Open access • Journal Article • DOI:10.1007/S13595-013-0299-3

Relationship between density and aesthetic attributes of wood and preference of Malagasy consumers — Source link

Tahiana Ramananantoandro, M. Ramanakoto, Andraina H. Rajemison, Florent Eyma

Institutions: University of Antananarivo

Published on: 20 Jun 2013 - Annals of Forest Science (Springer Paris)

Topics: Wood processing, Context (language use) and Preference

Relationship between density and aesthetic attributes of wood and preference of Malagasy consumers

Tahiana Ramananantoandro, Miora Ramanakoto, Andraina Rajemison, Florent Eyma

Annals of Forest Science (2013) 70:649–658
DOI 10.1007/s13595-013-0299-3

ORIGINAL PAPER

Relationship between density and aesthetic attributes of wood and preference of Malagasy consumers

Tahiana Ramananantoandro · Miora F. Ramanakoto · Andraina H. Rajemison · Florent Eyma

Received: 5 February 2013 / Accepted: 21 May 2013 / Published online: 20 June 2013

Abstract
• ***Context*** The knowledge of consumer preferences in wood furniture is crucial for the wood processing industries.
• ***Aim*** This study aims to identify the attributes of wood that affect the preferences of consumers from the city of Antananarivo, Madagascar, for wooden furnishings.
• ***Methods*** Quantitative measurements of the density and aesthetic properties of 12 wood species were carried out. The properties measured were the colour in the CIEL*a*b* colour space, the texture through greyscale image processing, and the density. Then, the wood specimens were subjected to sensory analysis with 100 consumers.
• ***Results*** The results showed that the "density" was a prime criterion in choosing a wood species. Concerning the visual aspect, Antananarivo consumers generally liked slightly dark wood colour (*L** around 52), tending towards yellow, with a visible oriented texture. The influence of socio-economic factors was also highlighted.
• ***Conclusion*** These results are of prime importance in the search for alternative species to replace precious woods that are becoming rare.

Keywords Consumers' preference · Colour texture · Density · Rosewood · Madagascar

Handling Editor: Jean-Michel Leban

Contribution of the co-authors Tahiana Ramananantoandro designed the study, carried out colour and texture measurements, and wrote the paper.
Miora F. Ramanakoto carried out the sensory analysis and density measurement, and wrote the paper.
Miora F. Ramanakoto and Andraina H. Rajemison carried out statistical analysis.
Tahiana Ramananantoandro and Florent Eyma supervised the work.
All authors discussed the results and commented on the manuscript.

T. Ramananantoandro (✉) · M. F. Ramanakoto · A. H. Rajemison
Université d'Antananarivo, Ecole Supérieure des Sciences Agronomiques, Département des Eaux et Forêts, BP 175, Antananarivo 101, Madagascar
e-mail: ramananantoandro@gmail.com

A. H. Rajemison · F. Eyma
Institut Clément Ader, IUT Département Génie Mécanique et Productique, 1 rue Lautréamont BP 1624, 65016, Tarbes Cedex, France

1 Introduction

Madagascar rosewood species (members of the genus *Dalbergia* L. f., Fabaceae) are among the most preferred species for the manufacture of furniture and musical instruments in the international market. As a precious wood, rosewood has an image of quality for the general public. Dalbergia includes 48 currently recognized species in Madagascar, all of which are endemic except one (Du Puy et al. 2002). At the national level, rosewood is also appreciated by Malagasy consumers (Schuurman and Lowry 2009). The species of rosewood most commonly used are *Dalbergia baronii* Baker, *Dalbergia monticola* Bosser & R. Rabev., *Dalbergia trichocarpa* Baker, *Dalbergia greveana* Baill., *Dalbergia purpurascen* Baill., *Dalbergia chapelieri* Baill., *Dalbergia lemurica* Bosser & R. Rabev and *Dalbergia neoperrieri* Bosser & R. Rabev. The main production areas in Madagascar are: Morondava, Mahajanga, Toamasina, Antsiranana, Antananarivo, Toliara, Masoala and the SAVA region (Rasamoelina 2001).

Unfortunately, the availability of rosewood in Madagascar is a real problem. It is now necessary to go further into the forest to find the trees with exploitable diameters. The latest surveys conducted in 2001 by Rasamoelina give the following rosewood densities (diameter >40 cm): three trees/ha in Toamasina, two trees/ha Morondava and seven trees/ha in Mahajanga. These values confirm the rarity of this species in the three main regions of production. In addition, rosewood is a slow-growing species. It has been estimated that trees reach a size large enough to yield a fair amount of heartwood

only after 70–100 years (Lemmens 2008). In this context, the rosewood sector is in danger of disappearing, and it is essential to find alternative species that can provide a sustained yield for timber production. Alternative species must have mechanical and physical properties suitable for use in furniture but should also be accepted by consumers. Products' sensory characteristics are critical in the acceptance of the product by the consumer and participate in their choice (Bumgardner et al. 2007). Therefore, knowledge of these preferences is essential for the development of new products.

In developed countries, several studies have dealt with consumer preferences on different wood products: Hansen et al. (1999) on lumber in the USA, Nyrud et al. (2008) and Hoibo and Nyrud (2010) on wooden decking products in Norway, and Lihra et al. (2008) on household furniture in North America. In Madagascar, no consumer preference study has ever been carried out for wood products.

The objective of this study is therefore to identify wood attributes that affect the preferences of consumers from the capital of Madagascar, Antananarivo, in their choice for wooden furnishings. The main question is: "What are the criteria that reflect the consumers' preferences for wood furniture?" As preference is a subjective perception, this study searched for quantitative parameters that could explain the subjective preferences. To this end, three hypotheses were proposed:

1. Aesthetic attributes (wood colour and texture) influence consumer preference;
2. Wood density influences consumer preference;
3. Purchasing power influences consumer preference.

