GREEN MOISTURE CONTENT, BASIC DENSITY, SHRINKAGE AND DRYING CHARACTERISTICS OF THE WOOD OF *CEDRELA ODORATA* GROWN IN GHANA

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OFORI, J. & BRENTUO, B. 2005. Green moisture content, basic density, shrinkage and drying characteristics of the wood of *Cedrela odorata* grown in Ghana. The green moisture content, basic density, shrinkage, susceptibility to drying defects and development of appropriate drying schedules for the wood of *Cedrela odorata* grown in Ghana were studied. The overall moisture content averaged 76%. The moisture content in the radial direction was high at the pith (92%) but reduced (66–68%) towards the periphery. The overall basic density averaged 476 kg m^{-3}. In the radial direction, the density was low at the pith (432 kg m^{-3}), increased rapidly outwards to a peak (500 kg m^{-3}) and declined steadily towards the periphery (365 kg m^{-3}). Overall total shrinkages in the tangential, radial and longitudinal directions were 4.5, 3.6 and 0.5% respectively, while shrinkages from green to 12% moisture content were 2.6, 2.0 and 0.4% respectively. Sapwood appeared to shrink slightly more than heartwood. The wood was not susceptible to collapse and honeycombing but checks occurred in the early stages of drying. The Forest Products Laboratory Madison kiln-drying schedules T10-C4 and T11-C5 were proposed for moderate and slightly severe drying conditions respectively.

Key words: Drying defect – checking – collapse – honeycomb – deformation – kiln schedule

OFORI, J. & BRENTUO, B. 2005. Kandungan lembapan basah, ketumpatan asas, kecutan dan ciri-ciri pengeringan kayu *Cedrela odorata* dari Ghana. Kandungan lembapan basah, ketumpatan asas, kecutan, kerentanan terhadap cacat pengeringan dan perkembangan jadual pengeringan untuk kayu *Cedrela odorata* dari Ghana dikaji. Purata kandungan lembapan ialah 76%. Kandungan lembapan jejari tinggi di empulur (92%) tetapi berkurang (66–68%) ke arah kulit. Purata ketumpatan asas ialah 476 kg m^{-3}. Ketumpatan jejari rendah di empulur (432 kg m^{-3}) tetapi bertambah dengan mendadak sehingga mencapai puncak pada 500 kg m^{-3} dan berkurangan beransur-ansur ke arah kulit (365 kg m^{-3}). Jumlah kecutan tangen, jejari dan membujur masing-masing 4.5%, 3.6% dan 0.5%. Kecutan tangen, jejari dan membujur daripada keadaan basah menjadi kandungan lembapan 12% masing-masing 2.6%, 2.0% dan 0.4%. Kayu gubal nampaknya mengecut lebih daripada teras kayu. Kayu ini tidak rentan terhadap kempisan dan rekahan sarang lebah tetapi retakan terbentuk pada peringkat awal pengeringan. Jadual pengering tanur Makmal Keluaran Hutan Madison T10-C4 dan T11-C5 masing-masing dicadangkan untuk keadaan pengeringan yang sederhana dan yang agak teruk.

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Introduction

Ghana has considerable wealth in tropical hardwood timber resources. Forest products exports represent about 12% of total export of goods. There are about 680 different species of trees in the forest reserves of Ghana. Approximately 420 tree species attain timber size and are therefore of potential economic value. About 126 of these species occur in sufficient volumes to be considered exploitable as a raw material base for the timber industry (Ghartey 1989). However, only about seven species contribute to 70% of the wood products export earnings. The dependence of the timber export trade on a few species represents an inefficient utilisation of the timber resource. In addition, a large portion of wood exported from Ghana is in the form of logs (55 to 65%) and rough lumber (32 to 47%). Their unit value prices are, however, very low compared with that of tertiary products such as furniture components and profile boards (Ofori *et al.* 1993). To take advantage of the social and economic benefits created by each additional processing operation, emphasis is being shifted towards the production of processed wood products using known, lesser-known and plantation-grown species of trees (Upton & Attah 2003).

