Development of Kiln-Drying Schedules for Two Lesser-Known Timber Species in Ghana

Bernard Effah[1,*], Jonny Osei Kofi[2]

[1]Department of Interior Architecture and Furniture Production. Kumasi Polytechnic, Post Office Box 854, Kumasi-Ashanti, Ghana-West Africa
[2]Department of Wood Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi. Ghana-West Africa

**Corresponding email: effah4real@yahoo.co.uk*

Abstract

Cola nitida and *Funtumia elastica* are two lesser- known species in Ghana that are not used for commercial timber purposes. The objective of this study was to develop kiln-drying schedules for *Cola nitida* and *Funtumia elastica* as the basis for determining the potential uses that may encourage the utilization and promotion of these lesser known species. The drying schedules were determined using the quick drying test method developed by Terazawa (1965). Three trees each per species were used in the study. The drying schedules comformed to those of *Sterculia rhinopetala* and *Alstonia boonei*. Checks in the early stages of drying were less severe in both *Cola nitida* and *Funtumia elastica* samples (Class 3). There were no honeycombing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. There was no deformation (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Experimental dry kiln schedules for lumber of thickness up to 38 mm corresponding to two Madison schedules were proposed: *Cola nitida* (T_{10}-C_4) and *Funtumia elastica* (T_{10} – D_4).

Keywords: lesser known; drying schedule; kiln drying; *cola nitida*; *funtumia elastic*

1. INTRODUCTION

Although there are many tree species in the world especially in the tropics, Ghana has considerable wealth in tropical hardwood timber resources. Forest product exports represent about 12% of total export of goods [1]. Before the ban on round logs export in 1994, about 55-65% of the wood exported from Ghana was in the form of round logs and 32-47% in green lumber [2]. The Ghanaian government's policy was aimed at encouraging the production of added value timber products and the export of kiln-dried sawn timber and other machined wood products [3].

There are nearly seven hundred different tree species in Ghana [4]. Approximately 420 of these tree species attain timber size and therefore are of potential economic value [5]. Almost 126 of them occur in sufficient volumes to be considered exploitable as raw material base for the timber industry [6]. However, about 90% of the country's wood exports are covered by 10 species [7], and only 4 species contribute roughly 60% of the total production [8].

Historically, most dealers in the Ghana wood industry have relied mainly on a traditional knowledge based on experience of use of the various species but with little or no information on their properties. Most of the species are also not being put to wider utilization because of inadequate data on the physical and technological properties that relates to the utilization of the species. One such important data is the drying properties of the species. For many lesser-utilized species, there does not appear to be any published record of a recommended kiln schedule [9], among them are *Cola nitida* and *Funtumia elastica*. For many end-uses and secondary manufacturing processes, lumber should be dried to avoid undesirable defects such as excessive shrinkage, warping, splitting and checking, stain and decay caused by fungal attack. Kiln schedules for drying the wood species chosen for the study have so far not been developed. Since drying improves wood quality and maximum value-addition, the target for the wood industry-kiln-drying, should be encouraged. It is, therefore, important that the susceptibility of the wood species to drying defects (splits, checks, collapse, honey comb, etc), which are related to its interaction with moisture, be studied to provide important information on the ability of particular species at particular moisture contents to be utilized for specific purposes [1]. Measurements of these physical and technological properties relevant to the drying of wood are also aimed at developing appropriate drying schedules for specific end-uses.

Presently, *Cola nitida* is widely used ceremonially and socially by the people of West and Central Africa and *Funtumia elastica* also gives the best indigenous rubber, and is the only true rubber tree of West African forests whiles their timber is used as firewood. Because few tree species are being utilized commercially, there is an erroneous impression that there is an insufficient raw material base for the timber industry. The present kiln-drying schedules in use in Ghana were development for only the so-called 'noble' species.

There is, therefore, the need to draw up satisfactory drying schedules for the numerous lesser-known species that may (soon) be exploited [1]. This means that suitable processing of *Cola nitida* and *Funtumia elastica* which are lesser-known to the timber industry are essential for the production of high quality products for national and international markets. It has, therefore, become imperative to adopt systematic and scientific techniques to develop drying schedules for *Cola nitida* and *Funtumia elastica* species to promote their utilization. This in turn may be followed by an evaluation of their utilization potential, marketability and performance, so as to serve as suitable substitutes for the fast-diminishing traditional market species in Ghana.

There is also very little information about the variability in timber properties with respect to drying, including how strongly they are correlated [10]. The variability of wood properties further complicates drying. Each species has different properties, and even within species, variability in drying rate and sensitivity to drying defects impose limitations on the development of standard drying procedures [12]. It is important that *Cola nitida* and *Funtumia elastica* to be subjected to these tests.

Proper utilization of a particular wood species must be based on both basic properties and processing properties. Drying properties are a set of the most important processing properties. A proper drying process will be the main key to efficiently utilize and ensure high quality wood products [13]. The purpose of the study was to determine the drying behavior of *Cola nitida* and *Funtumia elastica* species as means to propose kiln-drying schedules to dry them.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Species Used and their Origin

Three matured logs each of *Cola nitida* and *Funtumia elastica* species were procured from Siana in the Asunafo South district of the Brong Ahafo region within the southwestern part of Ghana to provide wood for the determination of drying schedules of the species. The logs were obtained from a cocoa farm in the same locality within the open forest of the area. The species were selected because of their availability in the forest, their commercial bye products of cola nuts and natural rubber respectively, whiles their timber resource are left unutilized.

