EFFECTS OF THERMAL MODIFICATION BY THE HOT OIL TREATMENT PROCESS ON SOME PHYSICAL PROPERTIES OF TWO CAMEROONIAN HARDWWOD SPECIES

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ABSTRACT

This work deals with the elaboration and the physical characterization of thermally modified wood with boiling palm oil. The heat treatment consists of dipping successively the wood into two baths of oil, the first one at a temperature about 200°C for 30 minutes and the second at ambient temperature of 23°C. This resulted in important color changes of treated specimens. The wood species used for the study are Sapelli and Ayous, two Cameroonian hardwoods. A compared study of the physical properties of treated and untreated wood was made. Hygroscopicity of heat-treated wood has been tested. Samples were dipped in water and then kept in a room with a relative humidity of 65% and a temperature of 23 °C. The samples were periodically weighed over a period of 8 days. The conclusion was that during a short period the water permeability of heat-treated Sapelli was 70 per cent lower than that of normal dried Sapelli. The same result was found for Ayous. Heat treatment significantly reduces the tangential and radial swelling. The Specific gravity of heat treated wood was almost constant, but higher than that untreated wood. After an adequate treatment, the moisture content of these woods after dipping in water for a long time was less than 7%. It is therefore possible for these treated woods to be used outside without biological attack due to moisture. In addition, the dimensions of treated wood were almost constant.

Keywords: Thermal modification of wood, hygroscopicity, swelling, water absorption, specific gravity, color.

INTRODUCTION

Cameroon has more than three hundred wood species. Some of these woods are not naturally durable and it is necessary to treat them before use, especially for exterior use. Several treatment methods of wood are available. All of these methods modify the chemical or physical nature of wood in order to increase its resistance to bad weather, insects, decay resistance and reduce the water sorption and swelling significantly [1].
The chemical treatment consists of dipping the wood into preservatives which are in the majority of cases made of metal salts of type CCA(Copper, Chrome Arsenic). But this treatment calls upon a heavy and expensive material with relatively toxic substances. The use of environment friendly heat treatment process for treating wood has become an alternative to enhance their durability [2], [3]. The physical treatment primarily consists of modifying the nature of wood thermically. The hot oil treatment process adopted for this study consists of successively dipping the wood into two palm oil baths, the first bath, maintained at a temperature of 200°C. The temperature of wood increases and its moisture content decreases. The second bath is maintained at ambient temperature and allows the impregnation of wood cells by the oil. The transfer between the two baths is carried out quickly, in order to support the penetration of the product. The hot oil treatment process is inexpensive in investments and not harmful for the environment.

MATERIALS AND METHODS

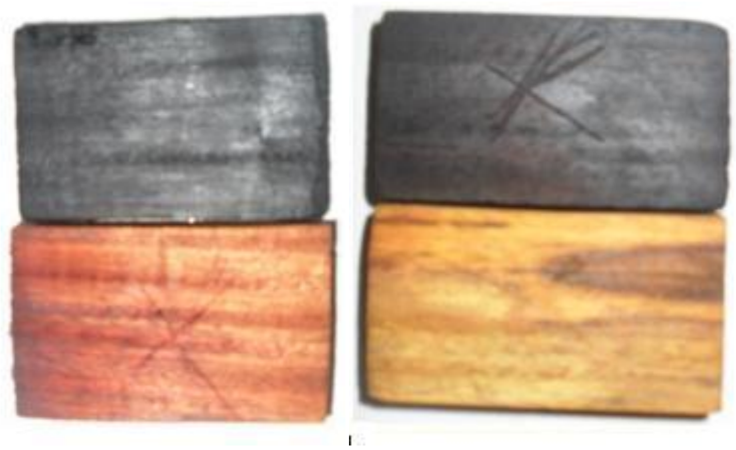
In this section, we present the material used during our experimentation. The materials used are four samples of wood from two different species (Sapelli and Ayous). Two of these samples are oil treated and two others are not The choice of Sapelli and Ayous is because these two species are abundant in Cameroonian marked also because they can not be easily used outdoor without biological attack or dimensional changes. Our study will enable us to evaluate physical changes between treated and untreated wood in several environments. First the samples of our wood were put in an oven dry at a temperature of 103°C until the stabilization of the weight (evaporation of all the water in the wood). After that wood was dipped in water until stabilization of the weight (maximum absorption of water). Our material was designed from two wood samples coming from trees arrived at maturity. These woods were dried naturally and samples were cut out before being treated in heating oil.

