Anatomical, physical and mechanical properties variability of bamboos in Togo

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RÉSUMÉ

Le Togo dispose d'importantes ressources en bambou utilisées en construction traditionnelle, en artisanat et comme matériau d'ameublement. Cette étude est effectuée sur quatre espèces de bambous dans un but de valorisation industrielle : Bambusa vulgaris Schrad. ex J.C. Wendl, Bambusa vulgaris var. striata Lodd. ex Lindl, Oxytenanthera abyssinica A.Rich. Munro et Bambusa sp. une espèce jusqu'à présent confondue avec B. vulgaris. Les caractéristiques anatomiques des fibres (la longueur des fibres, l'épaisseur de la double paroi des fibres et le diamètre des fibres), les paramètres tissulaires (proportion en fibres, en éléments conducteurs et en parenchyme) ainsi que les propriétés physiques et mécaniques des chaumes (la densité, le module d'élasticité MOE) ont été analysées. Les résultats permettent de donner un état d'avancement de la taxonomie de Bambusa sp. Bambusa sp., présente les fibres les plus longues, B. vulgaris et B. vulgaris var. striata ont les longueurs de fibres très proche tandis que O. abyssinica présente les fibres les plus courtes. L'épaisseur de la double paroi des fibres est semblable pour la quatre espèces. B. vulgaris var. striata présente les diamètres de fibres les plus épais (16.17 µm en moyenne) tandis que Bambusa sp. présente les fibres les moins épaisses. La proportion de fibres chez les quatre espèces est significativement plus élevée dans les parties périphériques du chaume. Chez O. Abyssinica, la position radiale des fibres à l'intérieur du chaume influence très peu sa longueur. Les facteurs écologiques n'ont aucun effet significatif sur la longueur moyenne des fibres. Les propriétés physiques et mécaniques (densité et MOE) montrent une grande variabilité entre les différentes espèces de bambous ainsi qu'à l'intérieur de chaque espèce. La densité varie de 510 à 600 kg/m3 pour B. vulgaris et de 640 à 788 kg/m3 pour B. vulgaris var. striata. Bambusa sp. présente la densité la plus élevée. A l'intérieur de chaque espèce, il y a une bonne corrélation entre le MOE et la densité. Cette relation est plus forte pour Bambusa sp. et plus faible pour B. vulgaris et Bambusa vulgaris var. striata. Les performances anatomique, physique et mécanique étudiées indiquent que Bambusa sp. est le meilleur bambou à promouvoir au cours des utilisations industrielles au Togo.

Mots clés : Proportion de fibres – densité - module d'élasticité - usages industrielles

ABSTRACT

Togo has important bamboo resources used as building, handicraft and furnishing materials. This study is carried out on four species for their industrial promotion: Bambusa vulgaris Schrad. ex J.C. Wendl., Bambusa vulgaris var. striata Lodd. ex Lindl., Oxytenanthera abyssinica (A.Rich.) Munro and a species until now confused with B. vulgaris. Anatomical characteristics (fibre length, fibre thickness and diameter, fibre, conducting tissues and parenchyma proportion), physical and mechanical properties (density, modulus of elasticity MOE) were analyzed. Results give a progress report on the taxonomy of the fourth bamboo (Bambusa sp.). Bambusa sp., presents the longest fibres, B. vulgaris and B. vulgaris var. striata have very close fibres length, and O. abyssinica the shortest fibres. Walls fibre thickness is similar for the four species. B. vulgaris var. striata presents higher fibres diameter (16.17 µm on average) whereas Bambusa sp. the lowest. Fibres proportion for the four species is significantly higher in the external areas of the culms. O. abyssinica is the species of which the radial position of fibres inside culms influences little the length. Ecological factors don’t influence significantly the average length of fibres. Physical and mechanical properties (density, MOE) have a great variability between different bamboos species and also inside each species. The density varies from 510 to 600 kg/m3 for B. vulgaris and from 640 to 788 kg/m3 for B. vulgaris var. striata. Bambusa sp. presents the highest density. In each species, there is a good correlation between the MOE and the density. This relation is stronger for Bambusa sp. and weaker for B. vulgaris and Bambusa vulgaris var. striata. Anatomical, physical and mechanical performances indicate that Bambusa sp. is the best bamboo to be promoted for industrial uses in Togo.