Cedrela (*Cedrela odorata*) is an exotic species grown in plantations in Ghana. Production volumes of 100 to 500 m^3 $year^{-1}$ have been reported by TEDB (1994). Cedrela could be used for furniture, joinery, fitments, framing, boat-building, veneer and plywood, toys and woodware (TEDB 1994).

The wood of cedrela is now being utilised in Ghana but its basic physical and technological properties, and numerical strength have not been determined. Figures in the literature on Ghanian-grown cedrela (TEDB 1994) seem to be derived from other countries. The density, shrinkage, drying rates, susceptibility to drying defects and recommended kiln-drying schedules of native central American cedar (*C. mexicana*), native South American cedar (*C. odorata*) and plantation-grown *C. odorata* from Tanzania and other sources have been reported by Farmer (1972) as well as Bolza and Keating (1972). Since plantation forestry rotations are significantly shorter than in natural stands, it is to be expected that some of their wood and utilisation properties will be affected. The character and behaviour of wood produced from plantation species and its suitability for sawn wood is markedly different from that of the same species derived from natural habitat (Brazier 1983).

The green moisture content and basic density of wood are directly related to the weight of logs and green lumber. Reliable information on green moisture content may be of concern to those who design harvesting and transport equipment, purchase wood on a weight basis (such as in pulpwood) or must transport green wood. Therefore data on basic density are needed in estimating the variability in the strength of a wood product (Haygreen & Bowyer 1996).

Within a single tree, there is radial variation between moisture content of green sapwood and heartwood, especially in softwoods (Kollman & Cote 1968, Panshin & de Zeeuw 1980, Haygreen & Bowyer 1996). Since denser wood shrink more than less dense wood, it is expected that radial and axial variations in basic density may lead to some variations in shrinkage.

Improved utilisation of tropical wood species can help increase economic value of the forest and thus improve the chances of sustainable management. Drying is one key step in processing wood products and solutions to drying problems will help establish value for the species. It is, therefore, important that certain fundamental physical and technological properties of wood (such as density and shrinkage) as well as the susceptibility of the wood species to drying defects (such as splits, checks, collapse and honeycomb), which are related to its interaction with moisture be studied to provide important information on the ability of this species at particular moisture contents to be utilised for specific purposes. Measurements of physical and technological properties relevant to the drying of wood are also aimed at developing appropriate drying schedules for specific end-uses.

Materials and methods

Materials

Five trees of plantation-grown cedrela were obtained from the Afram Headwaters Forest Station at Abofour (7° 14'–7° 18' N; 1° 25'–1° 32' W) in the dry semi-deciduous forest zone of Ghana. The diameters of the trees at breast height were 32 to 57 cm. Clear boles were cut at a height above the buttress. Each clear bole was cut into five to nine logs of 2.5 m lengths. Thirty-five logs were obtained from the five trees. The logs were immediately removed from the forest and conveyed to the laboratory.

Conversion and sampling

The next day, 20 cm piece was cut off from the thicker (lower) end of each log and discarded. Two 10 cm thick discs were then cut from the freshly cut end of the log for moisture content distribution and basic density studies respectively. Thereafter, 25 cm thick discs were cut from the remaining log for shrinkage, seasoning characteristics and kiln schedule determination studies. The remaining length of the log (after taking off the three discs) were sawn into lumber of thickness 25 mm and 50 mm for study on drying rates.

Moisture content distribution

For the moisture content disc, two 2.5 cm strips containing the pith and spatially at right angles to each other were extracted. The strips were planed to 2 cm thickness. Each strip was marked starting 1 cm from the centre of the pith outwards to the bark and then sawn to produce 2 × 2 cm square sections. The 2 × 2 cm square sections were then crosscut to 2 cm cubes. The green mass (*W*) of the sample cubes was determined and then oven dried at 101–105 °C until constant mass *(D)* was attained. The moisture content (*MC*) was then calculated according to the formula:

$$MC = \frac{W - D}{D} \times 100\%$$

Basic density

The other 10 cm thick discs earmarked for basic density studies were similarly converted like in the moisture content samples. Each cube was soaked in water overnight or swollen by means of vacuum impregnation with water. The basic density on swollen volume and oven-dried mass basis was determined by the hydrostatic or immersion method. The wood blocks were then oven dried at 101–105 °C to constant mass and the oven-dried mass determined. The basic density was calculated from the formula:

$$\text{Basic density (kg m}^{-3}\text{)} = \frac{\text{Oven-dried mass (kg)}}{\text{Volume of water displaced by swollen specimen (m}^{3}\text{)}}$$

