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Translated from the original in spanish

Original Article

Evaluation of the quality of wood used in social housing in Costa Rica

Evaluación de la calidad de madera en viviendas de interés social en Costa Rica

Avaliação da qualidade da madeira utilizada em moradias de interesse social na Costa Rica

Rudy Bello[1*] https://orcid.org/0000-0002-4354-5137

Lupita Vargas[2] https://orcid.org/0000-0001-6254-9507

Juan Carlos Valverde[3] https://orcid.org/0000-0002-3181-1346

Diego Camacho[4] https://orcid.org/0000-0001-7760-9664

Cynthia Salas[4] https://orcid.org/0000-0003-3098-1287

[1]Consultora Independiente. Costa Rica.
[2]Escuela de Ingeniería Forestal, Tecnológico de Costa Rica. Costa Rica.
[3]Laboratorio de ecofisiología forestal y aplicaciones ecosistémicas (ECOPLANT), Tecnológico de Costa Rica. Cartago. Costa Rica.
[4]Escuela de Ingeniería Forestal, Tecnológico de Costa Rica. Costa Rica.

*Correspondence author: rudybello@gmail.com

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ABSTRACT

In the construction process with wood, a rigorous evaluation of the quality of the implemented wood must be carried out, in order to have buildings with long life periods and optimal usability. However, there are limited methodologies available at the national level to evaluate the quality of wood in construction. Therefore, the objective was to evaluate the quality of the wood used in social housing. For this purpose, the INTE C99-2014 standard was implemented and the moisture content, dimensionality, visual quality and preservation of the wood were evaluated. The work was done with sawn wood products destined for the construction of houses of social interest. The supplier companies are located in Alajuela (Ecohouses) and Limón (ADITIBRI and SOMABACU) that implemented *P. caribaea var. hondurensis, C. alliodora* and *Pinus sp.*; in each site 10 sawn wood products were selected with repetitions of three to ten pieces. The pieces that showed the best results in terms of valuation were those of Pinus sp., being an imported material; it had a great uniformity and quality. In the case of the wood pieces of *C. alliodora* and *Pinus sp*. they presented fulfillments inferior to 60 % due to the heterogeneity of the materials, in many cases with contents of humidity superior to 30 %, with little control in the dimensionality and high presence of knots. Finally, in terms of preservation, specifically retention, none of the species achieved the minimum preservative concentration of 2.4 kg m-3.

Keywords: housing; construction; wood quality; preservation; Costa Rica.

RESUMEN

En el proceso constructivo con madera se debe realizar una rigurosa evaluación de la calidad de la madera implementada, con el fin de disponer de edificaciones con períodos de vida largos y usabilidad óptima. Sin embargo, a nivel nacional se cuentan de forma limitada metodologías que evalúen la calidad de la madera en construcciones. Por tanto, el objetivo fue evaluar la calidad de la madera utilizada en viviendas de interés social. Para ello, se implementó la norma INTE C99-2014 y se valoró el contenido de humedad, dimensionalidad, calidad visual y preservación de la madera; se trabajó con productos de madera aserrada destinada a la construcción de casas de interés social. Las empresas proveedoras están ubicadas en Alajuela (Ecohouses) y Limón (ADITIBRI y SOMABACU) que implementaron *P. caribaea var. hondurensis*, *C. alliodora* y *Pinus* sp.; en cada sitio se seleccionaron 10 productos de madera aserrada con repeticiones de tres a diez piezas. Las piezas que mostraron mejores resultados en cuanto a la valoración fueron las de *Pinus* sp., al ser un material importado; contó con una gran uniformidad y calidad. En el caso de las piezas de madera de *C. alliodora* y *Pinus* sp. presentaron cumplimientos inferiores al 60 % debido a la heterogeneidad de los materiales, en muchos casos con contenidos de humedad superiores al 30 %, con poco control en la dimensionalidad y alta presencia de nudos. Finalmente, en cuanto a la preservación, específicamente en la retención, ninguna de las especies logró la concentración de preservante mínima de 2,4 kg m^{-3}.

Palabras clave: vivienda construcción; calidad de madera; preservación.

SÍNTESE

No processo de construção com madeira, deve ser feita uma avaliação rigorosa da qualidade da madeira implementada, de modo a ter edifícios com longos períodos de vida útil e com uma óptima usabilidade. No entanto, existem poucas metodologias disponíveis a nível nacional para avaliar a qualidade da madeira na construção. Portanto, o objetivo era avaliar a qualidade da madeira utilizada na habitação social. Para tal, foi implementada a norma INTE C99-2014 e foram avaliados o teor de humidade, a dimensionalidade, a qualidade visual e a preservação da madeira; o trabalho foi realizado com produtos de madeira serrada para a construção de casas de interesse social. As empresas fornecedoras estão localizadas em Alajuela (Ecohouses) e Limón (ADITIBRI e SOMABACU) que implementaram P. caribaea var. hondurensis, C. *alliodora e Pinus sp*.; em cada local foram seleccionados 10 produtos de madeira serrada com repetições de três a dez peças. As peças que apresentaram melhores resultados em termos de valorização foram as de *Pinus sp*., sendo um material importado; tinha uma grande uniformidade e qualidade. No caso das peças de madeira de C. alliodora e Pinus sp. apresentaram preenchimentos inferiores a 60