2 Materials and methods

Once the species to be studied had been chosen, the aesthetic attributes and the density of wood samples were measured. After that, a sensory analysis was organized with households from the city of Antananarivo, Madagascar, in order to understand consumer preferences. From the sensory analysis results, a typology of consumers was deduced. Finally, the relationship between consumer preferences and quantitative criteria was investigated.

2.1 Specimen preparation

Twelve wood species were collected from furniture and joinery companies in the city of Antananarivo, Madagascar, including two species of rosewood (Fig. 1). These species were chosen to cover a range of yellow to red, light to dark, textured and non-textured surfaces. These species included light and heavy wood. To test the second hypothesis, 12 additional specimens were also machined. These additional samples were necessary to prevent consumer panels from recognizing samples, and thus to ensure that scores, attributed to specimens that were held and those that were not, were independent. Defect-free specimens were machined to uniform dimensions (200×100×20 mm). Their surfaces were sanded with P240 grit paper in order to avoid the influence of roughness on consumer preference. In addition, wood specimens were coded so that they were presented anonymously to consumers (Fig. 1).

2.2 Colour measurement

The CIEL* a* b* colour space was used to measure the colour of the wood specimens (Mazet and Janin 1990; Lafon and Ramananantoandro 2002). This space is device independent and perceptually uniform, i.e. a change of the same amount in a colour value should produce a change of about the same visual importance. In this system, L^* represents the lightness ranging from 0 (pure black) to 100 (pure white), a^* represents the red-green colour component, b^* represents the yellow-blue colour component.

The colour measurement was performed by using a MicroFlash 200d Datacolor spectrophotometer. D65 standard illuminant, which is intended to represent average daylight (ISO 11664–2: 2007), and a 10° angle of observation were used. For each wood sample, 11 random repetitions of colour measurements were made in distinct locations on the surface in order to take the heterogeneity of the wood surface colour into account.

2.3 Colour texture measurement

Wood is a material of biological origin. Its colour is not uniform due to the alternating earlywood/latewood, sapwood/heartwood colours and because of singularities such as knots. Therefore, considering only the chromaticity coordinates is not sufficient to characterize texture. Several studies, such as those of Van De Wouwer (1999) and Vandenbroucke et al. (2003), have attempted to characterize the colour texture through a study of the spatial distribution of chromaticity coordinates or the greyscale of image pixels. In this study, pictures of each specimen were taken under the same acquisition conditions using a Pentax K7 digital camera. Then, the images were converted to greyscale. From these greyscale images, the parameter "texture aspect ratio of the surface" (*Str*) was calculated. This parameter measures the texture strength, i.e. the randomness or directionality of the texture. It is defined as the ratio of the fastest to

slowest decay to 0.2 correlation length of the areal autocorrelation function.

$$Str = \frac{\text{Length of fastest decay to 0.2 of autocorrelation function in any direction}}{\text{Length of slowest decay to 0.2 of autocorrelation function in any direction}}$$

Values of $Str>0.5$ indicate uniform texture in all directions, i.e. no defined lay. Smaller values ($Str<0.3$) indicate an increasingly strong anisotropy, i.e. directional texture or lay (Blunt and Jiang 2003).

In addition, in order to study the visibility of the texture, the maximum colour difference, ΔE, was calculated. According to Hunt and Pointer (2011), an observer cannot distinguish the information provided by L^*, a^* and b^* components separately. The ΔE number represents the maximum value of the colour difference between the 11 random measurements measured on each sample and takes account of the difference in both clarity and colour tone (Mazet and Janin 1990).

$$\Delta E = \max\left(\sqrt{\left(L_i^*-L_j^*\right)^2+\left(a_i^*-a_j^*\right)^2+\left(b_i^*-b_j^*\right)^2}\right)$$

with

$i = 1, 2, \ldots, 11$

$j = 2, 3, \ldots 11 \quad \text{with } j \succ 1$

The higher ΔE, the more visible the texture.

Anakaraka *Cordyla madagascariensis* R. Vig. Fabaceae | Faho *Chloroxylon faho* Capuron Rutaceae | Famelona *Chrysophyllum boivinianum* Baehni Sapotaceae | Hintsy *Intsia bijuga* Kuntze Fabaceae | Katrafay *Cedrelopsis grevei* Baill. Meliaceae | Kesika *Pinus kesiya* Royle ex Gordo Pinaceae

Manary *Dalbergia trichocarpa* Baker Fabaceae | Ramy *Canarium madagascariensis* Engl. Burseraceae | Sohihy *Breonadia microcephala* Ridsdale Rubiaceae | Varongy *Ocotea cymosa* Nees Lauraceae | Vintanina *Calophyllum parviflorum* Bojer ex Baker Calophyllaceae | Voamboana *Dalbergia baronii* Baker Fabaceae

Fig. 1 Photographs of studied wood species (common, scientific and family names)

2.4 Density measurements

The density at 12 % moisture content (*D*) of the 12 twin specimens was measured according to the French national organization for standardization AFNOR NF B51-005 1985 standard. Five specimens of dimensions 20 mm (L)×20 mm (T)×20 mm (R) were cut, and then stabilized at 12 % moisture. Their weights were recorded using an electronic balance with an accuracy of 0.01 g. Their volumes were recorded using a digital calliper with an accuracy of 0.01 mm.

2.5 Sensory analysis with consumers from the city of Antananarivo, Madagascar

The ISO/DIS 11136: 2013 standard requires a minimum number of 60 individuals for a hedonic study. For this study, 100 consumers were recruited for good representation. This represents a sampling rate equal to 0.07 % of households from the city of Antananarivo, Madagascar.