Shrinkage

The 25 cm thick discs earmarked for shrinkage studies were sawn to include two 2.5 cm wide strips containing the pith and spatially at right angles to each other. The strips were planed to 2 cm^2 sections to give the radial and tangential faces. The 2 cm^2 specimens of length 10 cm were cut from the 25 cm long sections from the pith to the bark. The square cross-sectioned specimens were prepared from each log of each tree and dried at room temperature in the laboratory over a few days, conditioned to 12% moisture content in a constant humidity chamber, and later on by oven drying. During air drying, conditioning and after oven drying, the specimens were weighed periodically and the dimensions of each specimen were measured using a micrometer screw gauge in the radial and tangential directions, and vernier callipers in the longitudinal direction. Shrinkage in drying at various moisture contents and from green to 12% moisture content and oven-dried state were calculated for tangential, radial and longitudinal directions, and was expressed as percentage using the formula:

$$\text{Shrinkage} = \frac{\text{Change in dimension}}{\text{Green dimension}} \times 100\%$$

Susceptibility to drying defects and kiln schedule determination

The wood remaining from the 25 cm discs left after extracting the shrinkage strips were used for this study. The method developed by Terazawa (1965), which attempts to estimate drying time, sensitivity to drying defects and ultimately a kiln schedule was adopted. Flat-sawn sections of 2.5 × 12 × 25 cm were planed to 2 × 12 × 25 cm. The final specimen sizes used were 2 × 10 cm section, 20 cm long with the 2 × 10 cm faces being flat sawn. The specimens used for this study were then wrapped in polythene bag and kept in a freezer.

When needed, the specimens were taken out of the freezer and allowed to thaw. One end of each specimen was marked and selected for end-checking observation. Each specimen was then weighed. At intervals of 10 min, one specimen out of six specimens was placed edge-wise in an oven maintained at 103–105 °C. Each of the specimen was taken from the oven every hour for the first four hours and then every two hours for the next four hours on the first day during working hours and twice daily on the second and subsequent days for re-weighing to obtain the moisture content. At the same time, end and surface checks that had developed during the drying were observed. This was repeated until the specimen was completely dried. The condition of maximum checking was compared with the checking criteria set by Terazawa (1965) and the specimen was then awarded a corresponding checking classification.

At the end of drying, each specimen was sawn in the middle to give two approximately 2 × 10 x 10 cm pieces in order to measure the honeycombing and the cross-sectional deformation that had occurred. The newly exposed faces were examined and the number of honeycombs recorded. The specimen was then awarded a honeycomb classification set by Terazawa (1965). The maximum and minimum thickness values of each specimen along its freshly cut face were taken with micrometer screw gauge and the difference between the two measurements recorded as cross-sectional spool-like deformation. The specimen was then awarded a deformation classification set by Terazawa (1965).

Results and discussion

Cedrela logs were susceptible to splitting due to impact of felling. The sapwood was susceptible to pinhole borers when green. Rapid extraction, conversion and drying are necessary.