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% devido à heterogeneidade dos materiais, em muitos casos com teor de humidade superior a 30 %, com pouco controlo na dimensionalidade e elevada presença de nós. Finalmente, no que diz respeito à conservação, especificamente à retenção, nenhuma das espécies atingiu a concentração mínima de conservação de 2,4 kg m-3.

Palavras-chave: Construção de moradias; qualidade da madeira; preservação.

INTRODUCTION

The development of housing buildings has been fundamental in the human evolutionary process, as it is considered a fundamental element for personal and social development to have a physical area in which to sleep, eat and develop multiple physical activities that generate belonging (Hermawana *et al.,* 2015). In the last century, housing has been considered a status symbol, an element of consecration of the individual in society (Cabléa *et al.,* 2019); thus generating that in the last three decades there is a trend of 6.2 % increase in housing demand for Latin America and 3.5 % annually worldwide (Lenoch and Hlaváčkov, 2015).

In view of this scenario, construction systems have had to be adapted to the development of rapidly manufactured buildings, which are in line with current technologies and the perception of the demanding market (Malesza and Miedziałowski, 2017), for which the selection and use of materials is fundamental to generate greater marketing success (Lenoch and Hlaváčkov, 2015).

Iyamandoglu and Fortuna, (2015) mention that current real estate markets focus on four elements when acquiring housing spaces: spatial location of the building (considering the location, available services, resources and proximity of strategic points such as supermarkets, educational centers, among others.); functional characteristics of the building (distribution of the physical plant); aesthetic characteristics of the building (site aesthetics and visually pleasing composition) and materials implemented in the building (type of materials, quality of finish and state of the same at the time of evaluation). As the conditions of the property are better, the market price will be higher and therefore its value will increase and the possibilities of sale will be greater.

It is in the aspect of aesthetic and material characteristics implemented that the greatest amount of financial resources and time tends to be invested in the construction process (Risse et al., 2019). One of the most historically used materials is wood (Tonooka *et a.l,* 2014), which is characterized by being a material available anywhere in the world, with great workability, whose physical and mechanical properties allow it to be implemented in complex infrastructures for the absorption of sound waves that generate a quiet space, for its low thermal conductivity and the possibility of increasing insulation in other construction systems, which allows it to be the number one material in countries with extreme temperatures, also presents a great aesthetic appeal (Loughlin and Dodder, 2013). Risse *et al.,* (2019) mention that it is a sustainable material compared to concrete, steel, plastics, aluminum, among others, which require more energy consumption for its production, generate more pollution, residues and high environmental impact.

However, one of the biggest limitations that wood has had in the tropical region in the constructive use has been the little standardization, classification and adaptation of the material to the different potential uses, generating that the perception of wood is limited to aesthetic or temporary uses in buildings (Kern *et al.,* 2018). Therefore, in the last decades the creation of use regulations has started, highlighting the UNE standards, based on European regulations, which consider: general terms common to sawn wood and round wood (UNE-EN 844-1, 1996a); general terms related to sawn wood (UNE-EN 844-3, 1996b) and structural wood, dimensions and tolerances (UNE-EN 336, 2014).

There is also the visual grading standard for structural lumber; the latter is limited to coniferous wood only (UNE 56544:2007). In Chile, the standard of defects, to be considered in the classification, terminology and measurement methods (NCh 992:1972); procedure and evaluation criteria for classification (NCh 993:1972); preservation, classification, composition and requirements of wood preservatives (NCh 790:2012) and general terminology (NCh 173:2008) are highlighted. In the United States, a group of eight standards of the American Society for Testing and Materials (ASTM) stand out, which standardize aspects of drying, persistence, visual quality and structural use of wood for construction purposes.

In the specific case of Costa Rica, the Technical Standards Institute of Costa Rica (INTECO), in the last decade has initiated the creation of standards in the use of wood as a construction material, currently having two: wood terminology standard (INTE C98:2015) and sawn timber for general use (Requirements, INTE C99:2014). For the elaboration of these standards, ASTMD9-12 and NTC 1305 standards were used as reference respectively; however, at a national level there is a limited methodological standard that evaluates the aesthetics and the use of wood in social welfare constructions developed by the Costa Rican state. Therefore, the objective of this paper is to propose a methodology for evaluating the quality of wood in social welfare housing in Costa Rica.

