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Translated from the original in spanish **Original article**

Analysis of the use of wood for furniture production in Cabinda, Angola

Análisis de la utilización de la madera para la producción de muebles en Cabinda, Angola

Análise do emprego da madeira para a produção de mobiliário em Cabinda, Angola

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ABSTRACT

The objective of the study is to determine the preferred woods based on the analysis of different attributes for the production of furniture in the province of Cabinda, Angola. A population belonging to the municipalities of Cabinda, Cacongo, Buco Zau and Belize is used. The method used to measure the preferences of the specialists was the Hierarchical Analysis Process, based on a survey of personnel specialized in the processing and use of wood and professors of the Forestry Engineering Course at the University "11 de Noviembre" in Cabinda. To determine the quality of planning of highly abundant woods in Cabinda, the ASTM-D-1666-2004 Standard was used. The favorite woods in the furniture market are *Guarea cedrata, Lovoa trichiliodes*, *Grossweilerodendrum balsimifera, Ballonella toxisperma* and *Clorophora excelsa*. The result of the hierarchical analysis of the process shows that the most widely accepted species is *Grossweilerodendrum balsimifera*, presenting an acceptance range of 56%. There is a preference for woods with light colors, which is supported by the fact that, among the five preferred woods, three have light shades, representing 70.33% of the total sample analyzed. During the analysis of brushing quality, positive results are seen for the species *Entandrophragma angolensis*, *Entandrophragma cilindricum* and *Terminalia superba*; since they have an average of 24.4 blade marks per centimeter.

Keywords: statistics, processing, furniture, surface, quality.

RESUMEN

El trabajo tiene como objetivo determinar las maderas preferidas a partir del análisis de diferentes atributos para la elaboración de muebles en la provincia de Cabinda, Angola. Se evalúa una población perteneciente a los municipios Cabinda, Cacongo, Buco Zau y Belice. El método utilizado para medir las preferencias de los especialistas fue el Proceso de Análisis Jerárquico, a partir de una encuesta al personal especializado en el procesamiento y utilización de la madera y profesores de la Carrera de Ingeniería Forestal en la Universidad 11 de noviembre en Cabinda. Para la determinación de la calidad del cepillado

de maderas de gran abundancia en Cabinda se empleó la Norma ASTM-D-1666-2004. Las maderas de mayores preferencias en el mercado del mueble son *Guarea cedrata, Lovoa trichiliodes*, *Grossweilerodendrum balsimifera, Ballonella toxisperma* y *Clorophora excelsa*. El resultado del análisis jerárquico del proceso expone que la especie de mayor aceptación de manera es *Grossweilerodendrum balsimifera*, al presentar un rango de aceptación del 56 %. Se aprecia una preferencia de maderas con colores claros, lo cual se sustenta por el hecho que, entre las cinco maderas preferidas, tres presentan coloración con matices claros representando el 70,33 % del total de la muestra analizada. Durante el análisis de la calidad del cepillado se aprecian resultados positivos para las especies *Entandrophragma angolensis*, *Entandrophragma cilindricum* y *Terminalia superba*; al presentar un promedio de 24,4 marcas de cuchilla por centímetro.

Palabras clave: estadística, procesamiento, mueble, superficie, calidad.

RESUMO

O objectivo do trabalho é determinar as principais madeiras preferidas com base na análise de diferentes atributos para a produção de mobiliário na província de Cabinda, Angola. É utilizada uma população pertencente aos municípios de Cabinda, Cacongo, Buco Zau e Belize. O método empregado para medir as preferências dos especialistas foi o Processo de Análise Hierárquica, baseado num inquérito a pessoal especializado no processamento e utilização de madeira e a professores do Curso de Engenharia Florestal da Universidade "11 de Novembro", em Cabinda. Para determinar a qualidade do aplainamento das madeiras de grande abundância em Cabinda foi utilizada a Norma ASTM-D-1666-2004. As madeiras preferidas no mercado moveleiro são *Guarea cedrata*, *Lovoa trichiliodes*, *Grossweilerodendrum balsimifera*, *Ballonella toxisperma* e *Clorophora excelsa*. O resultado da análise hierárquica do processo mostra que a espécie com maior aceitação é *Grossweilerodendrum balsimifera*, apresentando faixa de aceitação de 56%. Há preferência por madeiras com cores claras, o que é corroborado pelo fato de que, dentre as cinco madeiras preferidos, três possuem coloração com tonalidades claras, representando 70,33% do total da amostra analisada.