Moisture content distribution

The green moisture content for 397 specimens ranged from 39 to 186% (Table 1). The overall mean was 76% with standard deviation 16%. The within tree mean green moisture content range was 71 to 86%. The analysis of variance indicated that differences between the mean green moisture content of the five trees were highly significant (df = 4, 392; F = 11.529; P value = 7.367E-09). The green moisture content (Figure 1) around the pith was high (mean 92%). It then

Table 1 Summary of statistics for green moisture content of cedrela trees from Ghana

Statistic	Tree A	Tree B	Tree C	Tree D	Tree E	All trees
Mean (%)	86.3	79.0	71.0	79.4	75.4	76.1
Standard deviation	21.1	12.2	14.9	15.1	11.8	15.5
Minimum (%)	50.6	65.2	39.0	54.7	53.3	39.0
Maximum (%)	157.9	120.4	185.7	119.4	116.4	185.7
No. of specimens	53	46	140	36	122	397
95% Confidence level	5.8	3.6	2.5	5.1	2.1	1.5

reduced gradually to 65–68% towards the periphery at radius of 16–20 cm. Analysis of variance indicated that the variation of the mean radial green moisture content with distance from pith of the five trees was also highly significant (df = 9, 387; F = 12.724; P value = 8994E-18). Apart from around the pith (2 cm) where the mean moisture content was about 92%, the moisture content for radial distances of 4 to 20 cm was 66 to 77%. This variation is not generally wide. However, in a study of moisture content distribution in *Pinus elliottii* stems, Jermyn *et al.* (1961) stated that since moisture content conditions are associated with cell function, it is expected that variation in moisture content occurs both radially and vertically.

Basic density

The overall basic density of the wood for 467 specimens ranged from 300 to 663 kg m^{-3} and averaged 476 kg m^{-3} with a standard deviation of 58 (Table 2). The mean basic density within tree ranged from 405 to 521 kg m^{-3}. The analysis of variance indicated that the differences between the mean basic densities of the

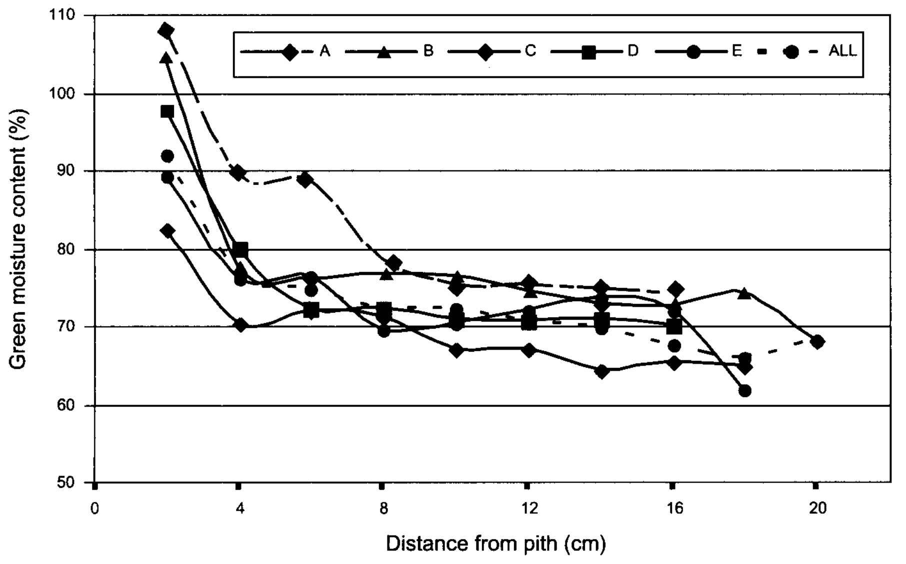

Figure 1 Radial green moisture content profile of cedrela from Ghana

Table 2 Summary of statistics for basic density of cedrela trees from Ghana

Statistic	Tree A	Tree B	Tree C	Tree D	Tree E	All trees
Mean (kg m^{-3})	466	405	521	482	470	476
Standard deviation	59	34	47	49	34	58
Minimum (kg m^{-3})	300	320	404	379	385	300
Maximum (kg m^{-3})	594	469	663	556	549	663
No. of specimens	53	81	154	33	146	467
95% Confidence level	16.2	7.6	7.5	17.3	5.6	5.3

