	0.01

Table 2. Quantitative of inorganic compounds of the species

The average silica content found was different in each species, where Dinizia *excelsa* Ducke obtained a value of 0.07% and *Manilkarahuberi* (Ducke) Chevalier presented a content of 0.01% (Table 2).There is a scarcity of studies in the literature related to the amount of silica present in tropical woods, mainly due to the costly cost of its realization, however, in one of the few studies related to Amazonian woods, [Santana *et al*., 2013] working with 36 species quantifies a variation between 0.07% to 1.6% of this inorganic compound.

Despite not measuring the species *Dinizia excelsa* Ducke, it was possible to observe a similar value working with the species *Diplotropis purpurea* (Rich.)Amshoff from the same botanical family. However, when analyzing the species *Manilkara huberi* (Ducke) Chevalier, no silica was found, which diverges from the result found in this work. This fact may have occurred mainly due to the different methodologies applied.

4.2 Visual analysis of the panels produced

In a succinct way the panels *of Dinizia excelsa* Ducke *and Manilkara* huberi (Ducke) Chevalier had better homogenization with resin than the mixture of Amazonian species. In the visual analysis performed, no defects were found, where the surfaces were flat and without roughness (Figure 2). The plates proved to be resistant to small manual efforts and with some depressions in the corners.

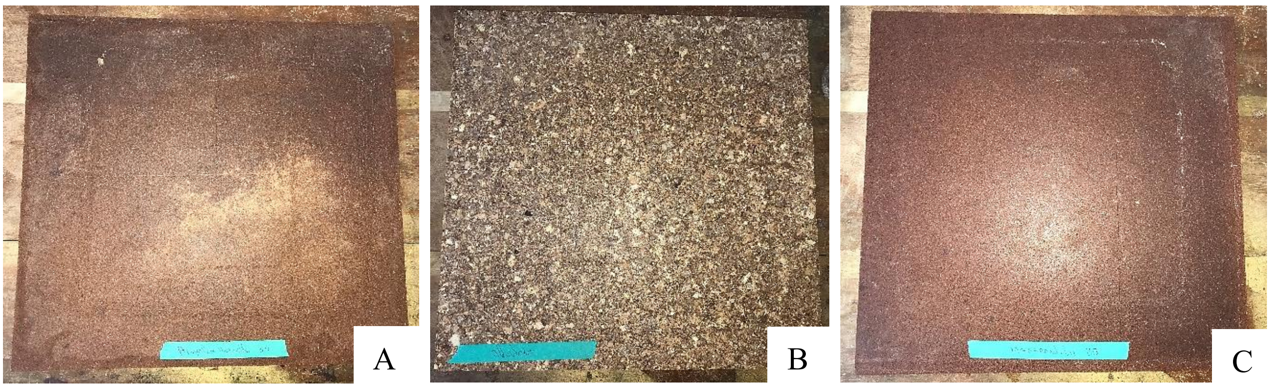

Figure 2. Wood waste boards: A) Dinizia *excelsa* Ducke; B) Mixture of high-density commercial Amazonian species; C) Manilkara *huberi (* Ducke) Chevalier.

4.3 Physical properties of the panels

The average values of the specific mass of the particle boards varied between 0.93g / cm³ to 1.20g / cm³ (Table 3), being higher than the established specific nominal density. According to the parameters of the ANSI A208.1 standard [CPA, 2009], these panels are characterized as panels of high density particles, as they presented values above 0.80 g/cm³.There was no effect of the treatment on the initial density (X^2 (2) = 5.82; p> 0.05), however, this effect was noticed after two hours of immersion (X^2 (2) = 11.16; p < 0.05), being highlighted by the differentiation between treatment with *Dinizia excelsa* Ducke and treatment with a mixture of commercial Amazonian species of high density (p0.05).

After twenty-four hours of immersion, an effect of the treatment on the density was also observed (X^2 (2) = 9.91; p <0.05), however this difference was noted between the treatment with *Manilkara huberi* (Ducke) Chevalier and treatment with a mixture of commercial Amazonian species of high density (p0.05).