Durante a análise da qualidade da escovação, são observados resultados positivos para as espécies *Entandrophragma angolensis*, *Entandrophragma cilindricum* e *Terminalia superba*; apresentando média de 24,4 marcas de lâmina por centímetro.

Palavras-chave: estatísticas, processamento, móveis, superfície, qualidade

INTRODUCTION

The demand for raw materials continues to increase and the supply of wood is even more limited, hence the diversification of fast-growing species plays a fundamental role, since they adapt to soil and climate conditions, are highly productive and have great wood quality (França *et al*., 2019).

Barrera *et al*. (2018), suggest that the great variability between forest species must also be considered, as well as their different properties, among them, those that indicate possibilities of using wood for the most diverse purposes, including, the production of furniture and the levels of customer satisfaction based on the psychological well-being provided by wood (Lipovac and Burnard, 2021).

Although there are important technological advances in the sector, the level of knowledge still needs to be improved in the area of the workability properties of wood (Valdés *et al*., 2018 and 2021); which makes them timber species of little use in the furniture sector.

Currently in the province of Cabinda, Angola, despite the existence in forest ecosystems of large volumes of wood used in the mechanical wood transformation sector, knowledge about the interaction of wood is minimal and its effect on professionals linked to the selection of different types of wood for the production of furniture. Thus, the objective of this study is to determine the main preferred woods based on the analysis of different attributes for the production of furniture in the province of Cabinda, Angola.

MATERIALS AND METHODS

Determining the species preferred by consumers of wooden articles in the province of Cabinda based on their attributes constitutes an important premise for the management and use of wood as raw material, increasing its added value.

To determine the species preferred by specialists, surveys were carried out in a population belonging to the municipalities of Cabinda, Cacongo, Buco Zau and Belize; Cabinda province, Angola (Figure 1).

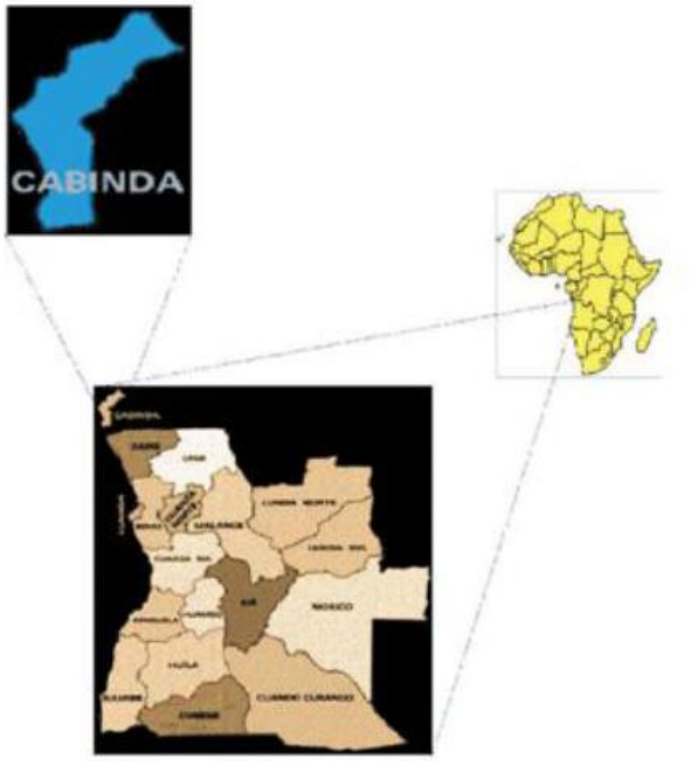

Figure 1. *- Location of Cabinda in Angola.*

Source*: Bauza et al. (2006); cited by Alvarez et al. (2020).*

The survey method with 13 items and alternative answers was applied. Therefore, personnel specialized in the subject who work in sawmills, carpentry, construction sites and professors of the Forestry Engineering Course at the University "11 de Noviembre" in Cabinda, consumers in the municipalities of Cacongo, Buco Zau, Belize and Cabinda, were

surveyed. That represents a universe of 1,550 individuals. The variable used was years of experience of the respondents.

