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Durability and moisture content of the wood for furniture products in the city of Mbalmayo in Cameroon

Authors:
Ateba François Rene[1], Abossolo Samuel[2] and Tolok Nelem[1]

Institution:
1. Institut Universitaire de Technologique du Bois de Mbalmayo, Université de Yaoundé, Cameroon.

2. Département de géographie, Université de Yaoundé, Cameroon.

Corresponding author:
Ateba François Rene

ABSTRACT:

Drying is an essential step in wood processing, it gives the characteristics necessary for rational and efficient use. It improves the dimensional stability, better mechanical properties, durability, bonding ability etc. To understand the mode of wood processing structures at Mbalmayo in particular and Cameroon in general, this study aimed to analyze the principle drying methodology used in the manufacture of objects of art and other furnishing products through the humidity of the wood used, existing materials and methods, conduction of dryness, the selection criteria and the influence of average life of dried essences. Also, this study is based on the data collected at the carpentry workshops gathered in the art wood craft shops at the town of Mbalmayo. The results highlight the spontaneous strategies or planned adaptations used in the present study. The study was conducted at the Institute of Wood Technology, University of Yaounde, located in the town of Mbalmayo.

Keywords:

Drying gradient artisans, Saturation point, Moisture equilibrium, Mbalmayo.

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INTRODUCTION

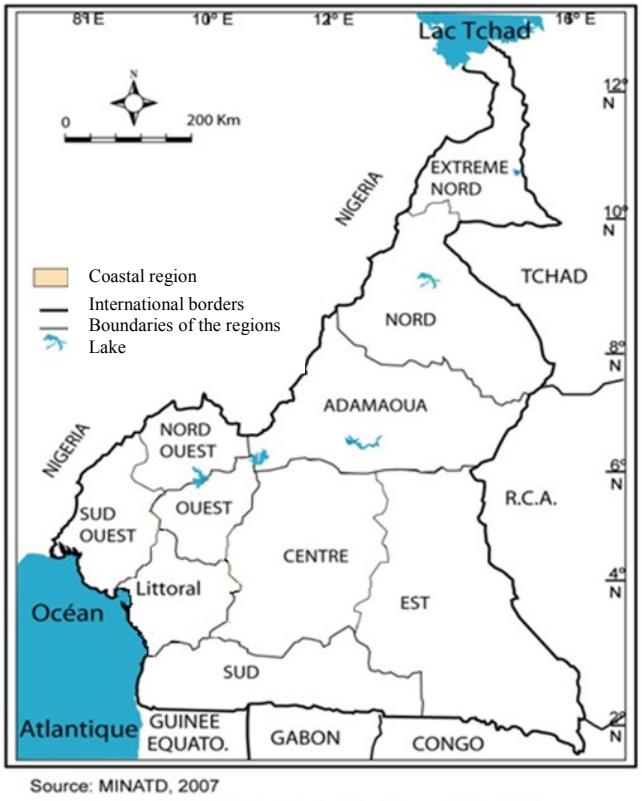
Timber management is the major concern of all processing industries involved in the wood industry to do wooden arts, more specifically for making well-defined features. Also, planning, compliance, operation and process of the structures of art woods have become essential. The survey of wood resources is a necessary step to this planning, in that it allows to estimate the potential of the wooden stock, and important steps for better optimization of wood in its use potential. The evalution for proper use of this potential requires some tools such as humidity, hystersis sorption moisture, handling and transportation of timber, forest products storage and preservation system and wood processing technology. Based on the data collected, it is tried to globally define the dominant relational settings between the variability of the likely characteristics of humidity used and types of art making in the town of Mbalmayo, large processing center and Centre for Wood Research, located at the Congo Basin area with its intense forest activity in Central Africa.

Context

The law no. 94/01 on 20 January 1994 governing foresets, wild life and fishing of Cameroon states in its article 23 (RC, 1994). The development of a permanent forest is defined as the implementation of plant and animal life on the basis of objectives and a plan agreed in advance for a number of activities and investments to the continued protection of forest products and services without prejudice to its intrinsic value or compromising future productivity of that forest, and without causing adverse effects on the physical and social environment. It is a repository of good practice for the development of wild life. Cameroon's forest code is a framework document in the country that general principles for businesses and other wooden products manufacturers who wish to engage in it can do on the basis of the same base. It offers the indicators to allow comparison between the processing based on wood products of the same category. This reference guide brings some explanations and concepts; with precise conditions on referential standards and requirement on some wooden objects. To make our analysis more detailed and readable, the products made from wood in Cameroon require reflection from the practises of the recent years. This pilot project will be finalized at the Graduate Institute of Wood Technology (IUT-Wood) Mbalmayo, linked to the University of Yaounde, giving practical importance to wooden buildings and other projects related thereto.