Sapelli

Sapelli (scientific name *Entandrophragma cylindricum),* is one of the wood species found in abundance in Cameroonian forests. It is a hardwood of red brown color and classified as fairly durable.

Ayous

Ayous is a nondurable wood of the family of the angiosperms (harwood). It is, like Sapelli, available in great quantity in Cameroonian forests. Its scientific name is *Triplochiton scleroxylon*. Ayous is a light wood of clear yellow color.



(a) (b)

Figure 1: Wood samples : (a) sapelli , (b) ayous, up treated , down untreated (control sample)

Sampling

The wood samples were air-dried then treated in hot refined palm oil. We kept some samples untreated with an aim of comparing the properties.

Table 1 Initial characteristics of the samples. NT untreated; T treated

Sample	Axial Length LA (cm)	Radial Length LR (cm)	Tangential Length LT (cm)	initial Weight (g)
Sapelli NT	8.35	5.35	2.01	65.1
Sapelli T1	8.10	5.11	1.91	62.3
Sapelli T2	8.31	5.12	1.92	61.5
Ayous NT	8.17	4.52	3.03	53.7
Ayous T1	8.37	4.52	3.00	60.8
Ayous T2	8.05	4.51	2.92	65.6

Dry Oven

Figure 2 Dry oven

It consists of two parts: the cockpit and the regulating circuit.
1. The cockpit is a room in which the temperature is regulated at a desired value.
2. Regulating circuit: a keyboard located on the lid of the device makes it possible to regulate the temperature. Within the framework of our work, the temperature was regulated with 103°C to allow water removal from the samples.

Measuring equipment

The masses are weighed using a numerical balance having an uncertainty of 0,1g. The dimensions of the samples are taken using a slide caliper having an uncertainty of 0,1mm.

METHOD

Treatment of wood

The treatment of wood was made by using two oil baths. Into the first one, we introduced refined palm oil which we carried to boiling and maintained at a temperature of 200°C. In a second bath, palm oil was at ambient temperature of 23°C. Two samples of each species were dipped successively into the hot and cold baths during approximately 30 minutes. The transfer between the two baths was made in a very fast way in order to facilitate the impregnation of oil in wood.

Humidification

We choose to humidify our samples by dipping them in water until saturation. During intervals of time, we made measurements of weigh and dimensions.

RESULTS AND DISCUSSION

In this part, we present the main results obtained in the laboratory and compare them with the literature in order to see whether these results are coherent and consequently if the method used is good.

Drying

The following table shows the dimensions and the weight of the samples at the end of the drying process.

Table 2 Characteristics of the samples at the end of drying

Sample	Axial Length LA (cm)	Radial Length LR (cm)	Tangential Length LT (cm)	final Weight (g)
Sapelli NT	8.33	5.14	1.91	52.4
Sapelli T 1	8.08	5.06	1.88	58.8
Sapelli T 2	8.30	5.06	1.88	57.5
Ayous NT	8.13	4.45	2.92	43.3
Ayous T 1	8.35	4.48	2.98	56.9
Ayous T 2	8.05	4.48	2.88	61.0

After 8 hours of drying, we noticed that the weights of the samples did not vary any more: wood was thus in an anhydrous state.

Humidifcation

The following table represents the dimensions and the weight of the various samples at the end of the humidification process. The humidification of wood took place right after drying.

Table 3 Characteristics of the soaked samples after stabilization of their weight.