Persons over 18 years of age were surveyed. As in the studies by Bumgardner et al. (2007) and Weinfurter and Eder (2009), household socio-economic categories were determined from the monthly salary of the head of the household and from the housing characteristics. The ranges considered were: less than 35 € monthly income for low income households, between 40 and 210 € for low to average income households, between 210 and 350 € for average to high income households, more than 350 € for high income households (1 Euro=2,970 MGA in local currency, December 2012). In addition, the dwelling type was also considered as suggested by the National Institute of Statistics of Madagascar (INSTAT) in 2010. Dwellings such as apartments and rooms were considered as belonging to low income households, houses to average income households, apartments and villas to high income households.

The consumer panel consisted of 62 % women and 38 % men. Almost half of the panel members were aged between 35 and 54 years. More than half were couples with children. These samples represent well the population of the city of Antananarivo, Madagascar. High income households accounted for 30 % of the sample, low income households for 26 %, and 44 % were of middle income. According to the National Institute of Statistics of Madagascar in 2010, the population of Antananarivo, Madagascar, is dominated by average income households (46 %) and low income households (38 %). Wealthy households are few (16 %). Although the study sought to understand preferences of consumers from the city of Antananarivo, Madagascar, this research focused on consumers most targeted by the furniture industry, that is to say average to high income households. Thus, these two categories of households were more represented in the sensory tests. However, the study also paid attention to lower income consumers' preference as part of the population of the city of Antananarivo, Madagascar.

Tests were conducted in areas likely to bring together the greatest number of people, i.e. in grocery stores and offices. Consumers were interviewed individually face to face. Wood specimens were presented in a monadic way to avoid comparison between them. Consumers were asked to rate each wood specimen indicating their level of appreciation on a 10-point hedonic scale, where score 1 means "dislike extremely" and 10 means "like extremely". Assessment criteria were not specified. Two sensory analyses were performed. In the first experiment, consumers looked at the surface of the specimen without touching it. In the second experiment, the panel members looked at the specimen and were allowed to hold it without touching the surface. In addition, questions were asked about the place where the subjects usually bought furniture and the amount of money generally devoted to the purchase of a wardrobe.

2.6 Statistical analysis

Univariate and multivariate analyses were performed using the Xlstat 2008 and Excel 2007 software packages (Microsoft Inc., WA, USA). The statistical approaches used for data analysis are summarized in Fig. 2.

3 Results

3.1 Characteristics of the specimens studied

The parameters of the aesthetic attributes, colour, colour texture and density are presented in Table 1. Those parameters were analysed using principal component analysis (PCA). PCA involves a mathematical procedure that transforms a number of correlated variables into a smaller number of uncorrelated variables called principal components. Samples that are close in the PCA plot have similar characteristics.

The eigenvalues of the covariance matrix showed that the first three principal components (PCs) accounted for 75.39 % of the total variance in the data set (Fig. 3). The first axis was dominated primarily by L^* and *D*. The second PC was represented by a^* and ΔE variables on the positive axis and *Str* variable on the negative axis. Only variable b^* was represented by the factorial axis F3.

PCA results (Fig. 3) showed four distinct groups of samples:

1. *Katrafay* and *Faho* were close by their lighter, yellow colour trend, and visible, slightly oriented texture.
2. *Vintanina* and *Sohihy* were close. They tended towards the lighter and redder part of the colour range and had oriented and visible texture.

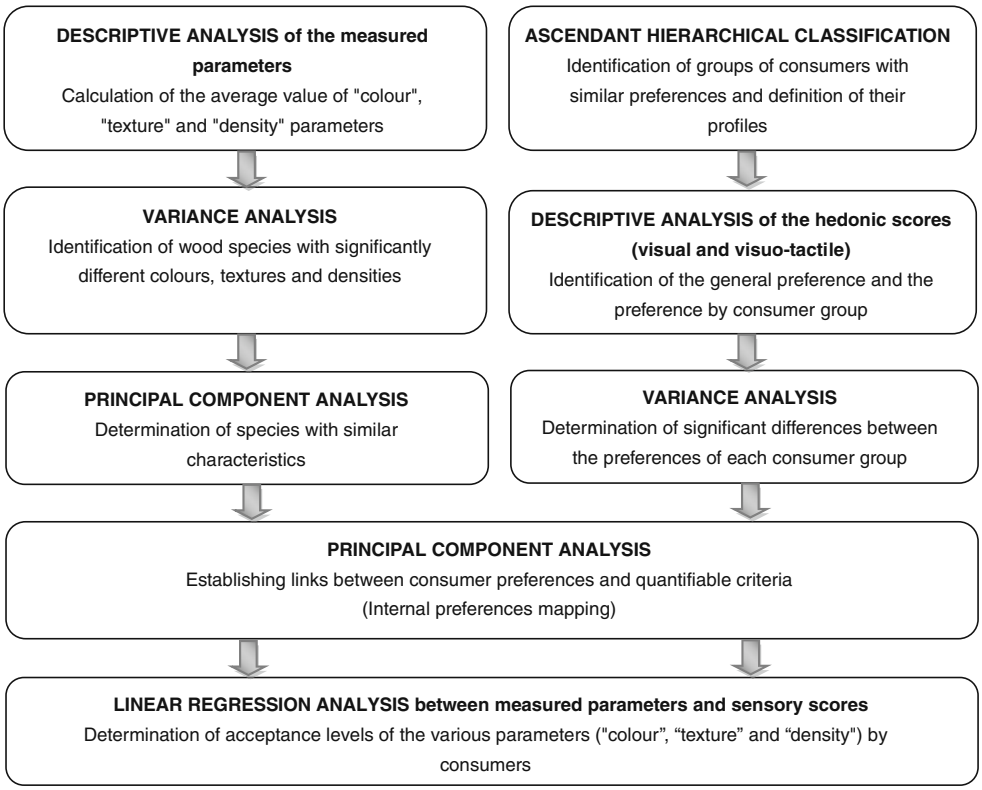

Fig. 2 Summary of the statistical treatment of the results

3. *Voamboana* and *Manary* had some resemblance in terms of lightness of colour (slightly dark) and colour itself (red). However, the difference between them lay in their texture and density. *Manary* was heavier and had a more visible texture.
4. Each of the last six samples, *Anakaraka*, *Varongy*, *Hintsy*, *Famelona*, *Ramy* and *Kesika* species, had its own characteristics.