Key words: Fibre proportion – density -modulus of elasticity - industrial uses

1. Introduction

Continuous and uncontrolled uses of fores. resources in tropical areas contribute to decrease

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in phytogenetic resources and forest ecosystems decline. Development of unknown forest resources such as bamboos is an efficient way to reduce the commercial pressure on the traditional timber species. The use of the bamboo as a substitute for common timbers species is frequent in Asia and in Western Europe, (Chung et Yu 2002 ; van der Lugt et al. 2006, Omar Ali, 1981). In West Africa, bamboos represent around 2-3% of the forest resources (Kigomo, 1997), but they are often used only in traditional furnishing, houses buildings, art objects manufacture, men and animals food supply. Despite these multi-purpose uses of bamboos, very few studies aimed at the improvement of their technological properties, particularly in West Africa, contrary to Asia and Latin America countries, where important development and research projects have been carried out (Omar Ali, 1981; Widjaja and Risyad, 1987; Sulthoni, 1990; 1995). In Africa, some countries (Zambia, Kenya, Tanzania, Uganda and Ethiopia) recently undertook studies concerning rational and efficient use of the bamboo resources (Kigomo, 1997). In the specific case of Togo, there is no database ; the only information available are provided by the flora of Togo which mentioned the presence of Bambusa vulgaris in the south part of the country and Oxytenanthera abyssinica in the north, center and south-east parts (Brunel et al. 1984). A recent studies (Kokou et al. 2006a, Kokou et al. 2006b, Gnama 2005) showed five wild or planted species of bamboo in Togo: Bambusa arundinacea, Bambusa multiplex, Bambusa vulgaris, Bambusa vulgaris var. striata and Oxytenanthera abyssinica. Most frequent bamboo species were Bambusa vulgaris (85.21% of bamboo clumps) and Oxytenanthera abyssinica (11.28%). The other bamboo species (Bambusa arundinacea, Bambusa multiplex, Bambusa vulgaris var. striata) represented only 3.51% of Togo bamboos. A bamboo species very close to Bambusa vulgaris, actually named Bambusa sp. (taxonomy must be clarified), represented around 2.33% of the bamboos clumps listed in Togo and its area is confined to the southern zone of Togo Mounts. Sometimes it was found on the same sites as Bambusa vulgaris, in depressions along rivers.

Moreover, the techniques of transformation remain traditional and do not allow a long-term use of bamboos, in the particular case of wood industry for which good technological qualities of wood products are necessary. Industrial use of the bamboos requires a selection on the basis of the best technological aptitude (shrinkage, density, modulus of elasticity MOE and modulus of failure MOR). Bamboos species show a variability of their properties at the intra specific level, as well as at inter specific level which could be related to the geographical origin and the genetic factors (Banik, 1997 ; Soeprayitno et al. 1990). Influence of variability on the products quality (Abd. Latif, 2002), appears important to study the bamboos properties in order to better know them and to work on long-term strategies aiming to improve significantly the technological value. This study presents anatomical variability of bamboos of different ecological areas in Togo. Physical and mechanical properties are also analyzed with relation to the anatomical characteristics.

2. Materials and Methods

2.1. Study site

Mature culms of bamboos from 1 to 6 years old were selected in clumps, chosen randomly in the five ecological areas in Togo (Figure 1). In each ecological areas, a maximum of five samples of each species were collected.

2.2. Anatomical study

2.2.1. Determination of tissues proportions

Bamboo samples taken from culms were approximately 50 cm length × the thickness. A subsample of approximately 15 mm length × the thickness was cut out in each culm sample. The 15 mm-sample obtained were boiled with water during 4 hours and soaked in a 1/1 mixture of pure alcohol and distilled glycerol until they became soft. Samples are then subjected to fine cuttings using a microtome with slide. These cuttings were performed from periphery towards interior of culms. They were then

coloured with saffron and fixed in Canada balsam. Fibres proportions (sclerenchyma),

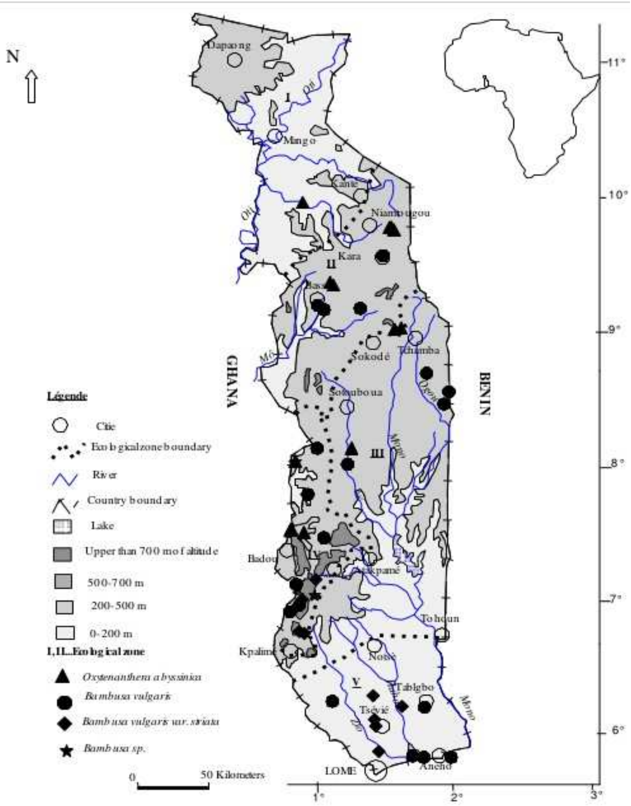


Figure 1: Distribution of the bamboo samples.