Sample	Axial Length LA (cm)	Radial Length LR (cm)	Tangential Length LT (cm)	final Weight (g)
Sapelli NT	8.35	5.33	2.00	63.5
Sapelli T 1	8.09	5.12	1.92	63.1
Sapelli T 2	8.31	5.13	1.92	62.3
Ayous NT	8.18	4.59	3.06	65.5
Ayous T 1	8.39	4.57	3.07	68.6
Ayous T 2	8.09	4.56	2.98	69.7

Exploitation of experimental results

In this section, we will adopt the following notations: SapNT for the sample of untreated Sapelli; SapT for the treated sample; AyNT for the sample of untreated Ayous and AyT for the sample of the treated Ayous

Moisture content of wood

After having determined the anhydrous weight of the various samples, we can draw the graph giving the moisture contents according to time. Specimen was heated in a dry oven at 103°C. The hygroscopic study of wood makes it possible to know if this wood can be used outside or not. Indeed, a wood which absorbs too much water cannot be used outside because it will be attacked by fungus or insects. The following graphs represent the curves of absorption of water by our samples when they are soaked in water and weighed at regular intervals of time until stabilization of weight.

Table 4 Initial an final moisture content in wood

Sample	initial weight (g)	finale weight (g)	Moisture content (%)
Sap NT	65.1	52.4	24.24
Sap T 1	62.3	58.8	5.95
Sap T 2	61.5	57.5	6.96
Ay NT	50.7	43.3	24.01
Ay T 1	60.8	56.9	6.85
Ay T 2	65.6	61.0	7.54

We observe that the heat treated wood absorbs less water than the untreated wood. We can say that during a short period the water permeability of heat-treated Sapelli is 70 per cent lower than that of normal dried Sapelli. The same results was found for Ayous.

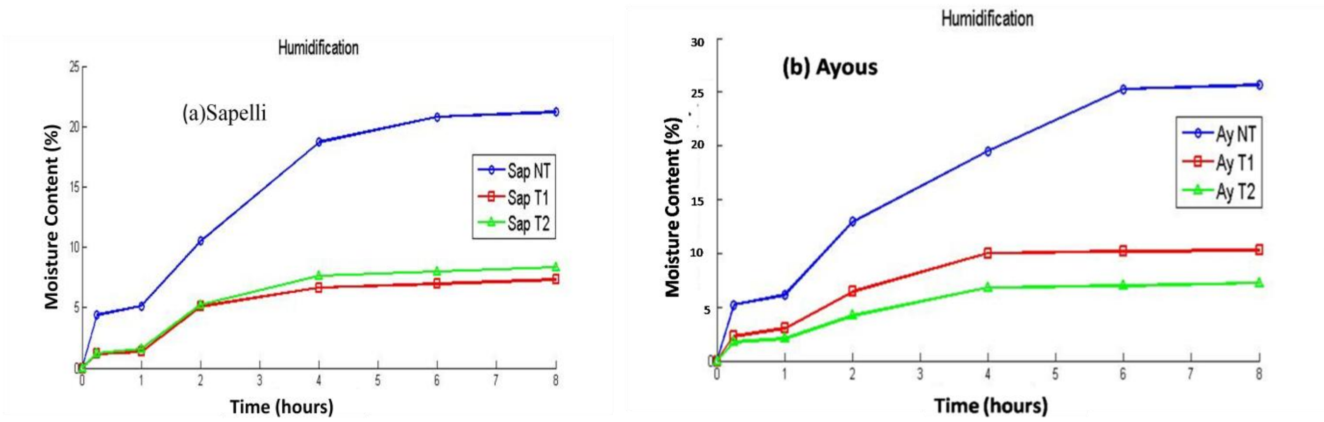


Figure 3. Evolution of moisture content of soaked samples as a function of time : (a) Sapelli, (b) Ayous.

Variation of weight according to time

The tables obtained during our experiments make it possible for us to see how the weight of wood varies according to time, when it is dried in a oven at 103°C, then humidified in water. This variation is illustrated by the graphs of figure 4 and 5.