3.2 Visual preferences of consumers

Eleven of the 12 samples were given appreciation scores above 5 on a 10-point scale (Fig. 4). Only *Kesika* had a score below 5. Analysis of variance revealed the existence of significant differences in visual score among the 12 evaluated samples at 5 % level. The results of Fisher's least square difference (LSD) test demonstrated that *Manary* was the most appreciated species. Preferences for *Faho*, *Sohihy*

Table 1 Values of the density and aesthetic parameters of the studied wood samples

Common names	Scientific names	*L**	*a**	*b**	*Str*	*ΔE*	*D*
Anakaraka	*Cordyla madagascariensis* R. Vig.	45.93 (0.98)	10.45 (0.32)	23.00 (0.80)	0.154	3.85	0.90 (0.008)
Faho	*Chloroxylon faho* Capuron	69.27 (0.90)	9.42 (0.44)	33.71 (1.31)	0.24	5.09	0.95 (0.002)
Famelona	*Chrysophyllum boivinianum* Baehni	53.99 (1.50)	11.21 (0.38)	19.60 (0.81)	0.549	5.26	0.81 (0.008)
Hintsy	*Intsia bijuga* Kuntze	45.45 (1.97)	16.40 (1.00)	27.53 (2.33)	0.051	11.85	0.70 (0.007)
Katrafay	*Cedrelopsis grevei* Baill.	72.12 (1.33)	9.53 (0.45)	33.44 (1.47)	0.102	5.66	0.89 (0.012)
Kesika	*Pinus kesiya* Royle ex Gordo	73.58 (2.66)	8.78 (2.05)	26.28 (3.84)	0.085	15.52	0.55 (0.010)
Manary	*Dalbergia trichocarpa* Baker	51.92 (2.22)	11.91 (0.51)	16.91 (1.61)	0.043	9.41	1.01 (0.006)
Ramy	*Canarium madagascariensis* Engl.	66.40 (1.64)	10.56 (0.60)	22.40 (1.31)	0.036	5.81	0.65 (0.007)
Sohihy	*Breonadia microcephala* Ridsdale	63.80 (3.01)	12.64 (1.05)	26.74 (1.11)	0.13	11.09	0.84 (0.015)
Varongy	*Ocotea cymosa* Nees	70.54 (0.72)	9.21 (0.53)	21.54 (0.30)	0.079	3.03	0.67 (0.005)
Vintanina	*Calophyllum parviflorum* Bojer ex Baker	65.30 (2.18)	14.76 (1.50)	20.33 (0.33)	0.071	8.55	0.75 (0.013)
Voamboana	*Dalbergia baronii* Baker	50.42 (2.08)	10.21 (0.42)	17.38 (1.03)	0.174	8.24	0.85 (0.011)
	Number of measurements per sample	11	11	11	1	1	5

Standard deviations are given in parenthesis

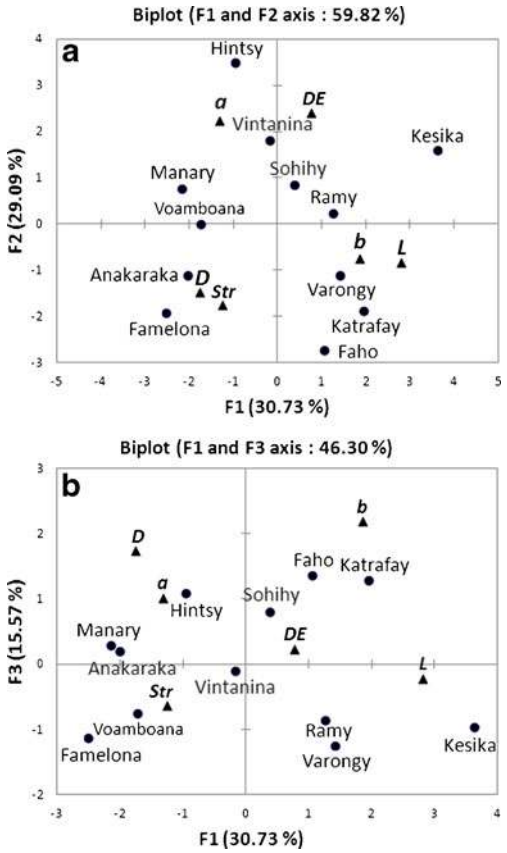

Fig. 3 Grouping of the 12 wood species based on their density and aesthetic properties provided by principal component analysis. *Circles* represent the 12 wood species. *Triangles* represent aesthetic attributes and density: **a** F1–F2 axis, **b** F1–F3 axis

and *Voamboana* species did not differ significantly at the 5 % level. These species were all highly appreciated by consumers. *Kesika* species had significantly lower scores compared to the other samples.