This study is a test approach in line for that indicators are appreciated in the present frame work. The moisture content of the wood processing, a major element of our study helped us to estimate the lifetime of objects according to their uses and their living environment. Therefore, in the analytical requirement we specified the calculation methods and the analysis of Life Cycle Assessment (LCA) of woods according to the reference humidity of the manufacturing objects based on the wood and living environment of the products. This research has identified all potential impacts of a product based on the wood and its environmental impacts associated with the possible treatments. This type of evaluation is framed by the International standards ISO 14040 and ISO 14044. These standards have left open some of our methodological choices (ISO, 2006a; ISO, 2006b).

In the wood work in Cameroon and around the world, the test range or lamellae (Svensson and Toratti, 2002) have shown that the timber under the conditions of temperature and relative humidity of the air was not immediately in hygroscopic equilibrium. It is considered that the wood surface effect in balance while the heart or central portion resist moisture thereof for a while to get there. The ratio of moisture in the heart of the wood and wood surface, called moisture gradient influencing life of the processed wood products. This will be the value common to all species which are not



Source: MINATD, 2007

Figure 1. Map of the location of Mbalmayo

dependent on the criteria of wooden objects related to their design and reference humidity. The woods life were assessed in a minimal or maximum way (extremum). To conduct this analysis, we have focused on a sample of wood processing workshops in the town of Mbalmayo, strong production and processing of timber in Cameroon.

The scope of our scientific analysis is a better classification and appreciation of high reliability moisture content of the wood based on its future use in its operating environment. As for the economic significance, it is aimed to assess the price of the basic wood products according to the estimable life and depending on their use, it will be subjected to further studies too.

The objective of this study is to evaluate the influence of temperature and moisture content of the wood and to analyse its mechanical properties for estimating the life of furniture products based on the initial water content and essences used. This would complete some gaps, and to plan knowledge in the midst of Cameroon's wood processing challenges in general and for processing facilities at Mbalmayo in particular.

MATERIALS AND METHODS

Choice of the study area and data collection

Surveys were conducted at Mbalmayo on 2017 with a hundred of companies and small manufacturers of art in the city of Mbalmayo (Figure 1). This city concentrates nearly 50% of the plated-industries at Cameroon, usually sawmills and craftsmen works of art objects. With this intense activity, the Cameroonian state has created two great schools in forestry and wood processing under the University Institute of Technology (UIT) and the National School of Forestry (NSF) to improve this division of processing timber forest products and non-timber. To appreciate wood art used in this work, several parameters were used:

The natural durability of wood depending on the piece of art to achieve. This settings brings up to five

Table 1. Classification of the natural durability of wood depending on the environment

S. No	Classes	Humidity and characteristics	Uses
1	Class 1	Dry wood; humidity always less than 20%	Interior joinery or areas resistant from moisture.
2	Class 2	Dry wood in casual contact with moisture; humidity greater than 20%	The framing of objects
3	Class 3	Wood in frequent contact with moisture; Humidity level beyond 20%	The external structures such as siding.
4	Class 4	Wood dry, stable and rot in constant contact with fresh water	Exotic constructions
5	Class 5	Dry and very durable wood in permanent contact with salt water	Exotic constructions

Source: Gandon (2007)

Table 2. Humidity of wood in the processing industry

S. No	Humidity level %	State of wood
1	>30	Green wood
2	<30	Pre dried wood
3	<20	Wood protected against fungal attack
4	<18	Dried wood

Source: FIBRA, 2007

classes in the realization of some wooden pieces and itself in turn involves five job classes, where a middle piece converted will be stored for its use (Table 1).