Simple random sampling was used to increase the precision of the estimates and reduce the costs of the survey (Aldana 2017 and Carballo *et al*., (2020).

To determine the number of people to be surveyed, the following mathematical expression Equation 1 was used (López and Fachelli, 2015):

$$N = \frac{Z^2 * p * q}{E^2} \qquad [1]$$

Where:

N - sample size; Z: for a 95% confidence interval = 1.96; P - hypothesis of the proportion of the population that possesses the distinctive characteristic or trait of the universe of the population; q = 1 p; E margin of sampling error allowed

For the present study, N is equal to 140 (25 % of the population), so the 1,500 surveys used in the demonstration test will be maintained with the intention of obtaining a higher level of reliability of the results; agreeing in this analysis with Alvarez *et al*. (2020).

Analysis of consumer preference for wood species through Heuristic Problem Analysis

The method used to measure the preferences of specialists was the so-called Hierarchical Analysis Process (AHP), proposed by Saaty (1980) and used by Scholz and Decker (2007), as well as Valdés *et al.* (2021), with the intention to analyze this decision problem through the hierarchical structure, based on the individual decision of the elements.

In this case, the AHP aims to evaluate the trends that certain segments of the population have in relation to their preferences for wood for the production of furniture, taking into consideration the different attributes that characterize wood.

To Hierarchize the model, the problem must be broken down into its relevant components. When building this model, enough details must be included to describe the problem as completely as possible.

The maximum limit of the hierarchy represents the objective of the decision problem (Preference of species in the production of furniture). This objective was characterized based on a first level of attributes (Criteria), Design and Quality were set within the latter. They were subdivided into several levels of attributes (Subcriteria), which include: style, individuality, surface finish, ease of working, type of construction, modern rustic, classic, surface finish, translucent, opaque, skill in premium, normal, type of construction, solid, veneer, oiled translucent, lacquered, veined and finally the alternatives; which will be the species that are identified as the preferred ones; in correspondence with the methodology proposed by Roche and Vejo (2005); as well as Reinoso *et al*. (2022).

In the next stage the possibilities that alternatives have are evaluated (five species are selected as favorite) out of a total of nine species derived from the results of the survey, through binary comparisons (pairwise) for each of the established criteria and subcriteria, the decision maker expresses his preference by assigning a numerical value to each comparison.

At each level of the hierarchy, comparisons were made between pairs of elements of that level, based on the importance or contribution of each of them to the element of a higher level to which they are linked.

This comparison process leads to a scale of relative measurement of priorities or weights of those elements. In both cases, pairwise comparisons are made through preference ratios that are evaluated according to a numerical scale from 1 to 9 proposed in Table 1.

With these results, the following matrix is formed: (Equation 2), according to Berumen and Llamazares (2007).

$$A=\begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ = & . & . & . \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \quad [2]$$

Once these matrices are constructed, we proceed to normalize them, dividing each number in the column by the total sum of the column and thus the Normalized Matrix will be obtained, (Equation 3)

$$A\ normalizada=\begin{bmatrix} 1/v1 & a_{12}/v2 & \dots & a_{1n}/vn \\ a_{21}/v1 & 1/v2 & \dots & a_{2n}/vn \\ . & . & . & . \\ . & . & . & . \\ a_{n1}/v1 & a_{n2}/v2 & \dots & 1/vn \end{bmatrix} \quad [3]$$

Subsequently, an arithmetic average is performed on each line of the normalized matrix and the priority vector is obtained for the alternatives, criteria and subcriteria (Equation 4).

$$p=\begin{bmatrix} \frac{1}{n}\sum_1^n a1j \\ \frac{1}{n}\sum_1^n a2j \\ \vdots \\ \frac{1}{n}\sum_1^n anj \end{bmatrix} \quad [4]$$

To determine the brushing workability property, 10 wood specimens per species were conditioned at a temperature of 25°C and relative humidity of 65%, according to ASTM-D-1666-2004 Standard. Three blades were used with a cutting angle of 30° and a feeding speed of 8 m min^{-1} with a cutting speed of 6500 revolutions per minute (rpm) (Reinoso *et al*. 2022).