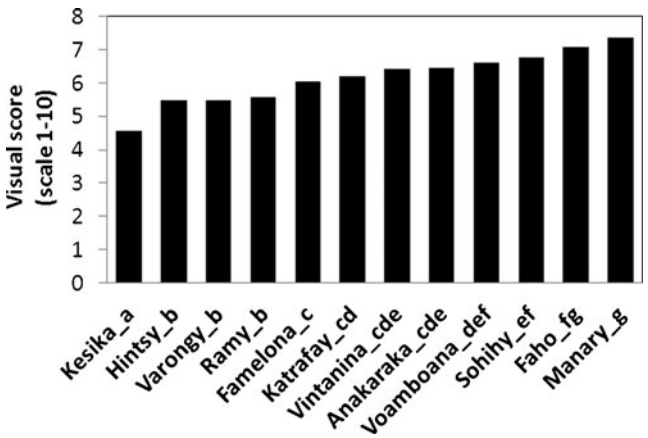

Fig. 4 Average visual scores assigned by 100 consumers to the 12 species. *Identical letters* indicate no statistical difference in visual score (Fisher's LSD test, $p<0.05$)

3.3 Consumer groups having similar preferences

The results of the hierarchical ascendant classification identified three homogeneous groups of consumers based on similarities in their assessments, i.e. different consumer groups score differently. Groups I, II and III were formed by 49, 42 and 9 consumers, respectively. A study of each consumer profile revealed that consumer group I had the following characteristics: average to high income households, generally older and in couples. Group II consisted mainly of low income households, mostly young, single women. No common characteristic was identified for consumer group III.

Figure 5 is a two-dimensional map of the visual preferences of the three consumer groups. It illustrates how each group of consumer hedonic scores, the aesthetic attributes and the 12 wood species were related to each other. The first three principal components explained more than 72.59 % of the variation. L^* had highest loadings on the first principal component; a^*, b^* and ΔE had higher loadings in the second principal component and *Str* in the third principal component.

Figure 5 shows that all consumers generally liked slightly dark-coloured wood (away from L^* in the F1 axis), tending

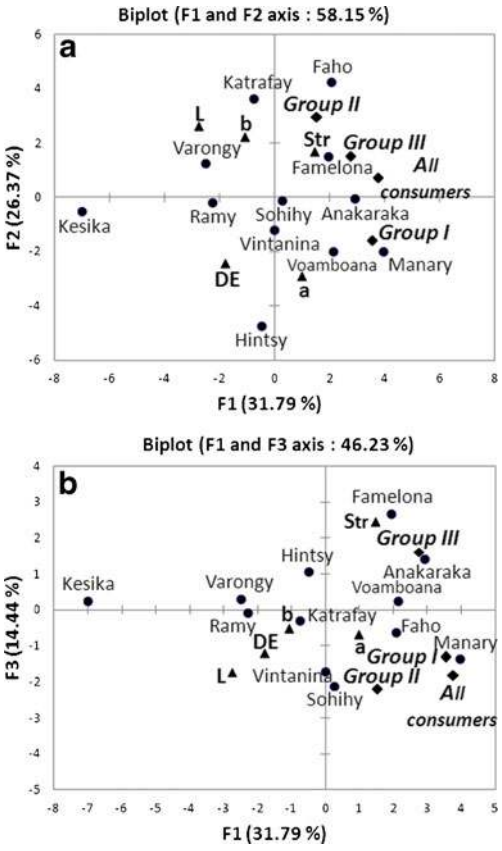

Fig. 5 Internal preference mapping of each consumer group. *Circles* represent the 12 wood species. *Triangles* represent aesthetic attributes and density. *Squares* represent the three groups of consumers: **a** F1–F2 axis, **b** F1–F3 axis

more towards yellow (closer to b^* in the F2 axis), with a directional texture (away from *Str* in the F1–F3 plane) and with visible texture (close to ΔE). In addition, if we examine each consumer group position in the PCA plot, the consumer group I had a tendency to prefer slightly dark, red-coloured wood, with an oriented and visible texture (*Manary*, *Voamboana*, *Sohihy*, *Vintanina* and *Anakaraka*). Consumer group II had a preference for yellower wood, slightly dark, with a strong directional and visible texture (especially *Faho*). Consumer group III also preferred yellow and dark wood colours (especially *Anakaraka*), but they preferred surfaces with a uniform texture (close to *Str*). The four species *Kesika*, *Hintsy*, *Ramy* and *Varongy* were commonly less appreciated by the three groups of consumers.

3.4 Comparison of scores attributed when holding or not holding the specimen

The comparison of Fig. 6 shows that, for the 12 species studied, there was an obvious difference between scores attributed to samples that were held and those that were not. In this figure, species are listed in ascending order of density. For species situated in the left part of the figure, i.e. with low density, scores obtained by specimens that were not held were higher than scores obtained when the specimens were held, except for *Ramy* species. The tendency was inversed for species situated in the right part of the figure. Density thus had an influence on consumer preference, high density accentuated the preference for a wood species.

3.5 Correlations between quantitative parameters and ratings by consumers

Linear regression analysis was applied in order to study the relationship between L^*, a^*, b^*, *Str*, ΔE, *D* parameters and scores given by consumers. In all cases, it was verified with Shapiro–Wilk test that the consumer scores followed a normal distribution. Results in Table 2 revealed that the visuo-tactile score was significantly and positively correlated with density for all consumers (r=0.874, P<0.05), the consumer groups I (r=0.850, P<0.05) and the consumer group III (r=0.755, P<0.05). The visual score was significantly and negatively correlated with L^*, only for consumer group I (r=−0.656, P<0.05). For those two significant correlations, regression lines (Fig. 7a) were modelled by the least squares method.