These five classes are taken into consideration to appreciate the relative humidity of the wood given by the formula below:

$$\text{Hygrometric state} = \frac{\text{Tension of the vapour}}{\text{Tension of the saturated vapour}} \times 100$$

Water content of wood are an important parameter not acting alone on the life of the wood, it would be important to involve other factors when drying as the drying gradient and the humidity too involve in the process. Drying gradient or drying rate is the ratio of the wood moisture content to its equilibrium moisture content should be less than 5.5%. But in experience it is know that the drying gradient can withstand according to the species differentially. Drying, is the relationship between humidity control and equilibrium moisture. Since there are seven reference tables for drying African wood base, it should be determined for the tables at-least at seven intervals of drying gradients. While the moisture gradient (G) is given by the ratio:

$$G = \frac{H\%_{heart}}{H\%_{area}}$$

Table 3. Rate of humidity acceptable for wood processing

S. No	Jobs	Humidity level
1	Carpentry and farmhouses	15% ≤H% ≤22%
2	Timber (MOB)	H% ≤18%
3	Exterior joinery	15% ≤H% ≤18%
4	Glued laminated framework	H% ≤13%
5	Exposed timbers indoors	10% ≤H% ≤13%
6	Interior carpentry and flooring	8% ≤H% ≤12%

Source: FIBRA (2007)

Moisture gradient tells us that the timber under the conditions of temperature and relative humidity of the air is not immediately hygroscopic in equilibrium. We consider that the surface of the wood is balanced for this purpose while the heart wood put on a while to get there. The ratio of the moisture in the heart of the wood and its surface is thus the moisture gradient. Both gradients have influenced our notions and the choice of method of calculating the life of each category of furniture produced by a comparative study in the same scope as that carried out in Canada in the same sector as a contribution on the valuation of wood products by Canadian processors (FIBRA, 2007); thus, standards were defined by craftsmen for Art wood objects as shown in Tables 2 and 3.

The comparative study between the standards of FIBRA, (2007) (Canada) and workshops of the city of Mbalmayo showed us easily that the essences of two opposite environments; leads us to choose two different geographical areas for better understanding the difference in the samples of study and the process of two drying methods based on the environments. This wood drying may be either natural or outdoor (for storage under cover storage ventilation) or artificial (in drying cell). It should be therefore necessarily be checked regularly regardless of the medium in order to obtain optimum humidity depending on the species and the use that will be made. The drying in open air for one year can dry hardwoods from 15 to 20% of humidity. While the artificial drying (at the cost of some expenditure of energy and labour) can give us a month of dry wood of the same nature of 8 to 10%. This life of wooden pieces depend on the type of furniture design, criteria and density. For better machining, the above mentioned characters are necessary for wood and are indispensable.

Data processing

In this study, we used data extracted from the available literature sources in the scientific aspect. This allowed us to determine the average characteristics

and do in choice of certain species mostly used in the city of Mbalmayo for a better evaluation primarily and were processed through statistical analysis software Excel, SPSS version 12.0 on the secondary to axis for statistical analyzes of the eight dominant species (SPSS, 2005) (Table 4).

RESULTS AND DISCUSSION

General description of the situation workshops

The survey conducted in Mbalmayo provides information on commercial reasons (speed of response to customer requirements) and financial (rotational speed of the stock) that the structures resort to natural drying for making art objects by transformation made without drying before hand and without the determination of humidity. This plays a major role on the life of parts to achieve. In addition, on a hundred witnesses of business structures (respondents), 95% were about the starting wood moisture content and the middle of the half life. Because of its hygroscopic nature, wood constantly tends to a hygrothermal equilibrium with the air surrounding with its properties well defined (Djolani, 1972). The moisture balance of wood increases with the relative humidity of the air decreases with increasing temperature as elucidated. These same variables significantly affect the main physical characteristics of wood, which in turn influence the lifespan.

$$PSF = \frac{\text{Mass of bound water saturated}}{\text{Mass of dry wood}}$$

For the studied woods, the PSF is of the order of 30% moisture and is considered a lump sum equal to the value in the majority of documents (Figure 2). However, the PSF of tropical timber in general varied between 15 and 45% depending on the species. For our sample