Zone I : zone of plains of north, tropical climate with one rainy season from June to October and a dry season from November to May (six to seven ecological dry months), corresponding to Sudanian savannahs; **Zone II**: zone of mountains of north, climate of the Sudano-Guinean type of altitude with fresh nights, one rainy season (April-October) and a dry season (October-March) marked by the harmattan, mosaic of dry forests and savannahs; **Zone III**: zone of central plains, tropical climate marked by one rainy season and at least 4 months a dry season, Guinean wood savannahs; **Zone IV:** southern zone of Togo Mounts, transitional subequatorial climate characterized by a great rainy season (March-October) with rain reduction in August or September semi-deciduous forests; **Zone V:** coastal plain in southern Togo, subequatorial climate marked by a very low rainfall (800 mm/year in Lomé).

conducting tissues proportion (phloem, metaxylem, protoxylem) and parenchyma proportions of culms were determined using a microscope with a small rule. The rule was superimposed on the cutting with an angle of 45°. Ratio of each tissue was obtained by counting tissues when they were located on the small rule. Ten measurements were made for each sample. Mean values were computed and variance analysis were carried out.

2.2.2. Measurement of fibres parameters

Two samples of match stick size were cut in each culm, one at the periphery and the other in the internal zone. Each stick was put in a test-tube containing a 1/1 mixture of acetic acid and pure peroxide of hydrogen solution. The tubes containing sticks were put in an oven at a temperature of 70°C during 24 hours. After, samples which became white were rinsed with water. Tubes were then strongly shaken in order to dissociate fibres and to isolate them individually. Solution drops of each tube containing fibres were assembled between blade and plates. Length and thickness of fibres, walls thickness and lumen diameter of fibres were measured using an optical microscope and a graduated micrometer. Fifty individualized fibres were measured for each sample, approximately 6900 fibres in total. At the level of each test-tube, 150 measures were made: 50 for the fibres length, 50 for the diameter and 50 for the lumen diameter of fibre. Properties average values were then calculated for all culms. Dimensions of fibres were obtained based on equations 1, 2, 3 and 4.

[Equation 1]

Where L=length of fibre read under the microscope;

$$LF=\frac{LxC}{1000}$$

C=37. 6179 = constant relating to the graduations of the micrometer and related to the objective;

LF=real length of the fibre (mm).

$DR=d\times K$ [Equation 2]

$DL=dl\times K$ [Equation 3]

Wher DR=real diameter of the fibre (µm);

DL=real diameter of the lumen (µm);

d=diameter of fibre read under the microscope.

dl=diameter of the lumen of fibre read under the microscope;

K=3.1339285 = constant value related to micrometer's graduations and linked to the objective;

Fibres walls double thickness (in µm) is the difference between fibres diameter and lumen diameter :

$2P=DR-DL$ [Equation 4]

2.3. Confection of the sub-sample for physical and mechanical measurements

Longitudinal modulus of elasticity and density at

12% of moisture content were measured with culms used for anatomical study. These measures were taken on sub-samples which moisture content was stabilized before the tests in an air-conditioned room at a temperature (T) of 20°C and an air moisture content (H_{air}) of 63%. Thirteen culms were selected without taking into account their ecological origin. The test pieces were made by using method suggested by Kouyoumji et al. (1999) (Figure 2). Six subsamples of 180 mm length (L) and 5 mm thickness (R) were made from each culm. Mechanical and physical tests were not performed on culms of Oxythenantera abyssinica because in this specie, the thickness of the culms is to low and do not permit to made the test pieces.

Each sub-sample was weighed and dimensions were taken (length, width and thickness) at three parts of the sample in order to obtain an average measure. Density was calculated based on ratio between mass and volume of the sample.