The number of marks per blade (NMC) is determined from the mathematical expression used by Zavala and Vázquez (2001) and Valdes *et al.* (2021) which is defined below Equation 5:

$$NMC = \frac{A*B}{Va*100} \qquad (5)$$

Where: NMC- number of marks per blades; A- cutting speed, rpm; B- number of blades used; Va- advance speed or feed speed, m min^{-1}

An evaluation of 100 % of the specimens was carried out through visual inspection to analyze their behavior in terms of the most frequent defects for this type of test, to calculate with the data obtained the number of blade marks per centimeter, to assess the behavior of the test tube of each of the species with the two angles studied and to define which of the combinations studied is the most appropriate for brushing each of the species.

For the evaluation of brushing defects and other wood workability processes, the ASTM D-1666 standard (ASTM, 2004) was taken as a reference, which establishes the work procedure for carrying out brushing tests. The quality of the brushing was determined by adding the percentage of excellent (E) and good (G) pieces for each of the tests Table 1.

Table 1. *-Evaluation of defects due to wood brushing. ASTM Standard D-1666-87 (ASTM, 2004)*

Degree	Condition	Description
1	Excellent	Free of defects
2	Good	With superficial imperfections that can be eliminated with number 100 sandpaper.
3	Regular	With marked defects that can be eliminated using a coarse number 60 sandpaper and then a fine number 100 sandpaper.
4	Poor	With very severe defects that require processing the piece of wood again to be eliminated.
5	Very poor	With very severe defects that to be eliminated it is necessary to sanitize the piece of wood.

Source: *ASTM Standard d-1966-87 (ASTM, 2004)*

RESULTS AND DISCUSSION

Determination of wood preferences in the furniture market in the province of Cabinda

To correctly issue criteria, respondents analyzed different attributes that characterize wood as a raw material. The results of the survey applied to determine the wood species preferred by consumers for the manufacture of furniture are below.

In Figure 2, it can be determined that the most used woods in the furniture market are concentrated in five timber species defined as *Guarea cedrata* (undiano white: 22.33 % of the total); *Lovoa trichiliodes* (undiano preto: 22 % of the total); *Grossweilerodendrum balsimifera* (tola branca: 30% of the total); *Ballonella toxisperma* (moabi: 6.33% of the total) and *Clorophora excelsa* (kambala: 19.33 % of the total), despite the abundance of timber diversity that exists in the forests of the province of Cabinda.

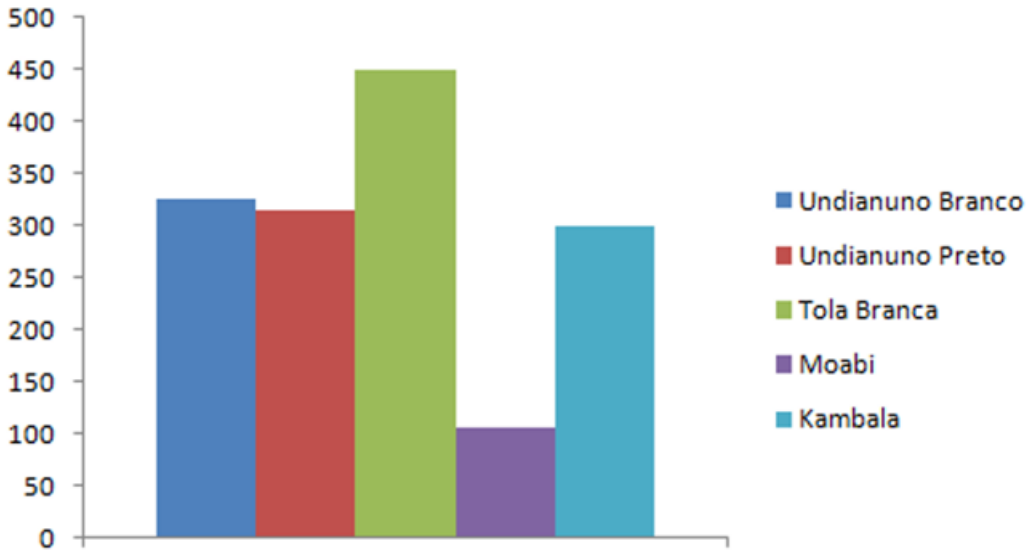

Figure 2. *- Preferences of wood from the market in Cabinda*

From the analysis of the surveys itself, it was possible to define that there is a marked social factor during the selection of the most chosen species in the sector, as the wood itself reports high well-being and comfort to specialists and wood consumers related to quality of life (Araujo and Savignon, 2018).