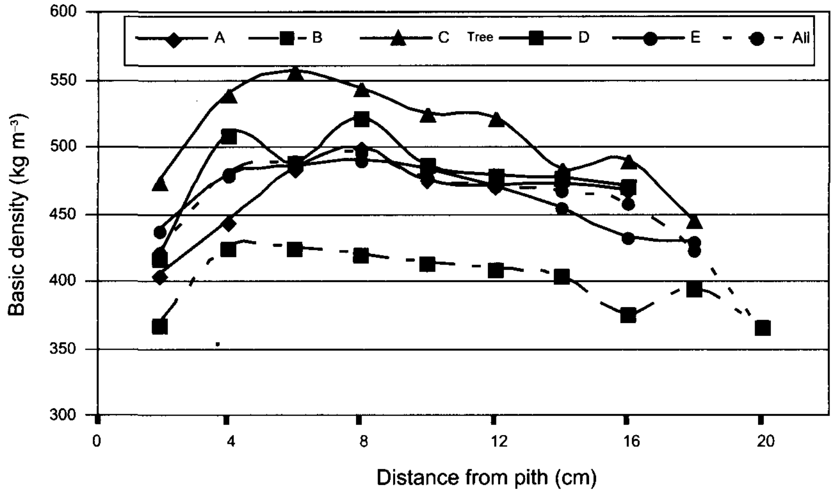

Figure 2 Radial variation in basic density of cedrela from Ghana

five trees were highly significant (df = 4, 462; F = 97.4576; P value = 4.5E-60). Tree B was the least dense.

The overall mean basic density of 476 kg m^{-3} compared favourably with the densities at moisture content of 12% of cedrela from Tanzania (410–450 kg m^{-3}) (Bolza & Keating 1972) and the estimated 450 kg m^{-3} for cedrela from Ghana (TEDB 1994). However, the values are far lower than the density at 12% moisture content of 510–570 kg m^{-3} for native central American cedar (Bolza & Keating 1972).

The mean density (Figure 2) rose from 432 kg m^{-3} at 2 cm from the pith and peaked around 500 kg m^{-3} at about 6–8 cm from the pith and then decreased to 365 kg m^{-3} at the bark (20 cm from the pith). However, in porous hardwoods, density is low in the centre of the tree but rapidly increases from the centre of the tree outwards, reaching a peak early in the life of the tree, after which it steadily declines (Haygreen & Bowyer 1996). The rather low value of 365 kg m^{-3} at the bark might be due to Tree B being the least dense tree and it was the only tree from which a value was recorded for the 20 cm section. The analysis of variance indicated that the differences between the mean radial basic densities of the five trees were highly significant (df = 9, 457; F = 13.1829; P value = 8.4E-19).

Shrinkage

The main trend investigated was across diameter or radial variation (i.e. effect of extraction site). Shrinkage appeared to be higher in the sapwood than in the heartwood. Overall shrinkages in the tangential, radial and longitudinal directions from green to oven dry were 4.5, 3.6 and 0.5% respectively, while those from green to 12% moisture content were 2.6, 2.0 and 0.4% respectively (Table 3). According to the TEDB (1994), the tangential and radial shrinkages from green to 12% moisture content in cedrela from Ghana were estimated at 2.5–4% and 1.0–2.0% respectively. These values have been classified as small. Farmer (1972) reported

Table 3 Directional shrinkage values for five trees of cedrela from Ghana

Statistic	Green moisture content (%)	Total shrinkage (%) L	R	T	T/R	Shrinkage from green to 12% moisture content (%) L_{12}	R_{12}	T_{12}
Mean	68.8	0.50	3.64	4.48	1.26	0.39	2.04	2.64
Standard deviation	21.2	0.25	0.61	0.90	0.33	0.23	0.35	0.70
Minimum	31.6	0.18	1.12	1.28	0.41	0.06	0.25	0.27
Maximum	201.2	1.60	5.69	9.67	2.99	1.43	2.82	7.87
95% Confidence level	4.4	0.05	0.13	0.19	0.07	0.05	0.07	0.14

approximate tangential and radial shrinkage values from green to 12% moisture content of 4.0 and 3.0% respectively for central and South American cedar. The shrinkage values obtained in this study for cedrela from Ghana were lower than the reported values for native central and South American cedar. The low shrinkage values for cedrela, coupled with its wide reputation for stability, show potential for exterior joinery.