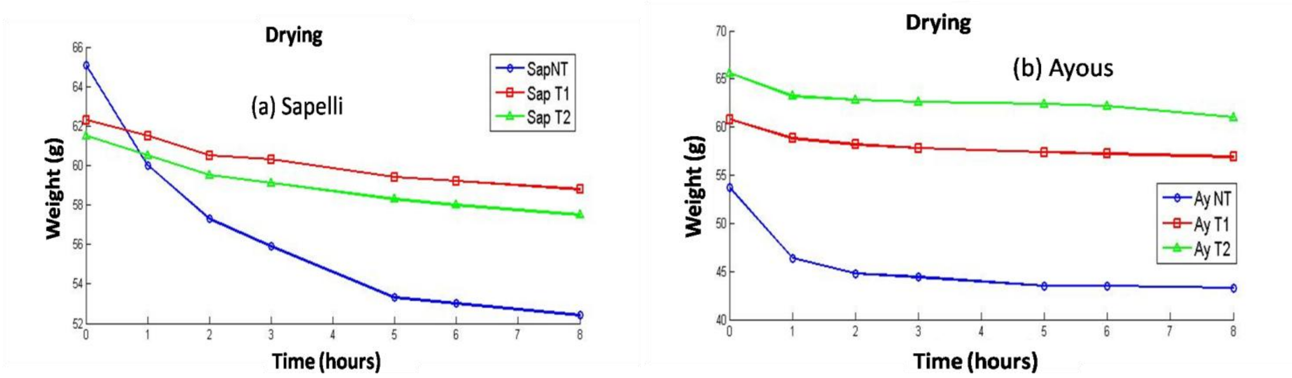


Figure 4 Variation of the weight as a function of time during drying : (a)Sapelli, (b) Ayous.

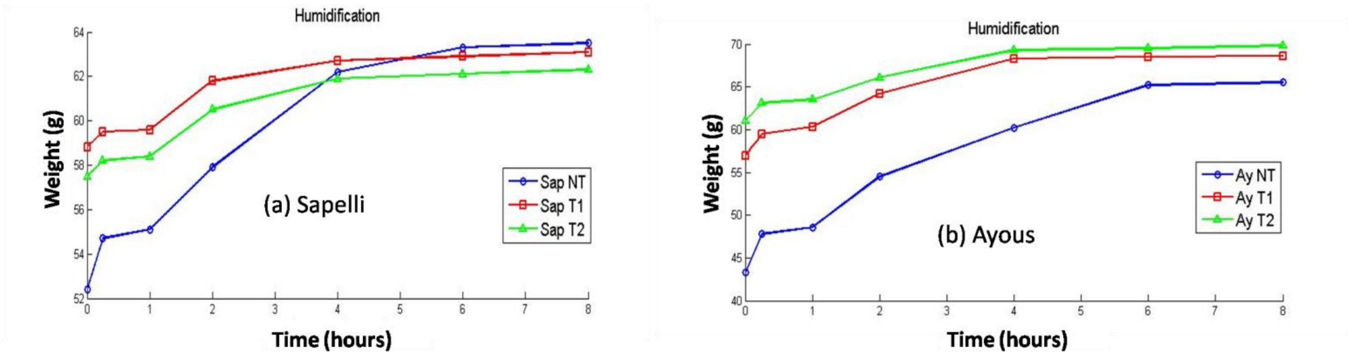


Figure 5: Variation of the weight as a function of time during humidification : (a)Sapelli, (b) Ayous.

These graphs show that the weight of treated wood is more stable than that of untreated wood.

Variation of the specific gravity according to time

Specific gravity is a measure of the amount of solid cell wall substance and is also known as “relative density”. It is a ratio of the density of a substance to the density of water. In our case, the ovendry (OD) weight of a wood sample is used as the basis and comparison is made with the weight of the displaced volume of water. In equation form this is:

SG = OD weight of wood/Weight of an equal volume of water

The graphs of the following figure gives specific gravities of our samples according to time. These graphs enable us to see that the specific gravity of treated wood is more important than that of wood untreated.

The following table recapitulates the various values of shrinkage in wood. In the table,

LAa is the axial length of the speciment in anhydrous state;

LTa is the tangential length of the speciment in anhydrous state;

LRa is the Radial length of the specimen in anhydrous state;

Va: Volume of the specimen in anhydrous state;

Las is the axial length of the specimen in saturated state;

LTs is the tangential length of the specimen in a saturated state;

LRs is the radial length of the specimen in a saturated state;

Vs is the volume of the specimen in a saturated state;