Taking these elements into consideration, it can be stated that the determination of the preferred wood species in Cabinda, for the manufacture of furniture, decorative objects, school materials and domestic materials based on sensory factors that influence the general vision we have of this product, is determined by its aesthetics and visual impact, considering that the characteristics of these woods influence the visual perception of customers.

To reaffirm the aforementioned elements, we can state, in accordance with the results obtained in the survey, that the sensations and emotions attributed to the selected woods are positive. Harmony, balance, relaxation and stability are highlighted among those senses. These elements are related to social well-being, coinciding with the approaches developed by Cardoso *et al*. (2020).

All participants in the research consider wood as very functional for the construction of articles, giving them value for physical and psychological health. Also, for having notable aesthetic qualities, highlighting the importance of knowing the different types, when choosing the appropriate one for each case.

Wood is marketed in a wide range of shades that create environments that modify the perception of individuals, influencing their emotional state and well-being in general. It is also evident that the light colors, the texture of these woods and their shine exert a marked influence on the psyche of individuals and their relationship with the well-being provided by wood, coinciding with the approaches presented by Malik *et al.* (2018) and Cisneros *et al*. (2019), who define that color is one of the main factors when selecting a product derived from wood (Risse *et al*. 2019 and Bello *et al*.2020).

La Tola Branca presents a frequency of acceptance among respondents of 450, which constitutes 30 % of the total sample analyzed. There is a preference for light colors, which is supported by the fact that, three out of five woods selected by consumers, are of light shades (Figure 3) representing 70.33 % of the total.

Figure 3. *- Representation of the tone of the woods preferred by the furniture market in Cabinda, Angola*

Figure 4 shows the main elements derived from the analysis of wood attributes that affect consumer wood preferences based on the materialization of the proposed hierarchy.

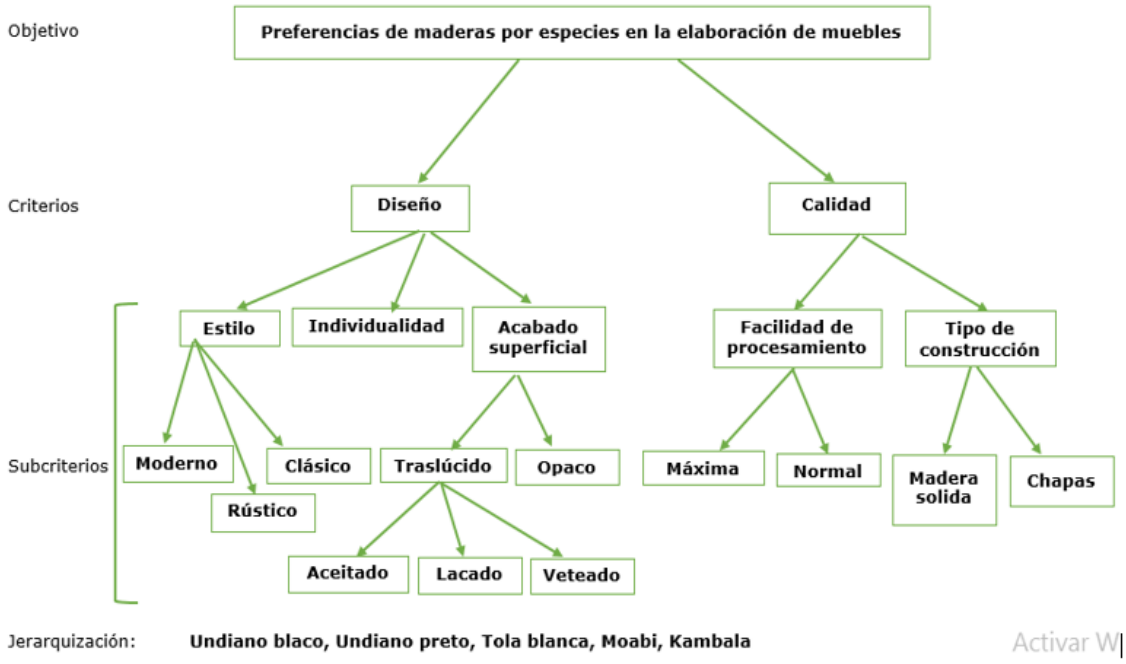

Figure 4. *- Hierarchical tree of the analyzed attributes*

In the case of selecting the species preferred by wood specialists, a priority vector is defined for each sub-criterion and criterion, as well as all the evaluated alternatives. The final result of the hierarchical analysis of the species selection process shows that the species with the greatest acceptance globally is the tola branca, presenting an acceptance range of 56 %.