Typically, total longitudinal shrinkage is only 0.1–0.2% for most species and rarely exceeds 0.4% (Haygreen & Bowyer 1996). Cedrela from Ghana in this study seemed to exhibit high longitudinal shrinkage values (mean of 0.5% and up to 1.6%). Attention should therefore be paid to structural design detailing in uses where longitudinal stability is important.

The ratio of tangential to radial shrinkage (T/R) is used as an index of dimensional stability. Ratios higher than 1.5 are considered pronounced. The mean T/R ratio was 1.3. However, the ratios for material close to the bark (i.e. 12–16 cm) were fairly close to 1.5 (Figure 3). This pronounced differential shrinkage is likely to cause wide splits, checks and distortions if the necessary precautions are not taken during kiln drying.

Susceptibility to drying defects

Table 4 shows the results of the type of defects (checking, honeycomb and cross-sectional spool-like deformation) and class of drying defects obtained for each of the five trees of cedrela from Ghana. It should be noted that defect type class 1 is the mildest and class 8 is the most severe.

Checks in the early stages of drying

There were moderate little checks (Class 2 to 3) in cedrela from Ghana. Initial checking is strictly related to initial relative humidity, and less so to initial temperature. It is not related to either final temperature or final relative humidity. Since cedrela from Ghana did not exhibit severe initial splitting, moderately higher initial temperatures (60–65 °C) and larger wet bulb depressions (WBDs) of 4.3–5.5 °C may be used.

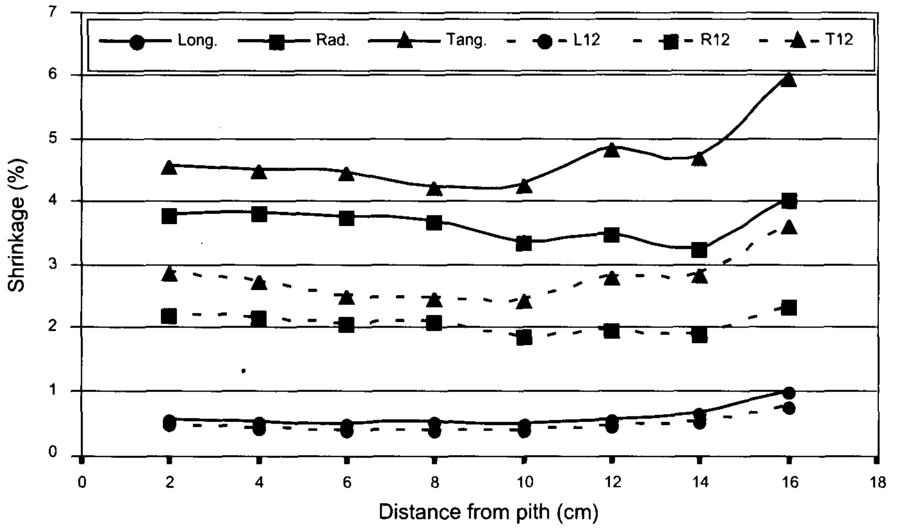

Figure 3 Shrinkage profile from pith to bark of cedrela from Ghana

Honeycombing (or internal checking)

There was no honeycombing (Class 1) in cedrela from Ghana. In kiln drying, honeycombing is related to the initial and final temperatures and the initial relative humidity but not to the final relative humidity. Since cedrela from Ghana does not honeycomb, it can thus tolerate high initial dry bulb temperatures DBT (70 °C) and high initial WBDs (6.5 °C).

Cross-sectional spool-like deformation

Deformation was low in cedrela from Ghana (Class 1). Deformation is related to the initial and final temperatures, and less so, to the initial relative humidity, but not to the final relative humidity. Thus, relatively higher initial dry bulb temperatures (70 °C) and high initial WBDs (6.5 °C) may be employed for drying cedrela. It was observed from the critical drying conditions corresponding to the defect type class column in Table 4 that checks on early stages of drying is the most critical defect that governs the kiln drying of cedrela from Ghana. It was not susceptible to collapse (class 1) and honeycomb (class 1). Splits and checks are aggravated by rapid drying or extremely fast, hot drying; slower drying will reduce these defects, except when they are a result of logging damage (Wengert 1991).

