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Research Article

Promotion and Utilization of Plantation Grown Timber Species in Ghana: The Kiln Drying Schedule of *Khaya ivorensis*

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Abstract: Mahogany is ranked as one of the best known and most valuable commercial tropical timbers on the international market. These species are becoming scarcer in the wake of dwindling forest cover in Ghana with illegal logging as the major contributing factors. Since plantation species have not been used enough in the past, their kiln schedules and their drying rates are unknown. In this study kiln drying schedule for plantation grown *Khaya ivorensis* was developed. The testing method followed Terrazawa: 1965. Results indicate that the mildest drying conditions for the plantation species would be the initial and final temperatures of 65°C and 90°C respectively and this coincided with the temperature schedule T11. The wet bulb depression (WBD) of 5.5°C which also corresponds to WBD schedule of 5 was recorded. Madison Drying Schedule T11-B5 is therefore proposed for the plantation grown *Khaya ivorensis*.
Keywords: *Khaya ivorensis*, temperature, drying schedules.

INTRODUCTION

In recent times, an increasing understanding of the science of ecology and society pressure, are causing a re-evaluation of our natural resources with emphasis on sustainable timber production, environmental awareness and improving rural economies. Ghana used to export large portions of its wood in log forms and rough lumber. In taking advantage of the social and economic benefits created by each additional processing operation, Upton and Attah [1] reported of a paradigm shift towards the production of processed wood products. Currently, the use of wood from planted forest is something we cannot avoid, once society consumption demands an increasing of the wood production with quality and environmental care [2].

As the volume of timber from preferred species decreases, potential for the commercially less-accepted species increases [3]. When the primary wood species becomes extinct and the availability of plantation species becomes the raw material for wood industry, there would be the need to inform industry of the properties of these timber species. Green boards are usually dried as a first step in their utilization. Improved utilization of tropical wood species can help increase the economic value of the forest and thus improve the chance of sustainable management. Since drying is one key step in processing wood products, solutions to drying problems will help establish value for the species [4, 3]. Information is therefore needed on the drying of plantation species. Mahogany is ranked as one of the best known and most valuable commercial tropical timbers on the international market. It is acknowledged that these species are becoming scarcer in the wake of dwindling forest cover in Ghana with illegal logging as the major contributing factor. Foli *et al*. [5] described *Khaya ivorensis* (Dubini) as a fast growing species, which does well in semi-deciduous and evergreen forest, tending to do better on banks of streams.

Kiln drying of wood as defined by Hart [6] is a dynamic balance between heat transfer from air stream to the wood, surface evaporation from the wood, diffusion of moisture through the wood and mass flow of free water in the wood. Kiln drying of wood, according to Klitzke and Batista [2] is currently recognized as a vital element in the value of processed solid wood, with an emphasis on the improvement of its quality and cost reduction.

Generally, a schedule is developed so that drying stresses or degrade (such as checks, splits, collapse) do not exceed the strength of the wood at any given temperature and moisture content. Tsoumis [7] defined drying schedule as a carefully worked out compromise between the need to dry lumber as fast as possible and at the same time avoid severe drying conditions that would cause drying defects.

Since plantation species had not been used enough in the past, their kiln schedules had also not been developed and that their drying rates and sensitivity to stain, surface checks, collapse, honeycomb, and warp are unknown [3]. The Forestry Research Institute of Ghana (FORIG) has a plantation of *Khaya ivorensis* at Amantia in the Moist Semi-deciduous ecological zone in Ghana which had attained felling diameters of 90-110 cm. The objective of this study was to determine the kiln drying schedules for the plantation grown *Khaya ivorensis* and compare results with schedules of samples from the natural forest.

MATERIALS AND METHODS

Sample Collection

The timber species, *Khaya ivorensis* (about 40 yr) were felled from both the natural forest and plantation plot of the Forestry Research Institute of Ghana (FORIG) at Amantia in the moist semi-deciduous forest zone of Ghana. *K. ivorensis* from the natural forest served as the control. Three discs (30 cm thick) were cut from different sections of each bole (1.3 m, 3 m and 7 m sections) and prophylactic treated with Dursban to prevent staining.

Sample preparation

A flat-sawn section of 2.5 x 12 x 25 cm from the heartwood was cut from each disc and planed through a Livello Olio (Model 700) thicknesser machine to a dimension of 2 x 10 x 20 cm with the 2 x 10 cm faces being flat-sawn. Six replicates each for the natural forest and the plantation were wrapped in polythene bags and kept in a freezer to avoid moisture lost. One end of each specimen was marked and selected for end-checking observation.

Two reference lines were drawn across the face of each specimen at right angle to each other and each 1 cm from the left most edge. The intersection of these two lines formed a reference point at which each micrometer reading was taken in the radial direction.

Each specimen was weighed using a digital balance for the initial green weight. This was done to be able to calculate the moisture content of the samples. The dimension of each specimen was measured using the micrometer screw gauge for thickness and the digital and the sliding veneer calipers for the width and length respectively.