MATERIALS AND METHODS

The research was developed with a mixed approach, in which measurable quantitative variables in wood and qualitative variables such as visual assessment of wood quality and perception of variables of interest were linked. Due to the fact that currently there is no national standard for the evaluation of wood quality in social welfare buildings, because the existing ones evaluate wood in constructions at a general level, it was decided to analyze existing considerations of the Spanish standard (UNE-EN 336:2014 and ASTM D9-12) together with the national standard INTE C99:2014 for sawn wood for general use and the standard INTE C98:2015 for wood terminology in Costa Rica.

Initial considerations for the evaluation of wood quality in social housing

The development of the methodology for evaluating the quality of wood in social welfare constructions considered the following elements in its process:

1. That it is in accordance with the existing and current regulations for Costa Rica, regarding construction systems and the use of wood.
2. Practices to be developed in the field, which simplifies the evaluation process and allows to give the necessary information for the decision making process in the buildings.

3. That it be of rapid learning, so that with it the process of training is the minimum and the major quantity of collaborators have a criterion sustained.
4. That it has a methodological support that can be verified by means of statistical tests; it is relevant to have a representative evaluation system (complementary to the existing one in the INTE-ISO 2859:2005 standard), in which the sampling and analysis system is statistically strong and with it it is possible to make improvement or correction actions to a whole project without the need to evaluate each piece.

To fulfill the four assumptions mentioned above, the criteria of professionals in the area were considered, together with national and international standards in force, from which four variables of analysis were selected: moisture content, dimensionality of the material, visual quality of the wood, penetration and retention of preservatives**.**

Analyzed quality variables

The following variables were analyzed at each study site, based on the methodology developed by Camacho-Padilla, (2014):

1. Moisture content of wood: defined as the amount of water present inside the wood; a portable borehole moisture meter (two 20 mm long measuring pins), PCE model Dam master, was implemented for evaluation, with an operating range of 5 to 100 % moisture content. The measurements were performed at the midpoint of each sample evaluated.
2. Material Dimensioning: the thickness, width and length of each piece of wood was measured according to the procedure established in the INTE C99:2014 standard for sawn wood for general use. Requirements. In the evaluation, a carpentry tape measure was implemented with a length of 5 m.
3. Visual Quality of Wood: The categories available in the INTE C99:2014 standard for general purpose lumber were implemented and defects were analyzed: missing edge, holes, bark included, planing failure, raised grain, face drying cracks, saw mark, dead knot, live knot and drilling defect. The analysis was carried out for all visible faces of the installed pieces and was developed in a visual way.
4. Penetration of the preservative in the wood: the penetration of the preservative in the wood was analyzed, for which a colorimetric test was applied in different pieces of wood with the Chromo-azurol reagent, which generated a change of color of the sample that allowed to determine the percentage of the piece in which the preservative remained. With the retention of the preservative in the wood it was applied for the species *Pinus radiata, C. Alliodora* and *Pinus sp*. for which samples were collected in each site and the laboratory technique of atomic absorption microscopy was applied, to determine the value of retention of the samples and compare it with the minimum value of permanence of the product, which for the species *Pinus Radiata* treated with Micronized Copper Azole corresponds to 3.3 kg/m3, for *C. Alliodora* preserved with xylochrome the minimum requirement is 1.1 kg/m3 and finally the minimum requirement for *Pinus sp.* is 2.4 kg/m3, as established in the wood preservation standard INTE C333:2018, with a triplicate sampling for each piece of each species analyzed.

Study sites and materials analysed

The evaluation was carried out on sawn wood products available in the companies (Figure 1): Ecohouses (Alajuela), SOMABACU (Limón) in charge of supplying and building social interest housing and in the Association for the Integral Development of the Indigenous Territory of Bribri (ADITIBRI) (Limón) which is entering the supply of wood for the construction of social interest housing. In each house the sampling pieces were selected (a sampling intensity of 3 % was implemented) according to the dimensions of interest, but the extraction point of each piece was random. The species analyzed were the dominant ones in the buildings, *Pinus radiata* in Ecohouses, *Pinus sp*. in SOMACABU and *Cordia alliodora* in ADITIBRI.