Proposed experimental kiln drying schedules

A kiln-drying schedule determines both temperature and relative humidity based on the type and degree of defects. The experimentally determined susceptibility class relationship (or critical drying conditions corresponding to adopted defect type class) shows the type and class of drying defects obtained for the five trees of cedrela from Ghana (Table 4). The most prevalent class for each of the three

Table 4 Type and class of drying defects and their critical drying conditions

Defect type or initial moisture content	Defect type class						Critical drying conditions corresponding to adopted defect type class		
	Mean defect type class for tree no.					Class adopted	Initial dry bulb temperature (°C)	Initial wet bulb depression (°C)	Final dry bulb temperature (°C)
	A	B	C	D	E				
Initial check	3.0	2.4	2.6	3.0	2.9	2 to 3	60/65	4.3/5.5	85/90
Honeycomb	1	1	1	1	1	1	70	6.5	95
Deformation	1	1	1	1	1	1	70	6.5	95
Intial MC (%)	70	73	68	64	65	68			
Replicates	4	9	9	2	11				

drying defect types (initial check, honeycomb and collapse or deformation) was adopted. It also indicates the appropriate starting and final drying conditions (initial dry bulb temperature, initial wet bulb depression and final dry bulb temperature) selected from tables in the study by Terazawa (1965). From each group of three possibilities, the mildest conditions (i.e. overall lowest initial temperature, overall smallest initial wet bulb depression and overall lowest final temperature) were selected, and are shown in bold and underlined. It is observed that checks on early stages of drying are the most critical defect that governs the initial drying conditions (i.e. initial dry bulb temperature and initial wet bulb depression) and the final temperature in kiln drying cedrela from Ghana.

The mean initial moisture content was determined to be 68% (Table 4). The initial mildest drying conditions so determined provided a starting criterion, which was applied in selecting the moisture content class, dry bulb temperature and wet bulb depression combinations from the tables provided by Simpson (1991), and used by Ofori and Appiah (1998) as well as Ofori and Obese-Jecty (2001). The Forest Products Laboratory (FPL), Madison has provided general temperature schedules for hardwoods ranging from a very mild schedule, T1, to a severe schedule, T14 (Simpson 1991). Initial temperatures, in all cases, are maintained until the mean moisture content of the control specimens reaches 30%. Wet-bulb depression schedules for six moisture content classes (A to F) that are related to the green moisture content of the wood (Class A being green moisture content of up to 40%, and class F being green moisture content of above 120%) are also provided. In addition, there are eight numbered wet-bulb depression schedules (No. 1 being the mildest and No. 8 the most severe).

Two types of schedules are being proposed. A severe schedule in which the critical drying conditions are based on the checking class 2, and a mild schedule in which the critical drying conditions are based on the checking class 3. A summary of the initial moisture content and adopted classification of defect types used in proposing the drying conditions is found in Table 5. A moderate experimental dry kiln schedule for lumber of thickness up to 38 mm corresponding to the FPL Madison schedule (Simpson 1991) of T10-C4 and a slightly severe schedule of T11-C5 are proposed. Kiln schedule T10-C4 is mild and it is recommended for kiln loads comprising a fair mixture of flatsawn and quartersawn or comprising mostly quartersawn material or squares or for more delicate loads. Kiln schedule T11-C5 is harsher and may be applied to thin loads, air-dry or mainly flatsawn loads, and for end-uses where the lumber quality is not exacting. The experimental dry kiln schedules have been assembled in Table 6. The 'Severe Schedule' corresponding to FPL Madison schedule T11-C5 with initial DBT of 65 °C, WBD of 6 °C, and final DBT of 80 °C; and a 'Mild Schedule' corresponding to FPL Madison schedule T10-C4 with initial DBT of 60 °C, WBD of 4 °C, and final DBT of 80 °C. In the two schedules, WBDs of 6 and 4 °C were selected because they were the mildest WBDs that are approximate to the 5.5 and 4.3 °C experimentally determined. The United Kingdom Kiln Schedule H (Farmer 1972) that has been recommended for kiln drying cedar (Farmer 1972) is fairly close to the Mild Schedule T10-C4. The initial drying conditions in the United Kingdom Kiln schedule H are: DBT of 57 °C, WBD of 4 °C and relative humidity of 80%; and the final drying conditions are DBT of 76.6 °C, WBD of 18.5 °C and relative humidity of 40%.