2.1.2 Conversion and Sampling

The logs were purposefully selected based on their diameters at the base (breast height) being greater than 40 cm and the overall straightness of the trunk. The clear boles were cut at heights of 50 cm and 70 cm from the ground respectively for the *Cola nitida* and

Funtumia elastica trees. Although the standard breast height for cutting timber is 1.3 meters, these two species were cut at lower levels because of the unbuttressed nature of their bases so as not to waste the wood. From each log, a section (billet) of 50 cm long was removed from the butt, the middle and the top portions of the clear bole. The sections were further sawn through and through to get flat sawn boards (planks). Two 5-cm thick flat grain boards for kiln schedule determination tests were sawn 10 cm away from left and right of the bark of the sections.

2.2 Methods

2.21 Kiln Schedule Determination and Susceptibility to Drying Defects

The flat-sawn boards of length 50 cm from both left and right sides of each axial section (billet) of the species were chosen for this test because those parts had more moisture (sapwood). The method used in this experiment was the quick drying test at 100℃ developed by Terazawa (1965) [14] as described by Ofori and Brentuo (2010b) [15] and Ofori and Appiah (1998) [1]. All the chosen boards which were in green condition were planed, trimmed and crosscut to specific sizes of 2 cm x 10 cm x 20 cm in thickness, width and length respectively. From every axial section (B.M.T), 12 defect-free specimens were selected for the study totaling 36 specimens for each tree. On one face of each sample, the widest growth ring and the widest rays were marked off. Both face edges of each sample were marked for end checking observation. The test was run in a set of six samples. The initial weight, length, width and thickness of the test specimens were measured and placed edge-wise in an oven at $103 \pm 2^{o}C$ until oven-dry condition was reached. During the first eight hours, the test specimens were weighed and critically observed for drying defects, ie, end and surface-check occurrences every hour.

Afterwards, two observations and measurements were made on the 24^{th} and 30^{th} hours on the second day and on the 48^{th} hour on the third day. During the drying and monitoring processes, checks occurred, movements of maximum check and check closing occurred were observed and their corresponding moisture contents noted. A scale of 1 to 8 was used to evaluate initial checks and deformation, while another from 1 to 6 was used to evaluate honeycombing. The condition of maximum checking was compared with the checking criteria set by Terazawa (1965) [14] and the specimens were then awarded a corresponding checking classification.

When the test specimens reached oven-dry condition, they were taken out from the oven and their weight, width and thickness directly measured. Afterwards, the test specimens were crosscut in the middle part to measure their degree of deformation. The specimens were then awarded a deformation classification according to Terazawa's method. The newly exposed faces were examined to determine whether honeycomb had occurred in them or not, and the number of honeycombs recorded. The samples were then individually awarded honeycomb classification according to the Terazawa method and their mean value determined. The maximum and minimum thicknesses of each specimen along its freshly sawn face were measured with a micrometer screw gauge. The difference between the two measurements on each sample was recorded as the cross-sectional spool-like deformation and the mean value determined. From each section, two rounds of drying tests were conducted. Initial and final temperatures as well as the wet bulb depression for the drying process of each species were set based on the highest scale of defects.

3. RESULTS AND DISCUSSION

3.1 Results of Susceptibility to Drying Defects

The result of the 100^{o}C – test is shown in Table 1. Visual observations made with respect to seasoning defects included checking and splitting, collapse and twisting. Table 1 shows the results of the types of defects (checking, honey comb and cross-sectional spool-like deformation) and classes of drying defects obtained for the two species.

Table 1: Summary of the types and classes of drying defects and their critical drying conditions for *Cola nitida* and *Funtumia elastica*

Species	Types of defects & initial MC%	Defects Types classes				Critical drying condition corresponding to adopted defect type class		
		Mean for tree No. 1	2	3	Class adopted	Initial Temp. (°C)	Initial WBD (°C)	Final Temp. (°C)
Cola nitida	Initial checks	2	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	69	60	64	64			
Funtumia elastica	Initial checks	3	3	3	3	60	4.3	85
	Honey comb	1	1	1	1	70	6.5	95
	Spool-like Deformation	1	1	1	1	70	6.5	95
	Initial MC%	87	84	88	86			

Checks in the early stage of drying were less severe in both *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) samples (Class 3). Initial checking in the samples is strictly related to initial relative humidity but less related to initial temperature. Moderately higher initial dry bulb temperature of 60^{o}C for both *Cola nitida* and *Funtumia elastic*, and a larger wet bulb depression of 4.3^{o}C for both species are critical to the drying of the species to prevent them from severe splitting in the early stages of drying.