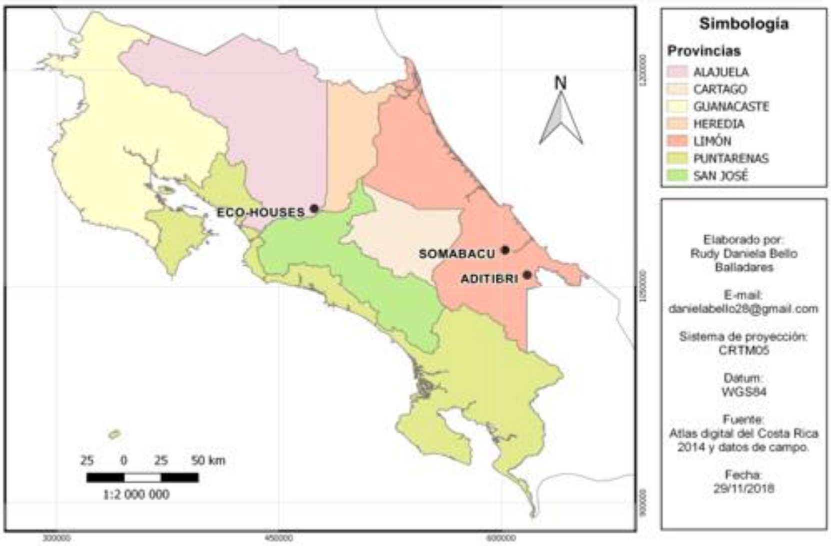

Figure 1. - Location of the three sites evaluated with the methodology for evaluating the quality of wood for social housing in Costa Rica, 2018

In each building, 10 wood products with the highest availability were selected (Table 1). Evaluating the 3 % of installed wood pieces of each house (estimated value to have a minimum statistical power of 85 %). The dimensions of thickness, width and length of each piece were measured with a tape measure. Also, the moisture content and visual quality was analyzed according to the standard INTE C99: 2014.

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Table 1.- List of construction materials evaluated with the quality standard of wood used in social housing in Costa Rica

Place	Specification per piece (mm)
Ecohouses	Balusters 41 x 41 x 800
	String 41 x 140 x 3200
	Column A 127 x 115 x3050
	Column C 127 x 115 x 2440
	Column D 127 x 115 x 3050
	Traces 41 x 140 x 960
	Handrail 41 x 90 x 3200
	Pole 65 x 65 x 1060
	Board 41 x 140 x 700
	Board 41 x 140 x 820
ADITIBRI	nailer 25 x 100 x 4250
	crown 50 x 75 x 3360
	crown 50 x 75 x 3780
	Corners 75 x 75 x 2500
	Step 50 x 250 x 1100
	petalillo 13 x 50 x 2500
	Floor 25 x 150 x 3100
	Floor 25 x 150 x 3250
	Short beam 125 x 125 x 3000
	Short beam 125 x 125 x 3500
SOMABACU	Eaves, bathroom and door 25 x 75 x 2500
	Eaves and handrails 25 x 75 x 840
	Craftsmanship and easel 38 x 125 x 2500
	chain 50 x 100 x 2500
	Lining 25 x 125 x 3650
	petalillo 13 x 50 x 1300
	Piles 100 x 100 x 2500
	Piles 90 x 90 x 2440
	Sills 75 x 75 x 2500
	Floor board 25 X 125 X 2500

With respect to measuring preservative penetration into the wood, three samples were taken from different pieces at each study site, the dimension of evaluation interest was chosen, but the specific point of extraction was random. A colorimetric test with the reagent Chromium-Azurol was performed; on the other hand, for the evaluation of the preservative retention a sample of 13 pieces was collected and sent to the chemical laboratory LAMBDA to know the amount of preservative present.

Statistical analysis

For each variable analyzed, a descriptive analysis was performed, from which the mean, median, standard deviation and coefficient of variation were generated. Later, the analysis of normality was made and an Analysis of One-Way Variance (ANDEVA) was performed, to identify if there were differences between the values of each variable present in each species; in case of finding differences a Tukey test was applied. The analyses were performed with a significance of 0.05 and in the statistical program InfoStat version 2018.

RESULTS

Variation in moisture content

The Figure 2 shows the variation in moisture content of all parts sampled from each site. In the case of Ecohouse (Figure 2a), an average moisture content of 11.4 % was identified for *P. radiata*; 85 % of the pieces were in the range of 10.4 to 12.6 %. Furthermore, all samples showed a categorisation according to the INTE C99-2014 standard, as they met the criterion for dry wood (less than 19 %) set out in the standard. In the case of ADITIBRI (Figure 2b), for the species *C. alliodora* the range for moisture content was 7.0 to 79.8 %; 86 % of the samples analysed were classified as green (average with a CH of 55 %), only 14 % as dry. Finally, in SOMABACU, for the species *Pinus sp.* (Southern Yellow Pine) the average moisture content varied between 14.95 and 20.32 %; on the other hand, *C. alliodra* wood varied between 16.9 and 83.2 %, in which 42.5 % of the material evaluated failed to comply with the standard, being considered as dry wood only 57.5 %.

The little variation in moisture content of *P. radiata* and *Pinus sp* is due to the fact that it is a material imported from Chile, so in the export process it is kiln dried to a final moisture content of 10 %. Miranda *et al.,* (2010) mention that in the export of wood, the aim is to have the pieces dry, in order to reduce costs and standardize the quality and dimensionality of the material; therefore, it is expected that the material would comply with the standard. In the case of *C. alliodora* wood, both dry and wet conditions are marketed nationally, since the market does not have a defined moisture content of acceptance (Moya *et al.,* 2010), it is explained that in tropical regions, the demand for wood does not take into account the humidity ranges of wood in residential construction, because it is assumed that in the building process it will dry out, besides, buying green wood implies an economic saving; however, defects, deformations and quality reductions that the building will have during the drying process of the installed pieces are not taken into account (Salazar, 2008).