The method developed by Terazawa (1965) that was adopted attempts to estimate drying time, sensitivity to drying defects and ultimately a kiln schedule by observing drying time and characterising the various kinds of defects (initial checks, cross-sectional deformation and honeycomb) that developed. The specimens

Table 5 Summary of proposed critical drying conditions used

Schedule type	Initial moisture content (%)	Adopted classification of defect type: Check on early stage	Honeycomb	Deformation	Proposed critical drying conditions: Initial dry bulb temperature (°C)	Wet bulb depression (°C)	Final dry bulb temperature (°C)	Corresponding Madison kiln schedule
Severe	68	2	1	1	65	5.5	90	T11-C5
Mild	68	3	1	1	60	4.3	85	T10-C4

Table 6 Experimental dry kiln schedules for drying plantation-grown cedrela from Ghana

Severe schedule (T11-C5)						Mild schedule (T10-C4)					
Step No.	MC %	DBT °C	WBD °C	RH %	EMC %	Step No.	MC %	DBT °C	WBD °C	RH %	EMC %
1	Above 40	65	6	74	11.5	1	Above 40	60	4	82	14.0
2	40-35	65	8	67	9.8	2	40-35	60	6	73	11.6
3	35-30	65	12	54	7.6	3	35-30	60	9	62	9.2
4	30-25	70	20	35	5.0	4	30-25	65	15	45	6.4
5	25-20	70	30	17	2.9	5	25-20	70	25	25	3.9
6	20-15	80	30	22	3.1	6	20-15	75	30	19	3.1
7	15 to Final	80	30	22	3.1	7	15 to Final	80	30	22	3.1
Equalise and condition as necessary						Equalise and condition as necessary					

MC = Moisture content, DBT = dry bulb temperature, WBD = wet bulb depression, RH = relative humidity, EMC = equilibrium moisture content

(2 cm thick × 10 cm wide × 20 cm long) used dried much faster than would a full-thickness lumber, so the method was very efficient in both time and material. The method has the limitation that subjecting specimens of that size to temperatures of about 100 °C imposed the severest conditions on them. However, the method at least indicates the mildest kiln schedule from which modifications could be made to obtain a commercial kiln schedule. Other defects such as warp and discoloration, and properties such as shrinkage, drying rate and basic density should be taken into consideration in adjusting the experimental kiln drying schedules to suit the conditions of the wood to be dried in commercial kiln runs to improve upon them. These might involve first shifting from one wet bulb depression schedule to another; the second is to shift the temperature schedules; and the third is to modify certain steps within the schedule.

Conclusions

The mean green moisture content was 76%. The differences between the average green moisture contents of the five trees were highly significant. The radial moisture content was high at the pith and gradually decreased towards the periphery.

The overall basic density averaged 476 kg m^{-3}. In the radial direction, the density was low at the pith, increased rapidly outwards to a peak and declined steadily towards the periphery.

Overall total shrinkage in the tangential, radial and longitudinal directions were 4.5, 3.6 and 0.5% respectively, and shrinkage from green to 12% moisture content were 2.6, 2.0 and 0.4% respectively. Cedrela from Ghana seemed to exhibit excessive longitudinal shrinkage. Sapwood appeared to shrink slightly more than heartwood.

The wood was not susceptible to collapse and honeycombing but checked moderately in the early stages of drying. The FPL Madison kiln-drying schedules T10-C4 and T11-C5 are proposed for moderate and slightly severe drying conditions respectively.

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