Table 4. Species studied in the city of Mbalmayo

S. No	Gasoline	Scientific name	Characteristics	Density at 12% humidity	Uses
1	Mahogany	*Khaya ivorensis*	Variable colour from reddish brown to light red	570	Cabinet making, marquetry and violin
2	Bubinga	*Guibourtia tessmannii*	Dark wood usually, occasionally, a purplish red Vernage	920	Lumber for furniture
3	Black ebony	*Diospyros crassiflora*	Dark to, smooth grain, very hard	900	Wood working, sculpture, violin and marquetry
4	Iroko	*Milicia excelsa*	Yellow-brown in colour with more or less dark brown having golden highlights	640	Exotic wood and cabinet-making
5	Padauk	*Pterocarpus soyauxii*	Reddish to orange-red, streaked with darker veins. When exposed to light, it takes a beautiful dark brown color. It could rot	750	Exterior joinery, cladding, furniture
6	Sapele	*Entandrophragma cylindricum*	Colour similar to that of mahogany, but fine texture and Stability	-	Exterior joinery, cladding, furniture, exterior carpentry, siding, furniture, manufacturing against plate, cabinet
7	Wenge	*Millettia laurentii*	Veining bicolor, rather coarse grain	870	Parquet, cabinetry, turnery, cutlery
8	Zebrano	*Microberlinia*	light yellow brown with dark brown veins, and many fine	700	Hardwood, Its veneer evokes skin zebra

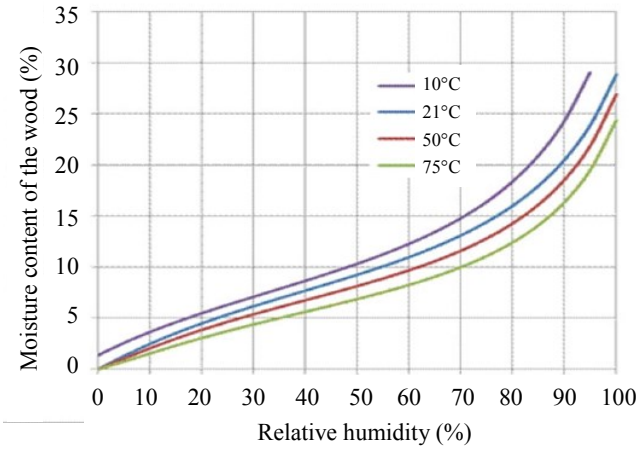


Figure 2. Relative humidity Vs moisture content of the wood

class, practice showed us that PSF is much more variable with steady humidity not always exactly the same. For wood with PSF is 30% located in an environment conditioned at 20°C temperature and a relative humidity of 65%, its hygroscopic equilibrium humidity is close to 12%, which greatly influences its average life. The time required for the timber to reach equilibrium moisture varies, also depending on the type of wood, its section and the variation of moisture to undergo. It can be accelerated at high temperature (artificial drying principle). In reality, the equilibrium moisture is never reached, humidity is stabilized at approximately 1% above the equilibrium moisture during drying and approximately 1% below the humidity of balance upon wetting. These studies led in turn to the hysteresis, the moisture sorption in the said location (Figure 3).

Hysteresis of moisture sorption in Mbalmayo

In general, more work on the wood showed that at a fixed temperature and relative humidity data balance achieved after a loss or moisture taken substantially differ from each other. This phenomenon is designated as the hysteresis of moisture sorption. Adsorption refers to the attachment of water at its molecular level to the inner face of a wood body and more through the capillaries present in the membranes. The reverse, the loss of moisture, is called desorption (Goulet and Fortin 1975). In the town of Mbalmayo by comparing the data, sorption curve of the timber indicated that it is a molecular poly, these zones are being described as follows:

- The zone at low humidity showed a relative value that the attachment of the first layer of water molecules on the sorption sites of cell membranes, the binding energy is important and low mobility of water molecules are considered.
- To intermediate relative humidities, the water molecules are fixed on the first layer which is already absorbed, the binding energy decreases with the number of layers.

To further deepen our study on the life of the wood in our sample, we are also interested in the behaviour of various constraints, important parameters of drying and removal of water in the wood. The stresses induced by differential withdrawals (mainly in the radial and tangential direction) (Figure 4) may therefore deform the work piece or even cause slot breaks. To avoid this on timber set up, the moisture (or moisture content: amount of water present in the wood, expressed as a percentage of dry weight) given by the formula the humidity H% quantitatively tells us the amount of water associated with it. Thus, the humidity is determined by the formula below:

Table 5. Comparative analysis of wooden parts based on the moisture content (dried and undried)

S. No	Durability class	Drying		
		Wood without drying (years)	Drying not reinforced (years)	Drying reinforced (years)
1	Average	6-8	15	30-40
2	Long	8-10	Around 20	40-100
3	Short	2-3	Around 10	20-30

Table 6. Characteristics of wood works from different regions

S. No	Characteristics	Mahogany	Azobé	Ebony
1	Hardness	2.5	10.7	7
2	Density	0.57	1.06	0.90
3	tangential shrinkage	5.5%	10.3%	11%
4	radial shrinkage	3.7%	7.3%	7.0%
5	Coef of volumetric shrinkage	0.39	0.69	0.51
6	PSF	28%	28%	29%

$$\frac{(\text{Mass}_{\text{wet}} - \text{Mass}_{\text{anhydrous}}) \times 100}{\text{Mass}_{\text{anhydrous}}}$$

It is known that water can be removed by drying naturally or using a mechanical dryer as close as possible to remove moisture content of the planned service. In North America, it is usually between 8 and 12%.