There were no honey combing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Honey combing is generally related to the initial and final temperatures and the initial relative humidity, but not to the final relative humidity. Since the species did not show honey combing, a high initial dry bulb temperature 70^{o}C and high initial

WBD of 6.5^{o}C may be used. There was no spool-like deformation (Class 1) in both *Cola nitida* and *Funtumia elastica* species. Spool-like deformation is related to the initial and final temperatures and less so, to the initial relative humidity, but not to the final relative humidity. A higher initial dry bulb temperature of 70^{o}C and a higher WBD of 6.5^{o}C may be employed for drying both *Cola nitida* and *Funtumia elastica*.

3.2 Proposed Experimental Kiln Drying Schedules for *Cola Nitida* and *Funtumia Elastica*

A kiln drying schedule is a series of temperatures and relative humidities that are applied at various stages of drying. Table 1shows the type and class of drying defects obtained from the two species. Using the adopted classes for each drying defect (initial check, honey comb and deformation), three possible drying conditions (initial temperatures, initial wet bulb depression and final temperatures) were obtained from the table of Terazawa (1965) [14]. The drying condition is inferred from the most severe grade of defects so it would be the mildest one and more safely. Table 2 is a summary of the initial moisture content and adopted classifications of defect types used in proposing the drying conditions.

Table 2: Summary of initial moisture content and adopted classification of defect types used in proposing the critical drying conditions

Species	Initial Moisture content	Adopted classification of defect type			Proposed critical drying conditions			
		Check on early stage	Honey comb	Deformation	Initial temp. (°C)	Wet bulb dep. (°C)	Final temp (°C)	Corresponding Madison Schedule
Cola nitida	64	3	1	1	60	4.3	85	T_{10}-C_4
Funtumia elastica	86	3	1	1	60	4.3	85	T_{10}-D_4

The Forest Products Laboratory (FPL), Madison, USA has provided general temperature schedules for hardwoods ranging from a very mild schedule, T_1, to a severe schedule, T_{14} [12,16]. According to Simpson (1991) initial temperatures, in all cases, are maintained until the average moisture content of the control specimens reach 30%. Wet-bulb depression schedules for six moisture content classes (A to F) (Table 2.3) 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 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). In the view of Ofori and Appiah (1998) 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 characterizing the various kinds of defects (initial checks, cross-sectional deformation, and honeycomb) that developed. The specimens (of size 2 cm thick by 10 cm wide by 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. As described by Ofori and Brentuo (2010) the procedure above took into consideration, only initial check, cross-sectional deformation, and honeycomb as presented in Table 1. Other defects such as warp, properties such as drying rate and basic density, and grade of lumber 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. Simpson (1991) schedules for severely warped lumber or high basic density and slow drying species might be modified by lowering both the initial DBT and WBD; while schedules for upper grade lumbers or fast drying species might be modified by raising both the initial DBT and WBD [1,12,14,15,17].

The experimental dry kiln schedules for lumber of thickness up to 38 mm have been assembled in Tables 3 and 4. In the schedules for both species, the initial WBD of 4.3°C as determined in Table 2was rounded to the nearest figures. Mild and moderate kiln schedules of T_{10}-C_4 and T_{10}-D_4 were proposed for *Cola nitida* (Bese) and *Funtumia elastica* (Funtum) respectively. These proposed schedules conform to those of *Sterculia rhinopetala* and *Alstonia boonei* respectively as proposed by Ofori and Brentuo (2010b).

Table 3: Experimental kiln drying schedule for *Cola nitida*

Madison Kiln Schedule T_{10}-C_4

Step No.	Moisture content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 40	60	4	82	14
2	40-35	60	6	74	11.4
3	35-30	60	9	63	9.2
4	30-25	65	15	45	6.4
5	25-20	70	25	23	3.5
6	20-15	75	30	20	2.8
7	15 to Final	80	30	23	2.9
	Equalize and condition as necessary				

Table 4: Experimental kiln drying schedule for *Funtumia elastica*

Madison Kiln Schedule T_{10}-D_4

Step No.	Moisture content Range %	Dry Bulb Temp. °C	Wet Bulb Depression °C	Relative Humidity %	Equilibrium Moisture Content %
1	Above 50	60	4	82	14
2	50-40	60	6	74	11.4
3	40-35	60	9	63	9.2
4	35-30	60	15	44	6.4
5	30-25	65	25	21	3.4
6	25-20	70	30	18	2.7
7	20-15	75	30	20	2.8
8	15 to Final	80	30	23	2.9
	Equalize and condition as necessary				

4. CONCLUSIONS

This study on the development of kiln drying schedules for *Cola nitida* and *Funtumia elastica* was necessitated by the over dependence of the timber industry on few species and the lack of technical data on the many species growing in Ghana's forests. Checks in the early stage of drying were less severe in both *Cola nitida* and *Funtumia elastica* samples (Class 3). There were no honey combing (Class 1) in both *Cola nitida* and *Funtumia elastica* species. There was no deformation (Class 1) in both *Cola nitida* and *Funtumia elastica* species during drying. The following experimental kiln dry schedules for lumber of thickness up to 38 mm corresponding to the FPL Madison schedules are proposed: *Cola nitida* ($T_{10} – C_4$) and *Funtumia elastica* ($T_{10} – D_4$).

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