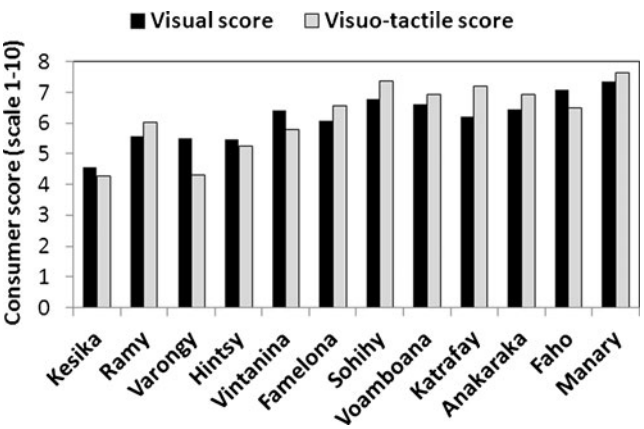

Fig. 6 Graphical representation of the scores attributed when the specimen was held (visuo-tactile score) and those attributed when it was not held (visual score). Species are listed in ascending order of density

The consumers gave a score on a scale of 1 to 10; therefore, the average score was 5. The regression line allowed the determination of a threshold at which consumers did not appreciate the species, i.e. when their assessment was less than 5. Considering the regression line between visuo-tactile score and density, consumers from the city of Antananarivo, Madagascar preferred species with density exceeding 0.63. Similarly, the equation of the regression line between lightness L^* and visual score (Fig. 7b) showed that consumer group I did not like very light wood with a value of L^* greater than 85.

3.6 Ranges of products purchased by each socio-economic category of consumers

Ranges of products purchased by each socio-economic category of consumers were studied from the knowledge of places where they bought furniture and the estimated expenditure for the purchase of a wardrobe. High income households, despite their social position, were not unanimous as to the place where they purchased furniture products. They bought high-end, mid-range and low-end products (Fig. 8a). Despite their wealth, a little more than half were not ready to spend more than 150 € to purchase a wardrobe. Only 10 % were willing to spend an amount exceeding 590 €. Average households mainly bought low-end products, but also mid-range products (Fig. 8b). Only 3 % could afford high-end products. Low income households could afford only low-end products. A minority bought mid-range products (Fig. 8c).

4 Discussion

This study showed the importance of knowing consumer preferences and their relations with the density and aesthetic properties of furniture products. Other studies, like those of Brandt and Shook (2005), have also found that consumer preferences are influenced by visual attributes. In addition, this study allowed preferences of consumers from the city of Antananarivo, Madagascar, for wood furnishings to be explored. Such a study has never been done before in Madagascar. This work thus provides a starting point for future research.

Based on the visuo-tactile analysis results, consumers usually have a preference for heavy species like *Manary*,

Table 2 Linear regression coefficient between the ratings given by consumers, aesthetic and density parameters

Consumer groups	Correlation between visual scores and parameters					Correlation between visuo-tactile scores and parameter
	*L**	*a**	*b**	*Str*	*ΔE*	*D*
All of the 100 consumers	−0.298	0.113	−0.099	0.143	−0.309	***0.874***
Consumer group I	***−0.656***	0.348	−0.373	−0.102	−0.059	***0.850***
Consumer group II	0.424	−0.223	0.198	0.275	−0.356	0.313
Consumer group III	−0.390	−0.067	0.332	0.401	−0.467	***0.755***

Fisher test at 5% was used to show significance. Italicized and bold values: reduction in residual variance significant at the 5 % level. Visual scores refer to scores obtained when consumers were not allowed to touch specimens. Visuo-tactile scores refer to scores obtained when consumers held the specimens

Sohihy or *Katrafay*. These results were consistent with the criteria provided by the panels. Thirty-three percent said they liked wood specimens to be heavy, 29 % considered the weight, the colour and the texture of the wood, 19 % considered weight and colour. Alternative species to rosewood thus should be heavy. Malagasy consumers' assessment criteria

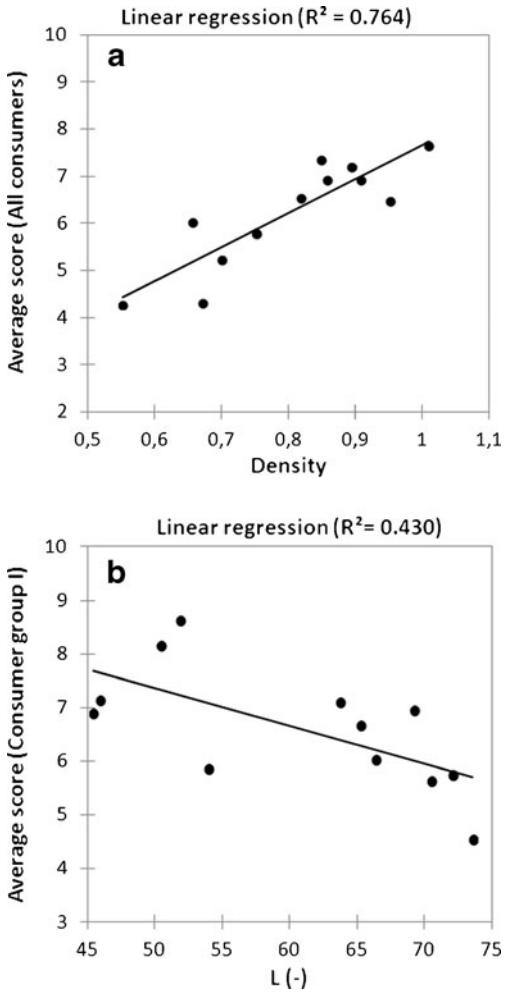

Fig. 7 Linear regression between **a** the overall rating given by all consumers and density *D*, **b** the rating given by consumer group I and lightness *L**. The fitted regression lines correspond to the equations: Overall score=0.41+7.26×*D* ; Group I score=11–7.06 E−02×*L**

seem different from those of French consumers. The study by Marchal and Mothe (1994) found that density did not play an important role in French consumer preference for oak wood (two oak species were studied). French consumers attach much more importance to the aesthetic attributes of the wood. Similarly, studies by Bigsby et al. (2005) and Lihra et al. (2008) also showed that the colour was a key attribute for American and Swedish consumers' choices.