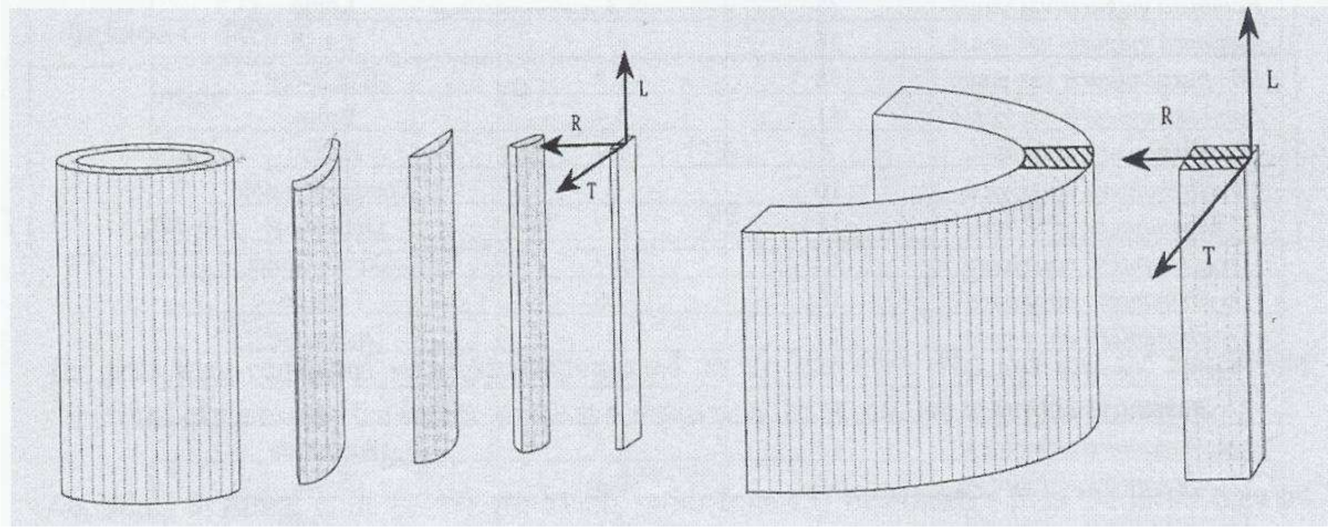


Figure 2: Methodology of specimen extraction in the LT (sub-elements of quarter sawn) and LR (quarter sawn) planes (Kouyoumji et al. 1999).

2.5. Determination of longitudinal modulus of elasticity

The method used is that of three-points bending test. Both force F applied and displacement of the middle point of the sample were recorded. Static elastic modulus E_{stat} was therefore computed during elastic phase of the loading. Calculations were done by applying strength of materials assumptions for a homogeneous material:

with L : distance between the two supports; h and b are respectively width and average thickness of 6 measures taken on the sample.

$$E_{stat} = \frac{\Delta F}{\Delta f}\frac{L^3}{4bh^3}$$

$\frac{\Delta F}{\Delta f}$: slope of the initial linear part of the force-displacement curve;

3. Results

3.1. Fibres variability with radial position

B. vulgaris fibres length varied between 1.13 and 3.73 mm. Thickness of the fibres double wall varied from 9.1 µm to 17.76 µm. Length and the thickness of fibres wall did not significantly vary according to radial position inside culms. Variance analysis showed a significant difference for fibres diameter according to radial position inside culms (F20,1=5.65; P=0;02). Fibres located inside culms had larger diameters than those located at the periphery (Table 1).

Fibres length of B. vulgaris var. striata varied from 2.05 mm to 3.06 mm; it did not vary significantly according to the radial position inside culms. Thickness of both walls and the fibres diameter varied respectively from 8.30 µm to 17.01 µm and from 12.54 µm to 20.37 µm. Radial position of the sample in the culms had no significant influence on these two parameters. Howe-

Table 1: Variation of different bamboo species fibres characteristics with position inside culms.

Species	Radial position	Fibre length (mm)	Fibre diameter (µm)	Lumen diameter (µm)	Fibre double thickness (µm)
Bambusa vulgaris var. *striata Lodd. ex Lindl*	Periphery	2.49 ± 0.11	15.14 ±0.71	2.89 ± 0.15	12.25 ±0.80
	Interior	2.60 ± 0.10	17.19 ±0.71	3.71 ± 0.29	13.48 ±0.76
Bambusa vulgaris Schrad. ex J.C. Wendl	Periphery	2.54 ± 0.10	14.63 ±0.49	2.79 ± 0.22	11.78 ±0.38
	Interior	2.62 ± 0.13	16.25 ±0.45	3.01 ± 0.20	12.95 ±0.45
Oxytenanthera abyssinica (A.Rich.) Munro	Periphery	1.98 ± 0.05	15.19 ±0.53	2.49 ± 0.17	12.70 ±0.50
	Interior	2.28 ±0.10	16.45 ±0.75	2.77 ± 0.20	13.68 ±0.66
Bambusa sp.	Periphery	2.55 ± 0.30	13.76 ± 1.58	3.12 ± 0.53	10.64 ± 1.20
	Interior	2.81 ± 0.28	16.88 ± 2.37	3.83 ± 0.81	13.05 ± 1.57

ver, fibres located inside culms had larger diameters than those located at the periphery (Table 1). Lumen diameter of internal fibres was more important than fibres diameter located at the periphery (F20,1 = 6.29; P = 0.02; Table 1).