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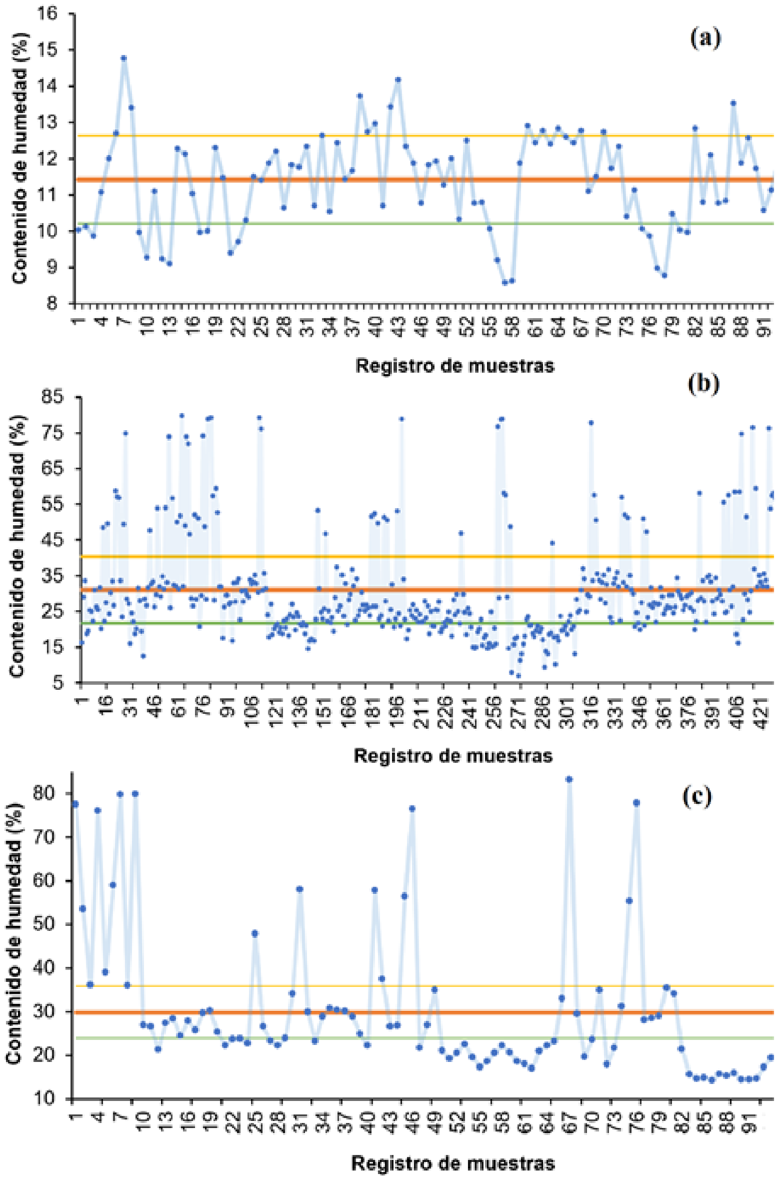

Figure 2. - Variation of moisture content obtained in wood products from *P. radiata* used in Ecohouse (a), *C. alliodora* in ADITIBRI (b) and *Pinus sp* in SOMABACU

Dimensional characterization of materials

With regard to the variability of the parts (Table 2), in general the following aspects were determined

1. Of the three species analysed, the materials used with *P. radiata* showed the greatest dimensional stability and compliance with the ranges of variation according to the INTE C99-2014 standard, which should not exceed 5 %.
2. The only pieces that showed non-conformities in *P. radiata* were in the product balusters (in the three variables), handrails (in the width) and poles (in width and length).
3. *C. alliodora* was the species with the least uniformity of the material, finding problems in thickness (in nails, steps, petatillo and floor), width (in petatillo and floor) and length (in all materials).

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4. with the species *Pinus sp.,* the non-conformity in thickness was given in the materials: petatillo and piles; in width it was given in piles and the length was given in all the evaluated materials.

The little non-conformity in *P. radiata* is due to the homogeneity of the imported material (which was determined for the study to be planed). According to Mora, (2016), the success of the commercialisation of wood products in high volumes is the dimensional homogeneity of the material; depending on the lots that have little variability, it will generate in the user the perception of ease of obtaining materials in time that will allow him to standardise the productive processes, in this case in construction systems. With the pieces of *C. alliodora* and *Pinus sp.,* the problem found in thickness and width of the pieces is directly due to the variation found in the moisture content (Figure 2). Lizán-Narro, (2018) mentions that green wood can have reductions of 10 to 25 % in dimensionality due to moisture loss. In the case found, the variability can be increased as the material loses moisture.