Table 3. Average values of the apparent density of the panels

Species	SM (g)	2H	24H
Dinizia excelsa Ducke	1.03 (0.05)	1.39 (0.04)	1.42 (0.04)
Manilkara huberi (Ducke) Chevalier	1.20 (0.12)	1.25 (0.11)	1.44 (0.06)
NI	0.93 (0.21)	1.02 (0.16)	1.17 (0.17)

ME = specific mass; 2H = 2 hours after immersion; 24H = percentage 24 hours after immersion; NI = Mixture of high-density commercial Amazonian species. Values in parentheses refer to the standard deviation.

Absorption and Swelling

The average values of absorption and swelling for the particle boards after two and twenty-four hours of immersion, for each treatment, are shown in Table 4. In the analysis of variation performed for swelling, no effects were found on the treatments of two hours (X^2 (2) = 5.66; p> 0.05) and twenty-four hours (X^2 (2) = 3.92; p> 0.05). However, it is possible to notice an effect on absorption (X^2 (2) = 10.58; p <0.05) after a period of two hours, highlighting this factor between the Manilkara huberi (Ducke) Chevalier treatments and the mixed treatment of high-density commercial Amazonian species (p0.05). In the evaluation carried out in the twenty-four hour period, there was no effect on the treatments and the absorption of the panels (X^2 (2) = 5.84; p> 0.05).

The ANSI A208.1 standard [CPA, 2009] does not present values for the physical property of absorption, therefore, the comparison between values found in the literature with compatible panels is adopted. The absorption found by [Negrão *et al*., 2014] working with agglomerated panels with mixtures of tropical wood particles was an average absorption of 6.44% for two hours and 20.07% for twenty-four hours.

[Surdi, Bortoletto Junior & Castro, 2018] when working with agglomerated panels of residues of Amazonian species, obtain values of 10.55% to 37.80% for two hours and 27.64% to 53.69% for twenty-four hours. The values obtained in this work are between 4.08% to 43.54% for two hours and 20.23% to 48.31% for twenty-four hours, being within the observed value range.

For swelling, the values found in this study are between 3.10% to 6.19% for two hours and 9.10% to 11.26% for twenty-four hours. [Negrão *et al.*, 2014] obtains an average of 3.46% for two hours and

9.35% for twenty-four hours, while [Iwakiri *et al.*, 2016] working with agglomerated panels of Amazonian species presents values ranging from 2.67% to 7.67% for two hours and 8.44% to 18.50% for twenty-four hours.

The ANSI A208.1 standard [CPA, 2009] does not specify values for the thickness property of the swelling in the classification corresponding to the panels, thus stipulating the maximum 8% used for panels used on *decks*, where the composite panels of *Dinizia excelsa* Ducke and the mixture of commercial Amazonian species of high density would not present conformity, however, the composite panel of *Manilkara huberi* (Ducke) Chevalier presented a value close to the requirement.

Species	AA (%)		IE (%)	
	Two hours	Twenty-four hours	Two hours	Twenty-four hours
Dinizia excelsa Ducke	32.95 (4.07)	35.50 (3.69)	6.19 (1.98)	11.18 (1.33)
Manilkara huberi (Ducke) Chevalier	4.08 (1.25)	20.23 (8.87)	3.10 (1.15)	9.10 (1.86)
NI	11.94 (10.82)	28.22 (14.44)	5.47 (2.68)	11.26 (4.82)

Table 4. Average values of water absorption and thickness swelling

AA = Water absorption; IE = Thickness swelling; NI = Mixture of high-density commercial Amazonian species; Values in parentheses refer to the standard deviation.

4.5 Mechanical properties

The results of the mechanical properties for each panel are shown in Table 5, where in the analyzes of variance performed, no significant differences were found between treatments. It is observed that the values of rupture modulus (MOR) vary from 14.17MPa (*Manilkara huberi* (Ducke) Chevalier) to 20.73MPa (NI), the deformation of the panels with the individual species was in the range of 4 to 5mm, while the treatment with a mixture of commercial species that remained between 5 to 8 mm.

This value by the ANSI A208.1 standard [CPA, 2009] would classify them as medium to high density panels, with the commercial to industrial range as employability. [Negrão *et al.*, 2014] in his study finds an average value of 1581MPa while [Longo *et al.*, 2015] observes average values of MOE ranging from 552.14MPa to 935.62MPa for particulate panels produced from processing residue from five commercial tropical species.