To reduce the pressure on the most preferred woods on the market, it is proposed that woods with these shades be also used (Figure 5).

Figure 5. *- Woods that are abundant in the Maiombe jungle that can be used in the construction of wooden articles. A- Entrandrophragma angolensis (tiama), B- Entrandrophragma cylindricum (sapeli), C- Terminalia superba (limba)*

Analysis of the quality of brushing of species that are not very preferred in the furniture sector in Cabinda with a wide existence in the Maiombe jungle

Table 2 shows the results related to the quality of brushing of the species proposed to be used in the furniture sector in Cabinda in addition to those currently preferred by consumers.

Table 2. *- Classification of the results obtained during the planing of the selected woods*

Species	**Humidity %**	**Number of test tubes used**	**Classification of the test pieces (E+B) %**
Entrandrophragma angolensis (tiama)	12	10	80
Entrandrophragma cylindricum (sapelli)	12	10	80
Terminalia superba (limba)	12	10	90

For the three woods shown in Table 2, brushing workability properties are classified as Excellent; coinciding that the defect that appears most frequently in the test tube used is the fluffed grain. These results are consistent with those obtained by Machuca *et al.* (2012) and Valdes *et al*. (2018). Therefore, it can be concluded that the woods of the species analyzed have excellent brushing qualities, reporting surfaces with excellent properties that facilitate the gluing and finishing of these surfaces; fundamental aspect in the processes of manufacturing wooden articles coinciding with Valdés *et al*. (2021).

Result of the combination used during the brushing test

During the materialization of the Brushing test, depending on the planned cutting regime, significant results (that appear in Table 3) are obtained for the three species proposed to be used in the furniture sector in Cabinda. This makes possible to increase the added value of these woods as raw materials in the production of wooden articles during the secondary wood transformation process.

Table 3. *- Results obtained for wood depending on the cutting regime used*

Combination	Number of test tubes	Cutting angle degrees	Feed speed m min^{-1}	Number of blades	Spindle rotation rpm	Number of blade marks cm^{-1}
1	10	30	8.00	3	6500	24.4

On the other hand, during the analysis of the test tubes used in the experiment, it can be seen that the three woods analyzed have satisfactory results for 24.4 number of blade marks, meaning that *Terminalia superba* and *Entrandrophragma angolensis* are those with the greatest number of test tubes free of defects (Table 4).

Table 4. *- Effect of the number of blade marks cm^{-1} per species*

Species	Number of faca marks per cm	
	24.4	
	E+B defect-free specimens	
Entrandrophragma angolensis (tiama)	8	10
Entrandrophragma cylindricum (sapelli)	9	10
Terminalia superba (limba)	8	10

According to Laina *et al*. (2017), it is also important to define that a poor selection of the cutting angle of the blades can favor the presence of defects on the surfaces of the brushed wood due to the presence of fuzzy and torn fibers. Therefore, the selection of the cutting angle of 30º allows for a high percentage of test bodies free of defects, with *Terminalia superba* being the one with the best results (90 %).

It was also observed that by using a cutting angle of 30º, the largest number of test tubes free of defects is obtained for the species *Terminalia superba,* with 90% of the test tubes free of defects. These results may be related to the density of the wood; since in the case of tiama and sapelli with densities of 550 Kg m^{-3} and 620 Kg m^{-3} are higher than the density of limba, which is located at a density of 520 Kg m^{-3} (Richter and Dallwitz 2000).

CONCLUSIONS

The most preferred woods based on the analysis of the different attributes in the furniture market in the province of Cabinda, Angola, are tola branca, kambala, undianuno preto and moabi; identifying that tola branca is the most selected wood.

There is a preference for woods with light colors, which is supported by the fact that, three out of five selected woods have light shades, representing 70.33% of the total sample analyzed.

The woods of the analyzed species have positive results in relation to the surface quality of the brushing.

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***Conflict of interests*:**

The authors declare not to have any interest conflicts.

***Authors' contribution*:**

The authors have participated in the writing of the work and analysis of the documents.