Table 2. - Variation of thickness, width and length obtained in *P. radiata* wood products used by Ecohouse, *C. aliliodora* in ADITIBRI and *Pinus sp.* in SOMABACU implemented in social welfare houses in Costa Rica

place	Specification per piece	Thickness (mm)		Width (mm)		Length (mm)	
		Average	E (±)	Average	E (±)	Average	E (±)
Ecohouses	Balusters 41 x 41 x 800	43,33*	0,15	42,48*	0,15	803,86*	0,17
	String 41 x 140 x 3200	43,48*	0,49	140,74	0,22	3204,89	0,89
	Column A 127 x 115 x3050	126,37	0,51	117,23	0,57	3203,40	0,60
	Column C 127 x 115 x 2440	125,73	0,70	117,6	0,48	2442,90	0,44
	Column D 127 x 115 x 3050	126,39	0,64	116,22	0,88	3204,33	0,63
	Traces 41 x 140 x 960	43,58*	0,74	140,21	0,68	963,00	0,55
	Handrail 41 x 90 x 3200	43,15	0,89	92,69*	1,32	3205,54	0,80
	Pole 65 x 65 x 1060	66,80	0,27	68,50*	0,25	1068,00*	0,00
	Board 41 x 140 x 700	41,67	0,05	140,03	0,53	702,10	0,24
	Board 41 x 140 x 820	41,63	0,19	139,87	0,34	822,80	0,14
ADITIBRI	nailer 25 x 100 x 4250	27,33*	0,19	101,8	0,48	4224,05*	3,47
	crown 50 x 75 x 3360	50,67	0,36	76,71	0,81	3554,13*	46,68
	crown 50 x 75 x 3780	50,10	0,48	79,12	0,35	3886,59*	24,91
	Corners 75 x 75 x 2500	77,33	0,44	77,50	0,43	2568,50*	5,38
	Step 50 x 250 x 1100	54,57*	0,52	254,97	1,15	1228,70*	16,86
	Petatillo 13 x 50 x 2500	14,76*	0,30	52,73*	0,25	2624,16*	19,42
	floor 25 x 150 x 3100	27,28*	0,13	149,96*	0,90	3136,73*	5,98
	Floor 25 x 150 x 3250	26,56*	0,79	154,50*	0,76	3610,17*	142,07
	Short beam 125 x 125 x 3000	125,60	0,77	125,60	1,43	3154,20*	13,57
	Short beam 125 x 125 x 3500	127,41	1,13	128,19	0,80	3562,11*	57,33
ASOMABACU	Eaves, bathroom and door 25 x 75 x 2500	23,77	0,27	73,23	0,53	2556,80*	28,25
	Eaves and handrails 25 x 75 x 840	24,13	0,78	74,20	0,67	883,70*	6,31
	Craftsmanship and easel 38 x 125 x 2500	36,83	0,32	124,03	0,46	2533,50*	6,72
	chain 50 x 100 x 2500	49,97	0,80	100,3	0,79	2533,60*	7,58
	Lining 25 x 125 x 3650	22,83	0,72	135,83	0,43	3677,80*	2,10
	Petatillo 13 x 50 x 1300	12,64*	0,33	47,40	0,43	1343,47*	13,33
	Piles 100 x 100 x 2500	107,90*	0,84	107,40*	1,47	2582,00*	35,34
	Piles 90 x 90 x 2440	92,53*	0,50	92,97*	0,62	2466,80*	7,25
	Sills 75 x 75 x 2500	74,10	0,49	74,30	0,58	2568,50*	21,63
	Floor board 25 X 125 X 2500	26,33	0,53	124,53	1,03	2536,00*	13,83

Note: *This is denoted for parts that demonstrate a variation in the dimensionality of the parts that do not conform to the INTE C99-2014 standard

Visual classification of materials

In the visual quality of the materials (Figure 3) it was found, for *P. radiata* pieces, that 65 % of the material evaluated did not present any defect; however, 35 % of the remaining material showed the presence of one of the following six types of defects identified: bark included, face drying cracks, pith included, dead knot and live knot (Figure 3a). The live knot was the dominant defect present in 50 % of the

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material; this is due, according to Camacho-Padilla, (2014), to the fact that the wood imported from Chile comes from intensive timber plantations in which the growth stimulus affects the trees to generate a large amount of knots, which are denoted in the outer pieces of the shaft, characterized by a lower quality and generally consumed by the Central American markets. In the case of the remaining defects, these are due to the quality of the material. Trujillo *et al.,* (2011) highlight that 60 % of the wood imported from Chile presents quality 3 or 4, considered as medium category, so it is common the presence of a high density of knots and defects.