The mean values of modulus of elasticity (MOE) ranged from 1522.76MPa (*Dinizia excelsa* Ducke) to 4185.74MPa (*Manilkarahuberi* (Ducke) Chevalier), with a variation of deformation in the range of 4 to 5mm, with only the exception of the treatment with mix of commercial species, ranging from 5 to 8mm. Only one panel fit the standardization made by ANSI A208.1 [CPA, 2009], this being the Manilkara huberi (Ducke) Chevalier panel, the others presented lower values based on density and the minimum elasticity module corresponding to 1725MPa.

[Negrão *et al.*, 2014] in his study finds an average value of 1581MPa while [Longo *et al.*, 2015] observes average values of MOE ranging from 552.14MPa to 935.62MPa for particulate panels produced from processing residue from five commercial tropical species. Therefore, the values obtained in this study are higher than the values found for mixtures of tropical species.

Regarding the results presented, the perpendicular tensile strength varied between 0.63MPa (NI) to 0.95MPa (*Diniziaexcelsa* Ducke, 85%), thus meeting the minimum requirement of ANSI A208.1 [CPA, 2009] and classifying them as a utility in an industrial environment. [Negrão *et al.*, 2014] in their study finds an average value of 1.17MPa, while [Iwakiri *et al.*, 2016] that addresses values of 0.75Mpa to 0.90MPa. Despite this, these values are lower than those found by [Surdi, Bortoletto Junior & Castro, 2018] of 1.16MPa and 1.61MPa.

Table 5. Average values of rupture modulus (MOR), elastic modulus (MOE) and tensile strength perpendicular to the surface.

Species	MOR (MPa)	MOE (MPa)	TP (MPa)
Dinizia excelsa Ducke	18.55 (1.74)	1670.39 (254.22)	0.95 (0.17)
Manilkara huberi (Ducke) Chevalier	14.17 (5.26)	4185.74 (4301.76)	0.77 (0.16)
NI	20.73 (9.63)	1522.76 (633.03)	0.63 (0.25)

NI = Mixture of high-density commercial Amazonian species; Values in parentheses refer to the standard deviation.

4.6 Machining test

The performance of the specimens and their evaluation were based on the observation made by the responsible technician of the sawmill of the Laboratory of Engineering and Wood Artifacts (Table 6) at the time of the tests, the samples had on one side performed the drilling test while on the other the nail cracking test.

According to the analyzes, it was possible to conclude that none of the specimens presented difficulties or imperfections for the drilling test (Figure 3), however, for the analyzes carried out by nail cracking, the majority showed cracks when drilled at a distance of 10mm from the edge with the exception of the sample with high density mixtures (Figure 4), this performance may have occurred due to a bad uniformity of the edge of the panels because the same specimens did not show this behavior when pierced further to the center of the sample.

Table 6. Results of sample evaluations after machining tests.

Species	Drilling test		Nail splitting
	Sample	Note	Classification
Dinizia excelsa Ducke	1	1	Accepts nails*
Manilkara huberi (Ducke) Chevalier	1	1	Accepts nails
NI	1	1	Accepts nails

NI = Mixture of high-density commercial Amazonian species; * Particularities found