Concerning visual preference, consumers generally like slightly dark wood with an oriented texture. In other countries, the results are a little different. Marchal and Mothe (1994) revealed the existence of two categories of preferences for oak wood: light colour and uniform textured wood are as well appreciated as dark and oriented textured wood. In addition, the study by Hoibo and Nyrud (2010) revealed the preference for a uniform surface texture in Norwegian consumers, giving them a harmonious vision of the surface. In other points, the study by Bumgardner et al. (2007) found that U.S. consumers tend to prefer dark wood (cherry, oak and alder), which is close to Malagasy consumers' preference.

Wood is a heterogeneous material and has many particularities that may influence consumers' choices of wood furniture (Broman 2000; Fell 2002 in Rice et al. 2006). In this study, samples had various grain patterns. Most of samples were straight, others like *Faho* and *Sohihy* showed visual figures. Grain pattern was not evaluated, yet this criterion may have an effect on consumer responses (Ilce et al. 2010). Visual attributes such as knots, studied by Marchal and Mothe (1994), Hoibo and Nyrud (2010), Nicholls et al. (2010), were not considered in this study. Those criteria are interesting area for future research.

Sensory analyses were conducted at groceries stores and offices because these locations provide a good cross section of the local populations at large. However, these respondents may have only limited interest in wood products. Therefore, it would have been interesting to sample potential buyers in furniture stores or at the market places. This was not done for this study because consumers were not frequent at the place of furniture purchase.

According to the current context, rosewood is a rare species but very appreciated by consumers. In the future, when

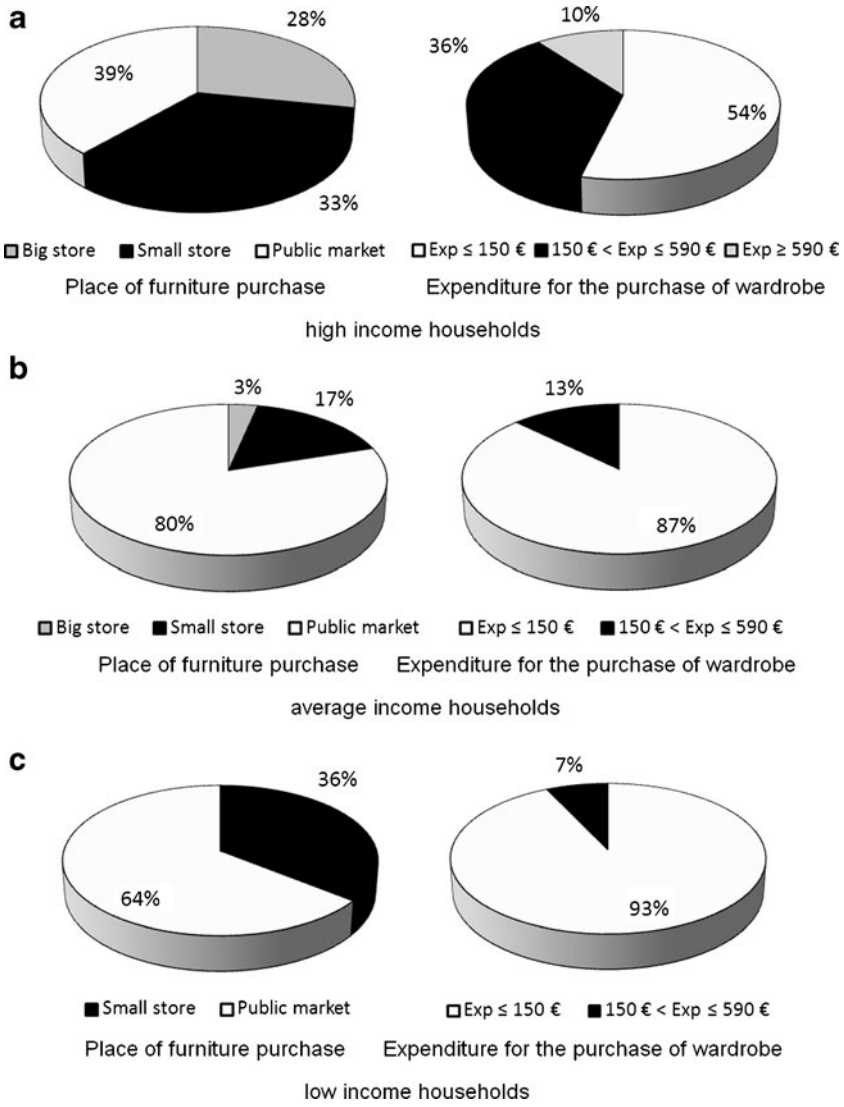

Fig. 8 Frequency of places where consumers bought furniture (percentage) and estimation of household expenditure (*Exp* in Euro) for the purchase of a wardrobe **a** for the high income households, **b** for the average income households, **c** for the low income households. 1 Euro= 2,970 MGA in local currency (December 2012)

searching for substitution species to rosewood, the preference of each group of consumers should be considered. If overall consumers from the city of Antananarivo, Madagascar, are targeted, substitution species should be heavy species, with a visible oriented texture, predominantly yellow and slightly dark. Concerning market segmentation, if the targets are average to high income households and the elderly, the proposed species must be slightly dark red. Low income consumers, women and young people like slightly dark, yellow species.

Finally, analysis of socio-economic factors should not be excluded. These factors may influence consumer choice. Studies such as those of Bumgardner et al. (2007), Jonsson et al. (2008) and Lihra et al. (2008) showed that the price of products was one of the main considerations in consumer choice. Following these analyses, furnishing industries should consider the aesthetic and physical preference of the consumers, but also the target customer groups. This would help them to decide how their products could be considered as the best value for money, and attract as many consumers as possible.