In the case of *C. alliodora* pieces (Figure 3b), 55 % of the material was found to comply with visual standards, the remaining 45 % had one of the following 10 defects: sharp knot (21 %), cracks (18 %), dead knot (16 %), bark included (13 %), saw mark (11 %), missing edge (9 %), raised grain (6 %), holes (4 %) and hole (2 %). The defects identified were characterized as being natural to the species (knots, holes, grain), but mostly due to poor processing of the material (saw marks, missing edge, hole and bark included). Mora, (2016) mentions that, generally, tropical species show aesthetic defects as a result of poor handling and processing of the logs, the use of equipment or poor cutting patterns, leading to lower quality material and requiring the use of secondary processes to increase the quality of the pieces.

Finally, with the pieces of *Pinus radiata* (Figure 3c), 71 % of the material did not show any kind of defect, the remaining 29 % showed one of the following defects: live knots (40 %), missing brush (20 %), drill (15 %) cracks due to drying (10 %), missing edge (10 %), dead knot (4 %) and saw mark (1 %). The defects identified are due to the same reasons mentioned for *C. alliodora*, as well as the combination of the characteristics of the species together with poor management of the material.

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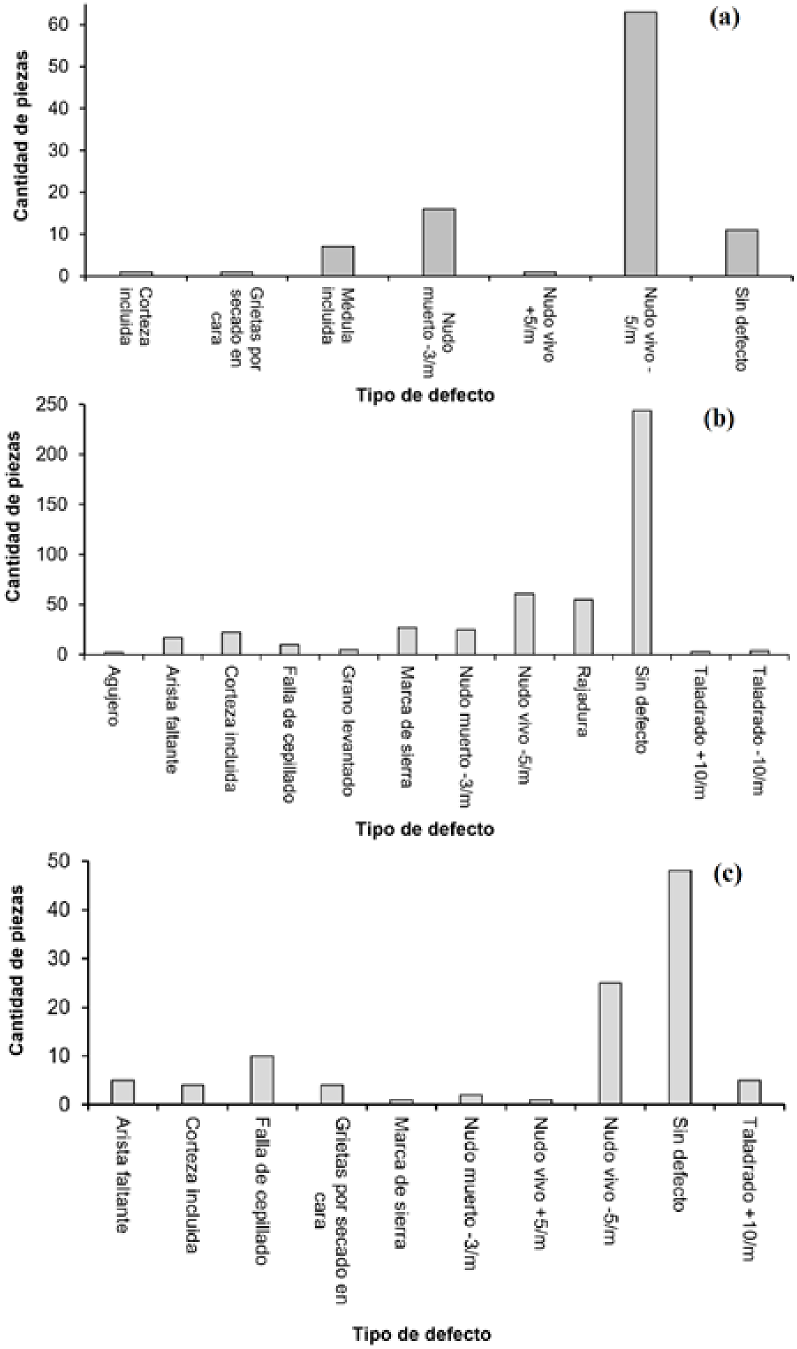

Figure - 3. Visual defects for *P. radiata* wood used by Ecohouse in (a), *C. alliodora* in ADITIBRI (b) and *Pinus sp*. in SOMABACU present in pieces of sawn wood to be used in welfare houses

Quality of preservation

Regarding the preservation of the materials (Table 3), compliance with 100 % penetration of the preservative in sapwood was obtained for the three implemented species (except for the SOMABACU eaves that showed 0% penetration due to the fact that the pieces were manufactured in heartwood). Penetration values were consistent with those presented by Moya *et al.,* (2010), in which total penetration

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was found for the species studied, since the permeability of the sapwood in green condition is ideal for the entry of preservatives. On the other hand, Harb *et al., (*2018) identified for species of the genus Pinus 95 % penetrations, due to the fact that the conductive system of the tracheids is ideal for the injection of preservants by autoclaving.