With the curve above, as the sample size increases, the factors affecting the mechanical properties of wood become more important. (Jayne 1972; Lang and Kovacs (2001) explained that the increase in sample size implies to increase the probability of occurrence of defects. Bodig and Jayne (1982) mentioned that the effect of the size of the specimens is often explained by three factors: the probability of occurrence of fractures by stress and the heterogeneity of the material which brings us to a second study of the comparative wood pieces depending on the humidity (dried and undried) (Table 5).

Data interpretation

Our study showed the results that the average term of art objects made of wood when class 1 is used (situation in which timber or product based wood is under cover, not exposed to weather and humidification) because not dried is 15 years when not undergone any

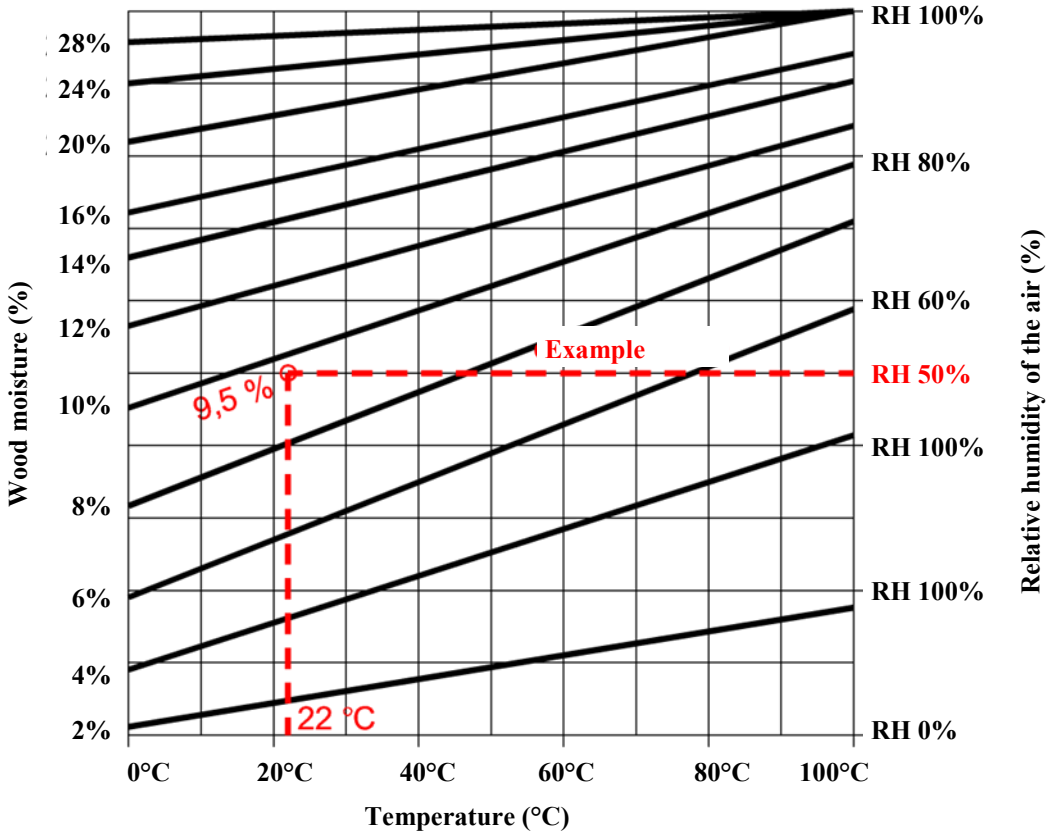


Figure 3. Feasibility moisture equilibrium

Table 7. Sawyers survey 2017 at Mbalmayo

S. No	Questions and answers to entrepreneurs: Why they do not dry the wood before processing?	%
1	No request or requirement of identified need?	35%
2	Dryer investment cost	18%
3	Cost and drying selling price	16%
4	Missing space	8%
5	Subcontracting	7%
6	Regional practice not to dry	4%
7	Other reasons	12%

Source: Folefack, 2016

type of drying under treatment. But if it has been dried and possibly treated, this period will be about 40 years old. When in use, class 1, the density also influences the life in general of the wood.