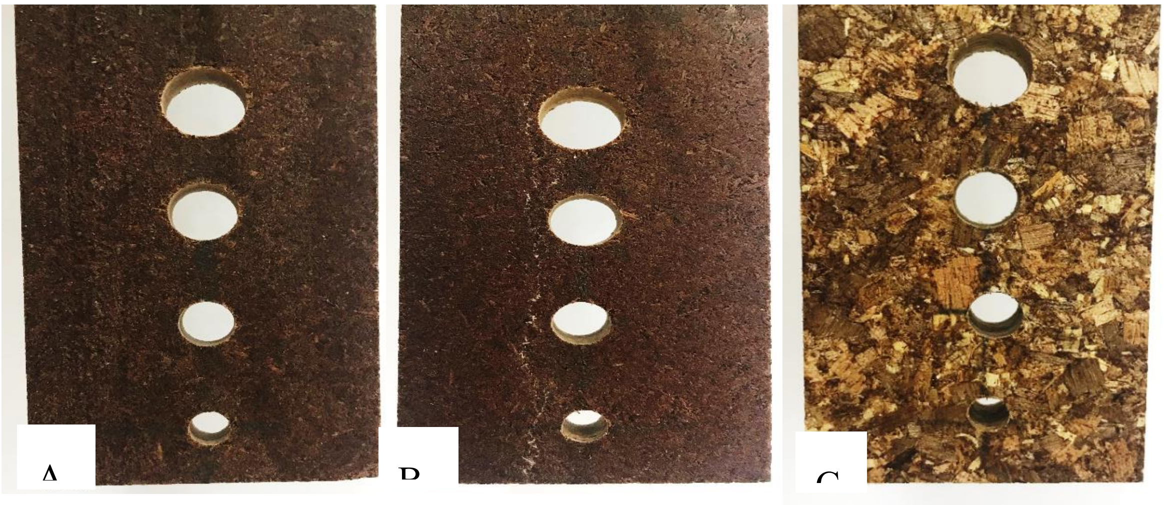

Figure 3. A) *Dinizia excelsa* Ducke; B) *Manilkara huberi* (Ducke) Chevalier; C) Mixture of species with high density

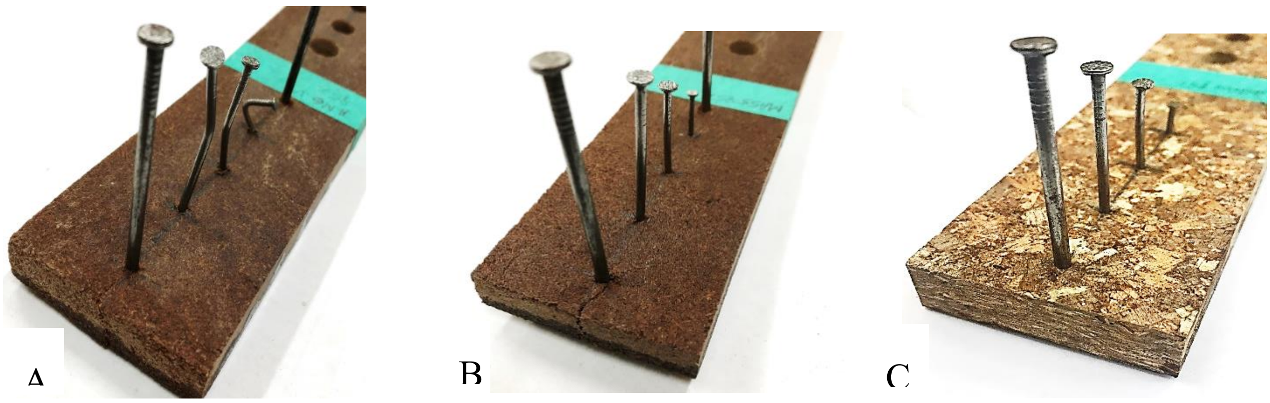

Figure 4. A) *Dinizia excelsa* Ducke; B) *Manilkara huberi* (Ducke) Chevalier; C) Mixture of species with high density

However, they obtained greater resistance as they approached the center of the piece, including the deformation of some nails (Figure 5). According to [Taques & de Arruda, 2016] the basic knowledge of the properties during the machining process provides adequate use, contributing to the better use of the raw material, consequently in less waste.

Figure 5. Nail deformities in the test specimen treatment of Dinizia *excelsa* Ducke (85%)

4.7 Analysis of production and use of panels

The panels produced have essential characteristics to be used in making different products. Considering that for every 9 tons of waste generated during the mechanical processing of the logs until the final product sold by the company, the amount of raw material used in each panel would produce 4500 panels, contributing to the environment and the insertion of a new line in the productive chain of the wood industry. Analyzing all the qualities of the panels, as well as the amount of raw material used, the possibility of large-scale production is envisaged in the future if any company is interested in selling.

5. CONCLUSION

The wood agglomerated panels of Amazonian species presented results similar to those found in the literature for physical and mechanical properties, with their highlight in the value of modulus of elasticity superior to the other studies.

The *Manilkarahuberi* (Ducke) Chevalier panel showed the highest viability of employability in the industry, however, the use of the other panels is also valid given its diversity of suitability of uses.