Table 3. - Percentage penetration of preservative applied to lumber pieces in *P. radiata* and *C. alliodora species*

Place	Material	penetration (%)
Ecohouses	Column	100
ADITIBRI	Chain Ladder Floor	100
		100
		100
SOMABACU	Piles	100
	Eaves	0

With regard to the retention of the preservative, evaluated in *P. radiata, C. alliodora* and *Pinus sp,* a total non-compliance with the retention of the preservative was determined which, according to the specifications, should be 3.3; 1.1 and 2.4 kg/m3 for the species, respectively. The values obtained are extremely low for *C. alliodora*; this is due to the fact that the preservation system used was of the immersion type, which, although it allowed a total presence of the preservative, its concentration is extremely low. Robey *et al.,* (2018) mention that a low preservative retention with total penetrations is due to the fact that the concentration of the solution was low, the preservation and drying system was not optimal and generated loss of preservative by leaching or the quality of the preservative was not the best (Table 4).

Tabla 4. - Porcentaje de retención del preservante aplicado en las piezas de madera aserrada en las especies *P. radiata* y C. alliodora

Place	Piece	Copper (mg/m³)	Retention (kg/m³)	Average retention (kg/m³)	CV (%)
Ecohouses	Column	1349,0	0,001	0,002 (0,001)	67,79
	Handrails	1291,0	0,001		
	Cercha	3866,0	0,004		
ADITRIBI	Step	4649,0	0,005	0,003 (0,005)	158,6
	Lining	14032,0	0,014		
	Long beam	0,1	0,000		
	Short Chain	850,0	0,001		
	Crown	0,1	0,000		
	Nailers' Stoppers	1747,0	0,002		
	Window and door frame	920,0	0,001		
	floor	1548,0	0,002		
SOMABACU*	Column	1291,0	0,001	-	-

Note: Values in brackets represent the standard deviation, in the case of the asterisk (*) only one test was applied in Southern Yellow Pine, since the procedure used in *C. alliodora* was a surface spray on the pieces

Quality Acceptability Criterion

It was determined that only the wood pieces owned by the company Ecohouse, from *P. radiata* presented an acceptance status in terms of quality, with retention being the parameter that presented the lowest note due to the low levels of retention of the product applied, Salazar, (2008) mentioned that the quality standards in construction with homogeneous wood tend to be high due to the little variation in the material, which allows the developer to build more easily and systematize the construction processes (Table 5).

In the case of the other two sites the acceptance was less than 60 %, due to the fact that most of the wood evaluated had a high moisture content, classifying the wood as green; likewise, there was total non-compliance in the length of the pieces and also the retention values of the preservative are well below the minimum requirements established, so greater control and accompaniment must be given to the constructions developed with both species in order to generate higher quality constructions. Qu *et al.*, (2012) mention that buildings with high dimensional variability and humidity in the pieces may be the basis for construction defects in the first five years of the project's life, since the drying process generates a reduction in the pieces, curvatures or effects on the finish that will affect aesthetics; furthermore, they may be ideal points for the presence of fungi and pathogens that generate greater deterioration in the construction.

Table 5. - Acceptance analysis of wood used in social welfare houses in Costa Rica

Species	Acceptance (%)					Considered status
	Moisture content	**Dimensionality**	**Visual characterization**	**Preservation**	**Average**	
P. radiata	100,0	94,0	65,0	50,0	77,3	Acceptable
C. alliodora	14,0	62,0	55,0	50,0	45,3	Not acceptable
Pinus sp.	57,5	59,0	71,0	50,0	59,4	Not acceptable

Of the species used*, P. radiata* obtained a 77.3 % acceptance in terms of quality, due to the uniformity in terms of moisture content, dimensions, aesthetics (which showed main limitation of live knots) and to a lesser extent in preservation (with total penetration, but a retention below the established), these good results are due to the fact that it is imported material with homogeneity in dimensions and previous processes. On the contrary, with *C. alliodora* and *Pinus sp.,* which presented an approval lower than 55 %, with moisture contents that consider wood as green (average 60 %), dimensional uniformity is deficient (with emphasis on length) and to a lesser extent on defects (emphasized in naturals as knots and management as saw marks). Finally, regarding preservation, specifically retention, for none of the species under study was the minimum value required.

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