O. abyssinica fibres length varied from 1.59 mm to 2.80 mm and their diameter varied from 9.80 µm to 22.53 µm. Lumen average diameter and thickness of fibres varied respectively from 1.71µm to 4.34 µm and from 8.12 µm to 18.55 µm. Fibres average length varied significantly according to radial position in the culms (F30,1 = 7.52; P<0.01), its value was 1.98mm ± 0.05 at the periphery and 2.28mm ± 0.10 at the interior. On the contrary, fibres mean diameter and double wall thickness did not vary with radial position in the culms.

3.2. Interspecific variability of fibres

Among species, Bambusa sp. was the one which had the most important fibres length (P<0,001, F101,3 = 10.04) (Table 2). B. vulgaris and B. vulgaris var. striata fibres lengths were similar (mean = 2.56 mm). Walls thickness sizes appeared to be identical for the four species. B. vulgaris var. striata fibres walls were the biggest (16.17 µm on average) whereas the smallest were Bambusa sp. fibres. Fibres of this species were the longest but the thinnest. O. abyssinica's fibres were the smallest and the thickest.

Table 2: Characteristics of different bamboo species fibres

Species	Fibre length (mm)	Fibre diameter (µm)	lumen diameter (µm)	wall double thickness (µm)
Bambusa sp.	2.68 ± 0.09	15.32 ± 0.73	3.47 ± 0.22	11.85 ± 0.53
Oxythenantera abyssinica (A.Rich.) Munro	2.13 ± 0.06	15.82 ± 0.47	2.63 ± 0.13	13.19 ± 0.41
Bambusa vulgaris Schrad. ex J.C	2.58 ± 0.08	15.44 ± 0.36	2.90 ± 0.15	12.61 ± 0.32
Bambusa vulgaris var. *striata Lodd. ex Lindl*	2.54 ± 0.07	16.17 ± 0.54	3.30 ± 0.19	12.87 ± 0.55

Table 3: Fibres characteristics variation of bamboo species studied with regard to ecological zone (average value ± average standard deviation)

Species	Ecological zone	Sample number	Fibre average length (mm)	Fibres average diameter (µm)	Lumen average diameter (µm)	Double thickness (µm)
Bambusa vulgaris var striata Lodd. ex Lindl	Zone IV	5	2.45 ± 0.09	17.34 ± 0.62	3.37 ± 0.32	13.97 ± 0.68
	Zone V	5	2.63 ± 0.10	15.00 ± 0.74	3.23 ± 0.20	11.74 ± 0.75
	Zone II	5	2.26 ± 0.12	14.87 ± 0.76	3.03 ± 0.40	11.81 ± 0.66
	Zone III	5	2.78 ± 0.14	15.82 ± 0.61	2.80 ± 0.30	12.97 ± 0.45
	Zone IV	5	2.52 ± 0.17	16.18 ± 0.80	2.63 ± 0.13	13.60 ± 0.70
	Zone V	5	2.67 ± 0.10	15.80 ± 0.73	3.31 ± 0.26	11.83 ± 0.62
	Zone I	5	2.21 ± 0.10	16.58 ± 0.82	2.83 ± 0.21	13.75 ± 0.74
	Zone II	5	2.11 ± 0.12	15.81 ± 0.35	2.51 ± 0.17	13.30 ± 0.36
	Zone IV	5	2.07 ± 0.08	15.07 ± 1.10	2.55 ± 0.28	12.68 ± 0.94
	Zone IV	5				

3.3. Fibres variability with ecological factors

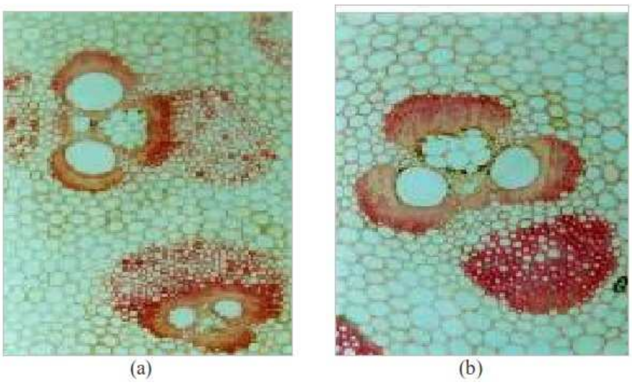


Photo 1: Vascular type in a transverse section of bamboo's internode.

a) Type Ib in Bambusa vulgaris: only one sclerenchyma continuous patch cover both metaxylems and the protoxylem (Liese, 1998);

b) Type III in Bambusa sp.: criblo-vascular fascicle covered of four sclerenchyma small patches and a isolated patch, internal of sclerenchyma located side of the protoxylem. The sclerenchyma patch of the protoxylem is always of small size (Liese, 1998).