At intervals of 10 minutes, one specimen out of six specimen from the plantation and the natural forest, was placed edge-wise in a well ventilated oven which was maintained at 103-105^{o}C for free air circulation.

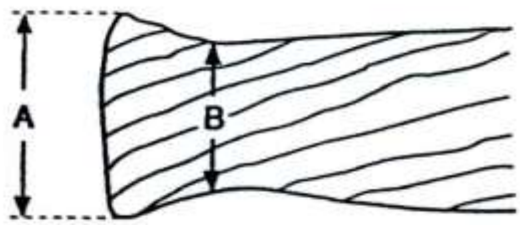
Each specimen was then taken from the oven every hour for the first eight hours on the first day. The specimen was then weighed; depth and width measured and at the same time, end and surface checking that was developing during drying at the marked ends were observed and recorded. The purpose was to ascertain the maximum value of the end check and the surface checks that was appearing in the initial stages of drying. These measurements were repeated on the second day at an interval of six hours and the last readings done on the third day. The longitudinal readings of the specimen were done only at the beginning and at the end of the drying process.

Degree of honeycombing

At the end of drying, the centre line of each specimen was cut off to give an approximate 2 x 10 x 10 cm piece in order to observe the degree of honeycombing and the cross-sectional deformation that had occurred. The newly exposed faces were examined for honeycomb defects and the specimen awarded a predetermined honeycomb classification set by Terazawa [8].

Spool-like deformation

The two extreme ends at the cut edge for each half was labeled (A), and a point (1-2 cm) apart from (A) with a reduced thickness was also labeled as (B).



A: The thickness at the edge, B: the thinnest 1-2 cm apart from the edge

Fig-1: Method for evaluating spool-like deformation on the section

Thickness at points A and B at the four edges of the two halves were measured using the micrometer screw gauge. Differences between the thickest and the thinnest for each of the four was then determined. An average value for the four differences, thickness and thinnest (A-B) for the edge of each sample was evaluated. The overall mean difference for the six replicates was determined by computing the average value of the six mean differences obtained.

The degree of spool like deformation for each sample was evaluated by computing the overall mean differences obtained with values awarded in the deformation classification set by Terazawa [8].

Kiln schedule code

The adopted class of initial moisture content, and wet bulb depression corresponding gives a code which in combination with temperature gives a propose schedule from the code. Each schedule is represented by a two-letter and two-number designation, such as T4–D2. The schedules merely represent a systematic way to develop the whole range of degrees of drying severity.

RESULTS AND DISCUSSION

Susceptibility to drying defects

The appearance and closing of end checks at the initial stages showed, in the case of the plantation species, while 33.34% started closing as early as the 6^{th} h, the rest (66.67%) closed after 30 hours of drying. As regards those from the natural forest, the earliest closing of checks on the samples was the 3^{rd} h (16.66%) and others were between the 5^{th} h (66.67%) and after 31 h (16.66%) of drying. The longest closing time registered for natural forest *Khaya ivorensis* may be attributed to felling injury which resulted in an end to surface checking during drying as depicted in the figure below. In all cases there was no evidence of internal checking or honeycombing.

Evaluation of spool-like deformation

Differences in spool-like deformation for the two species were evaluated as shown in Tables 1 and 2. On the cross sectional face of the cut samples, sides labeled A refers to thickness measurement taken at the edge and the B the thinnest 1-2 cm apart from the edge (A). Values recorded for side B was subtracted from side A. This was repeated for all the eight edges from a sample.

In Table 1, results show the mean differences in thickness between A (the thickest at the edge) and B (the thinnest 1-2 cm apart) of each sample. The mean minimum thickness recorded for plantation grown *Khaya ivorensis* was -0.02 cm whilst the mean maximum difference in thickness was 0.12 cm. From similar calculations, species from the natural forest, Table 2 depicts the mean thinnest (0.10) and maximum thickness (0.26).

Drying conditions corresponding to the adopted defects classes

The susceptibility class relationship (or drying conditions corresponding to adopted defect type class) shows the type and class of drying defects obtained for the two types of *Khaya ivorensis.* In Table 3, the type and sizes of defects (initial checks, honeycombing and spool-like deformation) that occurred on the samples were assessed from a predetermined corresponding classification numbers done by Terezawa [8]. The shape and degree of the initial checks that appeared on the samples in the early stages of drying, was classified 1 or 2 accordingly.

Under honeycombing or internal checking, the shape and sizes of appearance on the samples were classified using Terazawa [8]. From Tables 1 and 2, the values from the mean differences recorded for the samples were used to classify for spool-like deformation. Records of Initial moisture contents (%) were also classified.

The three drying conditions (the initial temperature, wet bulb depression and final dry bulb temperature) from all the defects classes were classified and the mildest conditions (i.e. overall lowest initial temperature, overall smallest initial wet bulb depression and overall lowest final temperature) of 65°C, 5.5°C and 90°C and 60°C, 4.3°C and 85°C adopted for plantation and natural forest *Khaya ivorensis* respectively.

In similar manner, the same procedure of assessing the corresponding values for all types of defects were determined for the possible drying conditions for natural forest *Khaya ivorensis* as depicted in Table 4. In both species type, the predominate class B for initial moisture content was adopted in proposing a drying schedule for them.