The density of the wood

The density is the main factor to estimate flawless timber mechanical properties, because it measures the relative amount of solid material of the cell wall. However, to further determine the strength of wood, consider the proportion of the components of the cell wall and the amount of extractables (Wangaard 1950; Panshin and Zeeuw 1980; FPL 1999; Hernández 2007). Bodig and Jayne (1982) state that the density of the timber is constant for all species and varies between 1508 kg/m³ and 1542 kg/m³. In this way, the large variation of density in existing gasoline or between species is mainly caused by anatomical differences expressed as the porosity of which the following Table 6 of the selected species.

Advantages

Production of timber necessarily involves the wood drying step to ensure the stability of the moisture content and size and to improve the mechanical properties for meeting the heat treatment programs according to the requirements of the export or processing market. This stage of production resulting in the loss of product quality due to the presence of curvature.

Dry wood allows best pose and that any small deformations or slots can be taken into account during installation to make them less visible hence the importance of drying before the sale of the products. The woods are encased in insulation, ceiling or wood frame wall are required to be dried, as moisture will remain imprisoned.

Influence of moisture on wood purchased in Mbalmayo

Using the detailed database on the sales of wood products purchased from Mbalmayo, we have highlighted the importance of the heterogeneity of the

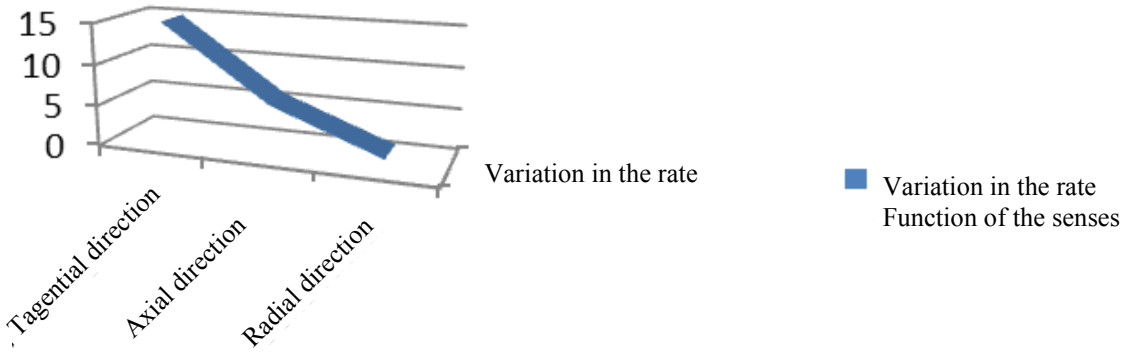


Figure 4. Change in the moisture content depending on the direction

wood on their probability of selling based on their price depending on drying or unprocessed. We first demonstrated the need to group wood essence to more accurately estimate the implicit prices and characteristics of different objects. In fact, the price equation changes depending on whether the species or batches of mixed first, and drying or not. Our in-depth analysis stresses the importance of the correlation between species and drying the outcome of the sale price. Several other characteristics significantly influence the likelihood of sale and the price of an object made of wood. This allows for valuable information about the optimal way to manufacture items such as we have shown in other more moisture content. In addition, several interesting results are worth noting; Firstly, the mode of sale by auction trading sometimes that does not alter the implicit price of the characteristics of these items. But, it turns out that the items traded wood are sold significantly cheaper than lots sold according to our study at Mbalmayo.

Finally, the methodology developed here provides valuable information to approximate optimal species composition before and after drying and likely a better estimate of the price itself, based on the life of then dried or non-dried essences to eventually allow the seller to commit credibly to a relevant price, the same price that is based on the life of the fabricated article.