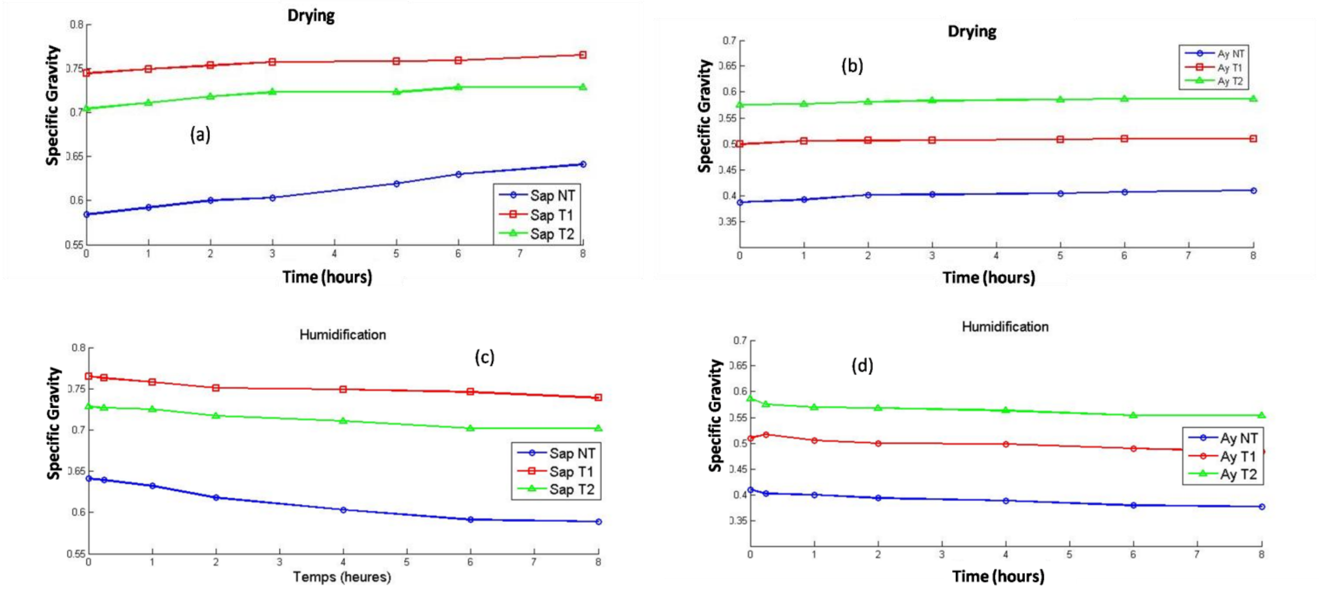


Figure 6 Variation of the specific gravity of wood : (a) Drying Sapelli, (b) Drying Ayous, (c) humidification Sapelli, (d) humidification Ayous.

Table 5 Dimensions of wood in anhydrous and saturated states

	LAa (cm)	LRa (cm)	LTa (cm)	Va (cm3)	LAs (cm)	LRs (cm)	LTs (cm)	Vs (cm3)
Sap NT	8.33	5.14	1.91	81.779	8.35	5.33	2.00	89.011
Sap T1	8.08	5.06	1.88	76.863	8.09	5.12	1.92	79.528
Sap T2	8.30	5.06	1.88	78.956	8.31	5.13	1.92	81.850
Ay NT	8.13	4.45	2.92	105.641	8.18	4.59	3.06	114.891
Ay T1	8.35	4.48	2.98	111.476	8.39	4.57	3.07	117.710
Ay T2	8.05	4.48	2.88	103.864	8.09	4.56	2.98	109.933

From this table we obtained the following swelling values.

Table 6 Swelling values in wood

	Axial Swelling (%)	Tangential Swelling (%)	Radial Swelling (%)	Volume Swelling (%)
Sap NT	0.239	4.501	3.561	8.125
Sap T1	0.124	2.083	1.172	3.351
Sap T2	0.120	2.083	1.365	3.536
Ay NT	0.611	4.572	3.051	8.051
Ay T1	0.477	2.932	1.969	5.296
Ay T2	0.494	3.356	1.754	5.521

It is deduced from these tables that wood can not only vary with weight in the surrounding medium, but also with dimensions.

DISCUSSION

We can observe the effect of swelling due to moisture in the tables above. Heat treated wood maintained its form. Unlike timber in general, heat treated wood does not feature drying stress. This is a clear advantage, seen when, for example, splitting the material and manufacturing carpentry products. In addition, the wood's swelling and shrinkage is very low. Heat treatment significantly reduces the tangential and radial swelling.