For B. vulgaris var. striata fibres mean length was the same in ecological zones IV and V. While considering ecological zones, fibres diameter (F20,1 = 5.92; P=0.02) and double wall thickness (F20,1 = 4.75; P=0;04) varied significantly. In zone IV, diameter of the fibre including lumen and wall, had the highest values (Table 3). The four fibres parameters of B. vulgaris did not vary significantly with ecological zones. However, in zone III average fibres length was the highest (2.78 mm ± 0.14). In the same zone, fibres maximum diameter was the highest with an average value of 15.82 µm which appeared to be close to the highest value that found in zone V. O. abyssinica's fibres characteristics were not statistically different from an ecological zone to another. Nevertheless, fibres in zone I were the thickest and the longest.

3.4. Intra specific variability of tissue: influence of sample position inside culm

For B. vulgaris and B. vulgaris var striata, percentage of tissues varied significantly from periphery to interior of culms (Table 5). On one hand, parenchyma (F10,1=17.08 ; P<0.001) and conducting vessels (F10,1 = 4962; P<0001) proportions were the highest inside culms of B. vulgaris var striata. On the other hand, proportion of fibres was lower inside culms than the periphery (F10,1=65.65 ; P<0.001). B. vulgaris fibres proportion decreased from periphery to interior of culms, but parenchyma and conducting vessels (2 metaxylems, protoxylem and phloem) proportions increased. At periphery, fibres represented 56.44% of all tissues against only 26.73% inside culms (F14,1=167.98 ; P<0.001). Ratio of parenchyma was 54.32% inside culm against 33.76% at periphery (F14,1=61.00 ; P<0.001) ; for conducting vessels, the ratio was 19.14% inside and 9.72% at culms periphery (F14,1=25.83; P < 0.001). Fibres ratio for O. abyssinica decreased significantly from periphery (54.97%) to interior (26.97%) (F12,1=38.76 ; P <0.001) ; parenchyma proportions increased from periphery (33.64%) to interior (58.19%) (F12,1=33.95 ; P<0.001). However percentages of vessels varied slightly with radial position, as in the case of other bamboo species. Fibres in culms of Bambusa sp. were more important at the periphery than inside ($F_{10,1}$ = 142.85 ; $P < 0.001$). Parenchyma ($F_{10,1}$ = 63.55 ; $P < 0.001$) and conducting vessels ($F_{10,1}$ = 15.50 ; $P = 0.004$) ratios were higher inside culms than the periphery (Table 4).

Table 4: Tissues percentage of four bamboo species with the radial position.

Species	Radial position	Fibres (%)	Parenchyma (%)	Conducting vessels (%)
Bambusa vulgaris Schrad. ex J.C. Wendl	periphery	56.44 ± 1.61	33.76 ± 1.57	9.72 ± 0.57
	interior	26.73 ±1.63	54.32 ± 2.11	19.14 ± 1.76
Bambusa vulgaris var. striata Lodd. ex Lindl	periphery	57.43 ± 3.08	33.62 ± 3.23	8.77 ± 0.67
	interior	25.55 ± 2.45	52.82 ± 3.34	21.45 ± 1.67
Oxytenanthera abyssinica (A.Rich.) Munro	periphery	54.97 ± 2.01	33.64 ± 1.78	11.52 ± 0.76
	interior	26.97 ± 4.02	58.19 ± 3.82	14.32 ± 1.42
Bambusa sp.	periphery	58.65 ± 2.26	31.76 ± 1.73	9.20 ± 0.95
	interior	20.35 ± 2.27	63.73 ± 3.62	16.35 ± 1.55

3.5. Inter specific variability of tissue

Among the 4 bamboo species studied, Bambusa sp. had the smallest fibres ratio (Table 5), this species appeared therefore to be different from the others. A clear anatomical difference between this species and the others was the vascular type (Photo 1) described according to Liese (1998). Both B. vulgaris and B. vulgaris var. striata fibres proportions were almost similar. The lowest value of parenchyma percentage was the one of Bambusa vulgaris var. striata (43.22%) but, it had the highest conducting vessels ratio (15.11%). Based on fibres percentage, O. abyssinica was very similar to Bambusa species (Table 5); the main difference was the parenchyma percentage which was the highest.