The residues of Amazonian species in the production of agglomerated panels enable a new product on the market, which will provide competitiveness to agglomerated panels generated by planted species, fostering a new market for the residues of the timber industry in the Amazon.

6. REFERENCES

[1] ABNT, NBR. 14810-1 “Mediumdensityparticlepanels–Part 1: Terminology,” BrazilianTechnical Standards Association, Rio de janeiro, Brazil, 2013, pp.1-4

[2] ABNT, NBR. 14810-1“. Mediumdensityparticlepanels–Part 2: Mediumdensityparticleboards Part 2: Requirement sand test methods,” BrazilianTechnical Standards Association, Rio de janeiro, Brazil, 2018, pp.1-3

[3] American Society for Testing and Materials (ASTM). ASTM D1102 – 84: Standard Test Method for Ash in Wood ASTM, Estados Unidos da América, 2007, pp3.

[4] American Society for Testing and Materials (ASTM). ASTM D1666- 11: Standard Test Methods for Conducting Machining Tests of Wood and Wood-Base Panel Materials. Philaldelphia, 2011, p. 226- 245.

[5] J.N. Aquino, Caracterização do carvão de resíduos de processamento primário da madeira e sua potencialidade energética, Universidade Federal Rural da Amazônia, Belém/PA, 2003, pp.81.

[6] H. J. B., Araújo, Aproveitamento de resíduos das indústrias serraria do Acre para fins energéticos, Embrapa Acre-Documentos 82, Rio Branco/AC, 2003, pp 38.

[7] R. D. Araújo, Avaliação do potencial de espécies manejadas na Amazônia para produção de painéis “EGP” (Edge GluedPanels) não estrutural, Tese (Doutorado em Ciências Florestais) – Instituto Nacional de Pesquisas da Amazônia – INPA, 2019, pp. 76.

[8] D. C. Batista, J. G. M. Da Silva, R. B. Corteletti, Desempenho de uma serraria com base na eficiência e na amostragem do trabalho, Floresta Ambiente, 2013, pp.276-277

[9] C.P. Biasi, M.P. Rocha, Rendimento em Madeira Serrada e Quantificação de Resíduos para Três Espécies Tropicais, Floresta, v. 37, n.1, 2007, pp.104-107.

[10] M.A. Brand, G.I.B. de Muñiz, D. A. da Silva & U. Klock, Caracterização do rendimento e quantificação dos resíduos gerados em serraria através do balanço de materiais, Revista Floresta, 2002, pp. 247-259.

[11] F. Collet, Estudos comparativos em escala laboratorial de diversas madeiras utilizadas na fabricação de carvão vegetal, Boletim da Associação Brasileira de metais, São Paulo, 1956, pp. 5-14.

[12] Composite Panel Association – CPA, ANSI A 208.1: particleboard standard, Leesburg, 2009.

[13] D. Fengel, G. Wegener, Wood Chemistr - ultrastructurereactions, Berlin, 1989.

[14] P. J. P. Fontes, Auto-suficiência energética em serraria de Pinus e aproveitamento dos resíduos. Universidade Federal do Paraná, Curitiba, 1994, pp. 32-33.

[15] M.M. Fortes, Efeito da umidade e da acústica na torrefação de madeiras de *Eucalyptusgrandis*, *Pinus elliottii*e *Dinizia excelsa*, Universidade de Brasília, DF, 2018, p.22

[16] ITTO, Biennial review and assessment the world situation 2013-2014. International Tropical Timber Organization, Yokohama, Japan, 2014, pp. 217.

[17] S. Iwakiri, Rendimento e condições de desdobro de 20 espécies de madeiras da Amazônia, Acta Amazonica, 1990, Manaus-AM, pp. 271-281.

[18] S. Iwakiri, R. Trianoski, C. C. Nascimento, R. da Rosa Azambuja, S. R, Campelo, R. Ribeiro, Produção De Painéis Aglomerados Com Misturas De Seis Espécies De Madeiras Da Amazônia e Pinus taeda. Floresta, 2016, pp. 259-267.