The Equilibrium Moisture Content (EMC) of wood soaked in water is observed, and we can find that heat treatment of wood reduces the equilibrium moisture content. Comparisons made of heat treated wood with normal untreated wood in water shows that heat treatment clearly reduces the equilibrium moisture content of wood. The equilibrium moisture content is about third that of untreated wood.

The specific gravity is determined by measuring the weight and the dimensions of the samples.

We found that thermally modified wood has a higher specific gravity than untreated wood. This is probably due to the penetration of palm oil in the wood cells during the cold bath and is not a proof that modified wood will probably have more strength than normal wood. In addition, the wood was heated for only 30 minutes. Yildiz [2] reported that the density observed for beech (2.25%) and spruce (1.73%) treated at 130 ºC for 2 h was higher than that of control samples. On the other hand, at longer treatment times and higher temperatures, the density decreased.

Decreases in swelling (Table 5)in radial, tangential and axial directions were found for both Ayous and Sapelli, when oil treated at 200°C for 30 minutes.

In general, the swelling reductions in the tangential direction were found to be greater than the reductions in the radial and longitudinal directions. A decrease in swelling results in an increase in dimensional stability, which is required for several uses of wood.

These results can be explained by material losses in the cell lumen and hemicelluloses degradation due to the high applied temperature. It is known that the weight of wood material and its swelling decreases when heat treatment is applied. Heat treatment lowers water uptake and wood cell wall absorbs less water because of the decrease of the amount of hydroxyl groups in the wood. As a consequence of the reduced number of hydroxyl groups, the swelling and shrinking were lower [4].

Similar results were also observed when samples were treated in an inert gas atmosphere at 180–200 ºC and 8–10 bar of atmospheric pressure (beech, 10–15% density decrease; spruce, 5–10% decrease) [5]. In another study, the dimensional stability was 60% higher for oak heartwood, 55% higher for pine heart- and sapwood, and 52% higher for spruce heart- and sapwood after heat treatment [6].

Gunduz et al. [7] found that the physical properties of wild Pear wood were improved as 2.6%, 5.3% and 0.8% swelling in tangential, radial and longitudinal sections, respectively at 180°C for 10 h.

CONCLUSION

From this work we can say that the heat treatment of wood give a greater hygroscopic stability. Treated samples of Sapelli and Ayous, contrary to untreated ones can be used outside without risk of humidification. The weights and dimensions of treated samples are more stable due to small values of shrinkage. This confers to treated wood a broader range of use.

Heat treatments described in this work offer significant improvements in moisture related properties of Cameroonian hardwoods, for their potential use in indoors applications.

References

1. Seborg, R. M., H. Tarkow, A. J. Stamm. 1953. Effect of heat upon the dimensional stabilization of wood. J. Forest Prod. Res. Soc. 3(3) : 59-67.

2. Rafidah, S., W. Razak, and S. Zaidon, 2008. Effect of Oil thermally modified on Chemical Constituents of Semantan Bamboo (*Gigantochloa scortechinii Gamble*). Journal of Sustainable Development 1(2): 91-98. Canadian Center of Science and Education.

3. Raazak, W., K. Izyan, Roziela, H. Hanim, S. Othman, M. Aminuddin, and H. Affendy, 2011. Effects of hot oil treatment on colour and chemical changes in year-old cultivated *Acacia hybrid*. Journal of Tropical Forest Science (JTFS) 23(1): 42-50.

4. Yildiz, S., E.D., Gezer, U.C. Yildiz, 2006. "Mechanical and chemical behavior of spruce wood modified by heat". *Build. Environ* 41, pp. 1762–1766.

5. Feist, W.C. and J., Sell, 1987. "Weathering behaviour of dimensionally stabilized wood treated by heating under pressure of nitrogen gas". *Wood Fiber Sci* 19, pp.183–195.

6. Burmester, A. 1973. "Effect of heat–pressure treatments of semi-dry wood on its dimensional stability". *Holz Roh- Werkst* 31, pp. 237–243.

7. Gunduz, G., D., Aydemir, and G., Karakas, 2009. "The effects of thermal treatment on the mechanical properties of wild Pear (Pyrus elaeagnifolia Pall.) wood and changes in physical properties". *Materials and Design* 30, pp. 4391–4395.

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