Table 7 shows survey results of sawyers and other processing units at Mbalmayo for not drying the wood. In view of the above table, the lack of demand by consumers and a lack of demand for dried products have little effect on the sales of basic wood products in the town of Mbalmayo, or drying as demonstrated influences life object made of wood materials. In general scientific results vis-a-vis the moisture content of said materials showed that in the achievements made in building homes and timber frame buildings and other products, the humidity should be below 18%, while in framing it should exceed 22%. In traditional frames and trusses, it is $15\% \leq H \leq 22\%$. With regard to the exterior carpentry this rate is between $15\% \leq H \leq 18\%$. For Glued-framing H% is lesser than ≤13% having visible framing within $10\% \leq H \leq 13\%\%$, the millwork and parquet $8\% \leq H \leq 12\%$. I therefore propose ANAFOR Agency, a responsible body for standards in Cameroon should have a set of specifications regarding wood materials especially the humidity necessary for wooden objects vis-a-vis their class of objects.

Depending on the destination, wood materials should follow a certain margin on the humidity and precautions by ANAFOR in the field of wood as woods need to be dried to a degree of humidity of 18% or less before being placed in the assemblies. The wooden interior usually need to be between 8 and 12% humidity; the exterior wood and construction between 13 and 22%. If the wood installed is too dry or too moist, it will swell or retract until reaching its equilibrium moisture. Wooden strong sections can thus work too, if they are not installed in the right humidity it would change towards its equilibrium moisture content.

Twisted wooden: causes and effects

To understand the deformation of wood, we are interested in first place in the constitutions of the wooden products. The living wood as any organic material, contains a lot of water (more than 50% of its mass). We distinguish three "kinds" of water: free water, between the wood fibers (in the vessels), water "constitution" that constitutes the molecules of wood, and finally bound water. The latter is contained in the fibers of the wood in the cell wall. When felling the tree, the "free" water will evacuate first by evaporation without the wood undergoes deformations. After all water have evaporated (about 15 days), it reaches the "saturation point fiber" condition. For example, for a temperature of 20°C and an ambient humidity of 80% for temperate countries like Cameroon, the equilibrium will be reached when the timber will have only a moisture content of about 16%. The wood will therefore lose water: it is the bound

water that will evaporate (in part), which cause a shrinkage of the wood and narrowing as the water evaporated from the cell wall can not be replaced by emptiness. Even after starting this adjustment, the wood can still undergo deformations, because the balance may see one of its parameters change which plays on its life: for example, when moving in a more humid environment, moisture content of wood will rise again and will again distort the wooden object. The deformities are common, especially for outsiders, exposed to the temperature and humidity changes. Compared to research conducted in the same scope in Saint-Laurent in Canada in 2013 (by the wooden craft of Experts), in their final report on the study of the potential use of wood in construction systems, the report of the same than the management of program of drying requires a margin content in humidity. Indeed, to achieve a target final moisture with less variation of the final object, the average shrinkage due to drying should not exceed 1.6%, no matter the process. It should remain very low by report on the withdrawal meet habitually in the wood of sawing (6-8%). This leads without deceiving us to say that these studies turn to St. Lawrence in Canada on one hand at the Boreal woodland Mbalmayo and the tropical wood according to different climates that have constant and direct correlation on characters of sustainability and the moisture content of the wood for furniture products, cum objects of our analysis.

CONCLUSION

The survey consisted of two parts, one qualitative, the other quantitative. The qualitative component was designed to uncover data on drying of wood in Mbalmayo, the nature of the manufactured products and the life of the products that are arising. As to quantitative component which sought to establish such forecasts, the price of these items were made according to the humidity. Regarding this component (qualitative), note that about a hundred companies participated in a vis-a-vis maintenance of this study. Given the quantitative side, we note that to constitute the list of enterprises to apply at the time of the survey, we used the students of IUTs wood Mbalmayo. From these companies, a sample of 19 companies was selected. From these companies, 11 were found relevant, that is to say that they have their employment of staff assigned to the tasks not relating to the drying of wood. Highlights of the study are structured around the three following points: the presentation of the income related to work organization, staff development needs in place and hiring forecasts of qualified staff or not.

Thus, this study has led us to demonstrate the nature, the density and the water of wood content and its influence in its properties mechanical properties, they who in turn influence the life of the products. The current analysis in the city of Mbalmayo offers the following assessment tools different rates wood moisture to determine the risks facing its life linked the low dynamics of drying of wood material in the Mbalmayo, an epicenter of the wood processing area in Cameroon. Wood drying plays an important role in the life of the wood material, the processing industry and the sawmill and flaking which is the first wood processing work place. These sectors are in the middle between the forest industry and occupies a strategic position in the timber industry. The same study will be conducted in other cities with high potential wood processing in the Congo Basin in the future.

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