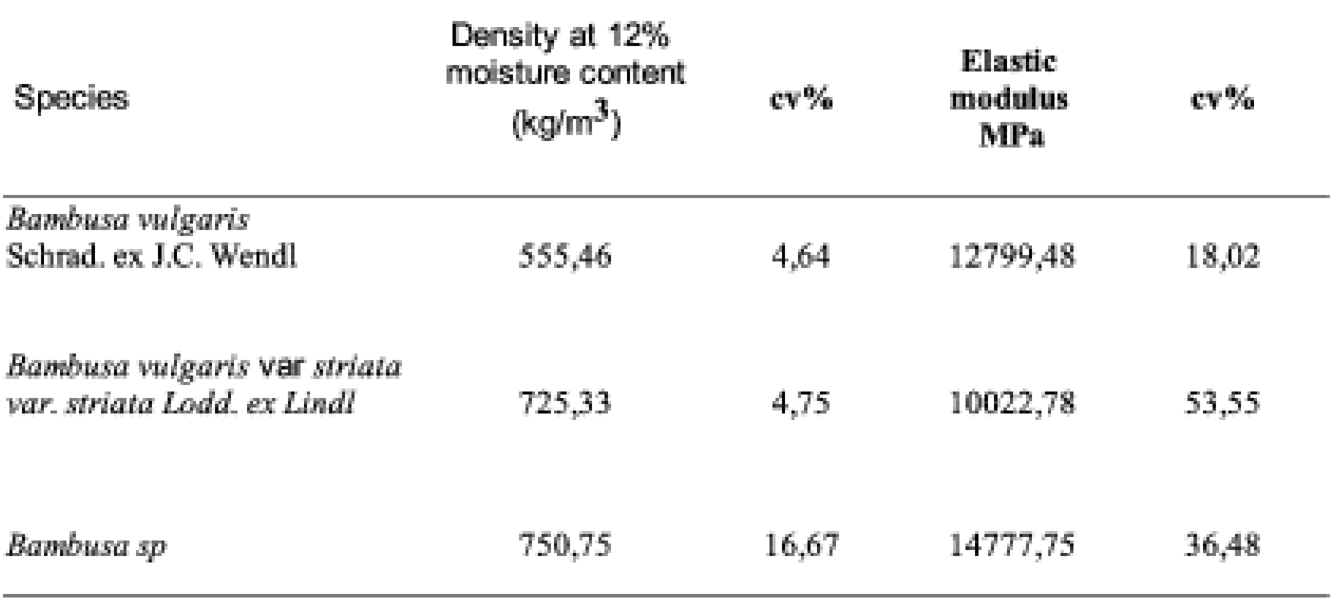
3.6. Density and modulus of elasticity (MOE)

The range of B. vulgaris density was 510-600 kg/m3 and for B. vulgaris var striata, density varied from 640 to 788 kg/m3. The highest value of density was the one of Bambusa sp.($F_{14,2}$ = 26.93 et $P<0.01$); coefficient of variation was also very high compared to those of other two bamboo species. Elastic modulus of B. vulgaris var.

Table 5 : Tissues proportions of four bamboo species (Average values ± average standard deviation)

Species	Fibres (%)	Parenchyma (%)	Conducting vessels (%)
Bambusa vulgaris Schrad. ex J.C. Wendl	41.59 ± 4.26	44.09 ± 3.12	14.43 ± 1.58
Bambusa vulgaris var. striata Lodd. ex Lindl	41.49 ± 5.63	43.22 ± 3.88	15.11 ± 2.28
Oxytenanthera abyssinica (A.Rich.) Munro	40.97 ± 4.73	45.59 ± 4.21	12.92 ± 0.90
Bambusa sp.	39.50 ± 6.56	47.74 ± 5.65	12.77 ± 1.47

Table 6 : Physical and mechanical properties of three bamboo species (Average values)



Species	Density at 12% moisture content (kg/m^3)	cv%	Elastic modulus MPa	cv%
Bambusa vulgaris Schrad. ex J.C. Wendl	555,46	4,64	12799,48	18,02
Bambusa vulgaris var *striata var. striata Lodd. ex Lindl*	725,33	4,75	10022,78	53,55
Bambusa sp	750,75	16,67	14777,75	36,48

striata was the lowest (Table 6), with an important variability between samples studied (cv = 53%). Such as density, modulus of elasticity for Bambusa sp. was significantly the highest while comparing it to other species (F12,2 = 5.73 et P=0.02). For each species, there was a good correlation between modulus of elasticity and density. While increasing culms average density, mechanical properties especially elastic modulus also increased. This relationship was the best for Bambusa sp. (y = -16866 + 42.2x, R2=0.96, P<0.001) and poor for B. vulgaris (y = -14332+49.9x, R2=0.48, P<0.001) and B. vulgaris var. striata (y = -67184+106x, R2=0.47, P=0.002).