5 Conclusion

Meeting the needs of consumers includes considering their expectations and tolerance levels for the aesthetic attributes and density of furniture wood species. The first two research hypotheses of this study were confirmed. Aesthetic attributes (colour and texture) and density of wood products influence consumer preference. The third hypothesis was partially confirmed, high income households do not systematically buy high-end products. All of these criteria must be considered in the search for alternative species for wooden furnishings.

The search for alternatives to rosewood requires the presence of one or more species that can be exploited in the forests of Madagascar. However, Madagascar is facing a major

environmental problem with an annual deforestation rate of 0.53 % between 2000 and 2005 (Ferguson 2009). In addition, species that provide timber with high density are generally slow growing. Thus, the proposed alternative species may be a solution only for the medium term, given the context of deforestation in the island. A possible alternative could then be the use of wood panels. Such panels have the advantage of recycling waste from wood processing industries and exploiting wood of small diameter. In developed countries, wood panels are widely used for the manufacture of quality furniture. However, the majority of Malagasy consumers do not know that these products exist and furniture industries are not open to innovation. In this sense, a study of "the perception of wood panels for furniture by consumers from the city of Antananarivo, Madagascar" might be a good follow-up to the present study.

Acknowledgments We owe special thanks to the test persons for help with collecting data for sensory analysis. The authors wish to thank S'Prix Meubles factory in Ambohidratrimo and sawmill in Ambatoroka for providing the wood samples used in the study.

References

AFNOR NF B51-005 (1985) Bois - Détermination de la masse volumique, 5 p.

Bigsby HR, Rai C, Ozanne LK (2005) Determining consumer preferences for furniture timber. J Forest Prod Bus Res 2:16

Blunt L, Jiang X (2003) Advanced techniques for assessment surface topography: development of a basis for 3D surface texture standards surfstand. Kogan Page Science, London, UK, p 240

Brandt JP, Shook SR (2005) Attribute elicitation: implications in the research context. Wood Fiber Sci 37:127–146

Bumgardner M, Nicholls D, Donovan G (2007) Effects of species information and furniture price on consumer preferences for selected woods. Wood Fiber Sci 39:71–81

Du Puy DJ, Labat JN, Rabevohitra R, Villiers JF, Bosser J, Moat J (2002) The Leguminosae of Madagascar. Royal Botanic Gardens, Kew, p 720

Ferguson B (2009) REDD comes into fashion in Madagascar. Madag Conserv Dev 4:132–137

Hansen B, Araman P, West C, Schuler A (1999) Hardwood timber product markets: a focus on small-diameter. Proceedings of the Society of American Foresters 1999 National Convention, Portland, Oregon, pp. 305–310

Hunt R. W. G., Pointer M. R. (2011) Measuring colour. Wiley-IS&T Series in Imaging Science and Technology John Wiley & Sons, Ltd, Chichester, UK. p 492

Hoibo O, Nyrud AQ (2010) Consumer perception of wood surfaces: the relationship between stated preferences and visual homogeneity. J Wood Sci 56:276–283

Ilce AC, Ciritcioglu HH, Burdurlu E, Altun S (2010) The figure preferences of the consumers on the panel furniture surfaces. Technol 13:219–228

ISO 11664–2 (2007) CIE standard illuminants for colorimetry, 14 p.

ISO/DIS 11136 (2013) Sensory analysis—methodology—general guidance for conducting hedonic tests with consumers in a controlled area, 49 p.

Jonsson O, Lindberg S, Roos A, Hugosson M, Lindström M (2008) Consumer perceptions and preferences on solid wood, wood-based panels and composites. Wood Fiber Sci 40:663–678

Lafon D, Ramananantoandro T (2002) Color images. Image Anal Stereol 21:S61–S97

Lemmens, R.H.M.J., 2008. *Dalbergia melanoxylon* Guill. & Perr. [Internet] Record from Protabase. Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa/Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands.

Lihra T, Buehlmann U, Beauregard R (2008) Mass customisation of wood furniture as a competitive strategy. Int J Mass Customisation 2:200–215

Marchal R, Mothe F (1994) Appréciation du bois de chêne (*Quercus robur* L., *Quercus petraea* Liebl) par les consommateurs et les professionnels français du bois. Ann For Sci 51:213–231

Mazet JF, Janin G (1990) The quality of appearance of oak veneers: colour measurements and visual appreciation of French and Italian professionals. Ann For Sci 47:255–268

Nicholls D, Bumgardner M, Barber V (2010) Consumer and manufacturer perceptions of hardwood panels made from character-marked lumber. Int Wood Prod J 1:28–34

Nyrud AQ, Roos A, Rodbotten M (2008) Product attributes affecting consumer preference for residential deck materials. Can J For Res 38:1385–1396

Rasamoelina M (2001) Etude et analyse de la filière palissandre - exportation en vue d'une contribution à la réforme de la fiscalité forestière Malagasy. Mémoire d'ingéniorat, Ecole Supérieure des Sciences Agronomiques, Antananarivo, Madagascar.

Rice J, Kozak RA, Meitner MJ, Cohen DH (2006) Appearance wood products and psychological well-being. Wood Fiber Sci 38:644–659

Schuurman D, Lowry PP (2009) The Madagascar rosewood massacre. Madag Conserv Dev 4:98–102

Vandenbroucke N, Macaire L, Postaire JG (2003) Color image segmentation by pixel classification in an adapted hybrid color space. Application to soccer image analysis. Comput Vis Image Und 90:190–216

Van De Wouwer G (1999) Wavelet correlation signatures for color texture characterization. Pattern Recogn 32:443–451

Weinfurter S, Eder A (2009) Consumer perceptions of innovative wood-polymer composite decking with a focus on environmental aspects. Lenzinger Ber 87:168–178