Proposed drying schedule

The mildest drying conditions (that is the lowest initial temperature, smallest initial wet bulb depression and the lowest final temperature) in Tables 3 and 4 were used to propose kiln drying schedules for the samples worked on. For the plantation species, the initial and final temperatures of 65°C and 90°C respectively from Table 3 were used in Appendix 8 from which their corresponding range of temperature coincided with the temperature schedule T11. The wet bulb depression (WBD) of 5.5°C also corresponded with WBD schedule of 5. So for the plantation species, in putting together the mean adopted classes of initial moisture content of B, the WBD class of 5 and the temperature schedule of T11, Madison Drying Schedule T11-B5 are proposed as depicted in the Table 5. In similar manner, a schedule code of T10-B4 was proposed as the schedule for natural forest *Khaya ivorensis*. The proposed drying schedule is therefore the Table 5.

Table-1: Spool-like deformation of plantation grown *Khaya ivorensis*

Sample Replicates	Thickness of cross section (A) at ends of boards (mm)				Thickness of boards (B) at 1cm away from (A)				Mean difference
No.	A1	A2	A3	A4	B1	B2	B3	B4	A-B
1	19.44	19.31	19.42	19.33	19.56	19.26	19.44	19.31	-0.02
2	19.46	19.41	19.51	19.47	19.39	19.33	19.43	19.4	0.08
3	19.71	19.5	19.59	19.44	19.55	19.45	19.49	19.37	0.09
4	19.54	19.26	19.45	19.22	19.35	19.18	19.32	19.15	0.12
5	19.56	19.47	19.56	19.5	19.49	19.36	19.5	19.41	0.08
6	19.9	1962	19.87	19.61	19.79	1958	19.81	19.57	0.06

Table-2: Spool-like deformation of *Khaya ivorensis* from natural forest

Sample Replicates	Thickness of cross section (A) at ends of boards (mm)				Thickness of boards (B) at 1cm away from(A)				Mean difference
No.	A1	A2	A3	A4	B1	B2	B3	B4	A-B
1	19.09	19.41	19.11	19.31	18.98	19.21	18.95	19.13	0.16
2	19.57	19.48	19.4	19.52	19.27	19.23	19.24	19.27	0.24
3	19.46	19.2	19.46	19.2	19.22	18.99	19.26	18.95	0.22
4	19.45	19.21	19.4	19.15	19.23	18.97	19.18	18.9	0.23
5	19.67	19.28	19.41	19.42	19.47	19.17	19.32	19.23	0.15
6	19.8	19.5	19.55	19.59	19.65	19.2	19.22	19.35	0.26

Table-3: Type and classes of drying defects for plantation grown *Khaya ivorensis*

Defects type and initial M.C.	Defect type class on samples						Drying conditions corresponding to adopted defect type class		
	1	2	3	4	5	6	Initial dry bulb temp. (°C)	Initial wet bulb temp. (°C)	Final dry bulb temp. (°C)
Initial checks	1	2	2	1	1	1	65	5.5	90
Honeycomb	1	1	1	1	1	1			
Deformation	1	1	1	1	1	1			
Initial MC (%)	41.91	52.03	60.35	61.43	54.45	48.25			
MC Class	B	B	C	C	B	B			

Table-4: Type and classes of drying defects for *Khaya ivorensis* from Natural forest

Defects type and initial M.C.	Defect type class on samples						Drying conditions corresponding to adopted defect type class		
	1	2	3	4	5	6	Initial dry bulb temp. (°C)	Initial wet bulb temp. (°C)	Final dry bulb temp. (°C)
Initial checks	1	3	3	2	1	1	60	4.3	85
Honeycomb	1	1	1	1	1	1			
Deformation	1	1	1	1	1	1			
Initial MC (%)	50.65	52.94	45.16	55.66	38.11	45.98			
MC Class	B	B	B	B	A	B			

Table-5: The proposed drying schedule T11-B5 for plantation *Khaya ivorensis*

STEP	MC (%)	Temperature (°C)		R.H (%)	EMC
		Dry bulb	Wet bulb depression		
1	above 50	65	6	74	11.5
2	50-40	65	6	74	11.5
3	40-35	65	6	74	11.5
4	35-30	65	8	67	9.8
5	30-25	70	12	52	7.6
6	25-20	70	20	35	5
7	20-15	80	30	39	4.8
8	15-final	80	30	39	4.8

CONCLUSION

The oven drying method adopted attempts, to estimate sensitivity to drying and ultimately a kiln schedule by observing the characteristics of the various kinds of defect that developed. The wood was not susceptible to collapse or honeycombing but checked moderately in the early stages of drying. Based on the experiment at high drying temperature, initial temperatures and wet bulb depressions for *K. ivorensis* were 60-65°C and 4.3-5.5°C respectively. However, these drying schedules need to be modified during its implementation and adjusted to kiln drying condition, initial moisture content and the lumber dimensions, because drying schedule vary by species, thickness, grade and end use of the lumber.

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