4. Discussion and conclusion

Anatomical study of four bamboos species of Togo showed that parenchyma were the culm predominant tissue. Sclerenchyma (fibres) was the support tissue which was in charge of culms mechanical rigidity and, then for material which derived from it (Camefort, 1972). Two metaxylems, one protoxylem and phloem were found to be the conduction tissues, constitute the vascular fascicles. In culms, fascicles were surrounded by fibres and their number decreased from periphery to interior. The way this vascular system is organized, was the main subject of several studies (Grosser and Liese, 1971; Alam and Dramsfield, 1981; Jiang, 1992; Sekar and Balasubramanian, 1994; Dramsfield and Widjadja 1995; Liese, 1998; Liese and Grosser, 2001; Abd Latif and Liese, 2001), which pointed up existence of special anatomical characteristics within different bamboos genera and species. Distribution of vascular system and its size could also show variability at different heights of the culms. Vascular system analysis of Togo bamboo species revealed that ecological factors could influence organization of vascular tissues, contrary to their main influence on culms morphology (Gnama 2005; Kokou et al. 2006a). Abd Latif and Liese (2001) also showed that bamboos anatomical characteristics, particularly distribution and size of vascular system did not vary with site environmental conditions.

Fibres (sclerenchyma) quality and anatomical structure determined physical and mechanical properties of bamboos culms. Results of the present study showed an important variability of fibres characteristics with position between nodes and ecological conditions. For the four species, fibres proportion was significantly high in culms external areas. On the other side, percentages of conducting tissues and parenchyma increased from periphery to internal parts of culms. Ecological factors did not significantly influence tissues percentages of all four bamboos species. Except O. abyssinica for which fibres located inside the culm were significantly longer than those located at the periphery, fibres radial position in the culm did not influence its length. Nevertheless, age and height of culms can influence fibres length (Abd Latif and Liese, 2001). Fibres length also varied with different species. The length was very high for Bambusa sp. and very short in the case of O. abyssinica. Fibres wall thickness did not significantly vary with radial position inside culms (except for Bambusa sp.). Fibres length was not influenced by ecological conditions that appeared to be beneficial to bamboos fibres use (Abd Latif and Liese, 2001). Effect of ecological factors on other fibres characteristics were also unimportant, except B. vulgaris var striata for which fibres wall thickness and diameter were significantly the most important in ecological zone IV, this zone represented the main forest area in Togo.

Such as fibres anatomical characteristics, physical and mechanical properties (density, MOE) presented a great variability between different bamboos species and inside each species. Bambusa sp. had the highest values of density and MOE. Physical and mechanical properties (MOR, MOE, etc.) of bamboos were mainly determined by the anatomical structure (Liese, 1998). Weimer and Liese (1994) showed that fibres wall thickness, diameter and percentage were parameters of bamboos quality as a building material. Epsiloy (1992 and 1994), Abd. Latif and Liese (1995) indicated that a high fibres proportion and a thick fibres wall increased specific gravity of material, its tensile and compression strengths, but decreased the MOR. Very high lengths of fibres increased MOE. The very high value of MOE found for Bambusa sp. was probably due to this species important fibres length. Indeed, for Bambusa sp. MOE was strongly correlated to fibres length ($y = 31710x - 69867$, $R2=0.93$ and $P = 0.02$). Moreover, results showed there was a strong correlation between MOE and density at 12%.

Mechanical properties determination also revealed that bending resistance was strongly correlated to MOE (Betoko, 2005). Based on fibres quality, physical and mechanical roperties, Bambusa sp. appeared as the species to be promoted and popularized in Togo. Bambusa sp. culms very interesting morphological performances (very important height and circumference) (Gnama 2005) can be correlated to anatomical characteristics, physical and mechanical properties of this species. Due to a lack of information, Kokou et al. (2006a) mistook Bambusa sp. for Bambusa vulgaris, thus they considered B. vulgaris as the one with good morphological performances. It should be noticed that in a bamboo popularization program in Togo, such as the one currently initiated by Opportunities Industrialization Centers (OIC-Togo) (Siativi 2004), Bambusa sp. appeared as species to which priority should be given. It is better to promote this species which was already naturalized in Togo rather than introducing new exotic species. Further researches are being carried out on this species in order to clarify its systematic position.

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