[19] M. D. F. Lima, Utilização de resíduos da espécie Dipteryxpolyphylla (Cumarurana), Dipteryxodorata (Cumaru) e Brosimumparinarioides (Amapá) na produção de painéis de madeira aglomerada com resina poliuretana à base de óleo da mamona, Universidade Federal do Amazonas, Manaus, 2012, pp.21-45.

[20] B. L. Longo, A. B. da Cunha, P. D. Rios, R. F. Terezo, C. C. F. de Almeida, Caracterização tecnológica de painéis particulados produzidos com resíduos de cinco espécies tropicais. ScientiaFlorestalis, 2015, pp. 907-917

[21] L. E. D. L. Melo, C. D. J. Silva, K. V. Lopes, P. G. M. D. Brito, I. S. Santos, Resíduos de Serraria no Estado do Pará: Caracterização, Quantificação e Utilização Adequada. Floresta e Ambiente, 2012, pp. 113-116.

[22] A. de L. Mesquita, Estudos de processos de extração e caracterização das fibras do fruto de açaí (Euterpe Oleraceae Mart.) da Amazônia para produção de ecopainel de partículas homogêneas de média densidade, Universidade Federal do Pará, Belém, 2013, pp.90.

[23] W. H. Negrão, S. A. M. D. Silva, A. L. Christoforo, F. A. R. Lahr, Painéis aglomerados fabricados com mistura de partículas de madeiras tropicais, Ambiente construído, 2014, pp. 103-112.

[24] J. R. C. Nobre, A. Napoli, M. L. Bianchi, M. G. Silva, S. Numazawa, Utilização de resíduos de Manilkarahuberi do Estado do Pará na Produção de Carvão Ativado. 2014, p.7

[25] S. Numazawa, Aproveitamento de resíduos de exploração florestal em Curua-Una/Pa, para produção de carvão vegetal. Universidade Federal do Paraná, Curitiba, 1986. pp.126.

[26] Precious Woods Amazon, Resumo Público: Manejo florestal sustentável, Itacoatiara/AM, 2018, pp.7.

[27] W. F. Quirino, Briquetagem de resíduos ligno-celulósicos, Brasília: LPF/IBAMA, 2004, pp.10.

[28] B. Rivela, A. Hospido, T. Moreira, G. Feijoo, Life cycle inventory of particleboard: A case study in thewood sector. InternationalJournalof Life CycleAssessment, 2006, pp. 106-113.

[29] M. A. E. Santana, E. Y. A. Okino, Chemicalcomposition of 36 Brazilian Amazon forest wood species. Holzforschung, 2007, pp. 469–477.

[30] M. A. E. Santana, L. C. Rodrigues, V. T. R. Coradin, E. Y. A. Okino, M. R. de Souza, Silica content of 36 Brazilian tropical woodspecies, Holzforschung, 2013, pp. 19–24.

[31] A. C. Hummel, M. D. S. Alves, D. Pereira, A. Veríssimo, D. Santos, A atividade madeireira na Amazônia brasileira: produção, receita e mercados, Belém: Imazon, 2010, pp.31.

[32] A. M. V. D. Silva, Avaliação do comportamento térmico de compósitos poliméricos produzidos com resíduos de açaí em edificações na Amazônia, Universidade Federal do Amazonas, Manaus, 2019, pp.37-47.

[33] S. A. M. da Silva, A. L. Christoforo, T. H. Panzera, F. A. R. Lahr, Painéis MDF produzidos com resina poliuretana à base de óleo de mamona. Vértices, Rio de Janeiro, 2013, pp.7-20.

[34] M. C. Stragliotto, Qualidade da tora de espécies tropicais e rendimento em madeira serrada para exportação, Universidade Federal de Mato Grosso, Cuiabá, 2019, pp.52.

[35] P. G. Surdi, G. Bortoletto Junior, V. R. D. Castro, Evaluating the effects of removing fines from particleboards manufactured from Amazonian wood residue. Floresta e Ambiente, 2018, pp.5-6

[36] A. C. Taques, T. P. M. de Arruda, Usinagem da madeira de angelim pedra (Hymenolobium petraeum), Revista De Ciências Agroambientais, 2016, pp.97

[37] A. I. Vogel. Análise Inorgânica Quantitativa, 4.ed, Rio de Janeiro: Guanabara, 1981.