Accelerated kiln drying of wawa (*Triplochiton scleroxylon*) sawn timber

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Kiln dried wawa boards with blue coated ends prepared for overseas export.
Photo C.-T. Bues.

A modified accelerated drying schedule was defined for wawa boards, which reduced drying time by 67%, with degrades acceptable to Ghana's grading standards. An evaporable value of 0.21 and an average moisture content of 23.3% were used as a guide to modify drying conditions in order to prevent honeycomb formation.

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RÉSUMÉ

SÉCHAGE ACCÉLÉRÉ AU FOUR POUR LES SCIAGES D'AYOUS (*TRIPLOCHITON SCLEROXYLON*)

Afin de développer de nouveaux schémas de séchage sans dégradation et conformes aux normes de qualité ghanéennes pour le bois scié avivé (Ghana timber grading standards for square-edged sawn wood, 1995), les caractéristiques de déformation du bois d'ayous sont testées sous différentes températures et humidités relatives. Les données obtenues pour la déformation de planches d'ayous séchées au four selon un schéma de séchage classique servent de guide pour développer un schéma de séchage accéléré pour des planches de différentes dimensions (25 et 50 mm d'épaisseur). Le nouveau schéma permet d'obtenir un taux d'humidité de 11 % en quatre jours, soit un gain de temps de 67 %. En adoptant une méthodologie similaire, on peut développer des schémas de séchage accéléré pour tous les sciages de bois durs tropicaux de faible à moyenne densité et de dimensions diverses. Pour l'ayous, le taux d'humidité relative a été initialement réduit pour atteindre une valeur prédéterminée d'humidité moyenne évaporable (E) comprise entre 0,70 et 0,56. Lorsque les déformations intérieures et extérieures ont atteint une tension correspondant à ce stade, une valeur d'humidité évaporable moyenne de 0,21 a été établie pour des planches d'épaisseurs différentes. Le taux d'humidité moyen au point d'équilibre de déformation (Sets) est alors de 23,3 %, valeur de référence pour modifier les conditions de séchage lors des phases intermédiaire et finale afin d'éviter la formation de gerces internes.

Mots-clés : ayous (*Triplochiton scleroxylon*), sciage, séchage au four, schéma de séchage accéléré.

ABSTRACT

ACCELERATED KILN DRYING OF WAWA (*TRIPLOCHITON SCLEROXYLON*) SAWN TIMBER

In order to develop new drying schedules without drying degrade in accordance with the Ghana Timber Grading Standards for Square-edged Sawn Wood (1995), strain characteristics of wawa were investigated under various combinations of temperature and relative humidity conditions. The strain data obtained from kiln dried wawa boards using a conventional drying schedule was taken as a guide to develop an accelerated schedule for various board sizes (board thickness: one and two inches). The new accelerated schedule took 4 days to reach 11% moisture content, thereby reducing the conventional time by 67%. Adopting similar methodology makes it possible to develop accelerated drying schedules for all low and medium density tropical hardwood sawn timber of various dimensions. In the case of wawa, relative humidity was reduced initially to a predetermined average evaporable moisture value (E-value) between 0.70 and 0.56. When the inner and outer strains reached equal magnitude in tension at this stage, an average evaporable value of 0.21 was established for the wawa boards of different thicknesses. The average moisture content at equilibrium tension strain (SETS) was 23.3%. This value was used as a guide to modify drying conditions in the intermediate and final drying phases to prevent honeycomb formation.

Keywords: wawa (*Triplochiton scleroxylon*), sawn timber, kiln drying, accelerated drying schedule.

RESUMEN

SECADO ACELERADO EN HORNO PARA MADERAS ASERRADAS DE OBECHE (*TRIPLOCHITON SCLEROXYLON*)

Con el fin de desarrollar nuevos procedimientos de secado sin degradación y conformes con las normas ghaneanas de calidad para la madera de arista viva (Ghana Timber Grading Standards for Square-edged Sawn Wood, 1995), se experimentaron las características de deformación de la madera de obeche a diferentes temperaturas y humedades relativas. Los datos de deformación de tablas de obeche secadas en horno, siguiendo un programa clásico de secado, sirven de guía para desarrollar un procedimiento de secado acelerado para tablas de distintas dimensiones (25 y 50 mm de grosor). El nuevo procedimiento permite lograr un porcentaje de humedad del 11% en cuatro días, lo que representa una ganancia de tiempo del 67%. Adoptando una metodología similar, se pueden desarrollar procedimientos de secado acelerado para todas las maderas aserradas de maderas duras tropicales de baja a media densidad y de distintas dimensiones. Para la madera de obeche, el tipo de humedad relativa se redujo inicialmente para alcanzar un valor predeterminado de humedad media evaporable (E) comprendido entre 0,70 y 0,56. Cuando las deformaciones interiores y exteriores alcanzaron la tensión correspondiente a esta fase, se estableció un valor de humedad promedio evaporable de 0,21 para tablas de grosores diferentes. El porcentaje de humedad promedio en el punto de equilibrio de deformación (Sets) es entonces del 23,3%, valor de referencia para modificar las condiciones de secado en las fases intermedia y final para evitar la formación de grietas internas.

Palabras clave: obeche (*Triplochiton scleroxylon*), madera aserrada, secado en horno, procedimiento de secado acelerado.

Introduction

The Ghanaian government's new policy is aiming to encourage the production and export of kiln dried sawn timber and other machined wood products (value added products). This is because in the past, a large portion of the wood exported from Ghana was in the form of round logs (about 55-65%) and green lumber (32-47%) (Ofori *et al.*, 1993). Subsequent studies showed, however, that the unit value price of round wood and green lumber was low compared to that of tertiary products such as furniture, flooring and moulded boards (Ofori *et al.*, 1993).

In order to build on the socio-economic benefits generated by each additional processing operation performed in the country's timber industry, emphasis was therefore shifted towards the production of manufactured wood products. In order to stimulate and expand the young kiln-drying industry, kiln drying was therefore considered as the first phase in downstream timber processing. However, due to missing or inadequate knowledge on accelerated drying techniques for Ghana's abundant hardwood species, kiln operators are facing seasoning problems. Attempts have been made to kiln dry some of the potentially marketable Ghanaian hardwood species but without developing any specific drying. The schedules available involve well-known conventional methods developed over many years of experience with kiln drying operations. However, drying degrades and long drying times often cause seasoning problems, which now require immediate attention. It has therefore become imperative to adopt systematic and scientific techniques to modify the conventional drying schedules for sawn wood, in order to accelerate the drying process and help improve the quality of hardwood lumber without worsening the drying degrade. The pattern of the new drying schedules should be developed not only on the basis of fundamental physical properties and the percentage moisture content of the wood, but should also include stress measurements caused by wood shrinkage and the relationship between moisture content, temperature and the strength of the wood.

The main aim of this study was to develop a new accelerated drying schedule for *Triplochiton scleroxylon* (wawa) sawn timber of 25 and 50 mm (one and two-inch) thickness, to comply with the regulations set out in the Ghana Timber Grading Standards for Square-edged Sawn Wood (1995).

Materials and methods

Preparation of materials

The study employed test procedures similar to those used by McMillen (1955a), Alexiou (1991) and Sagoe (1993), with a few modifications. For the research, wawa logs were obtained from three ecological forest zones in Ghana, namely wet-evergreen, deciduous and semi-deciduous forests. In this study, green sawn wood with the following dimensions

A stack of wawa boards ready for a kiln drying experiment using a 35 m^3 commercial kiln dryer made by Copcal International Dryer Co. (Italy).
Photo C.-T. Bues.

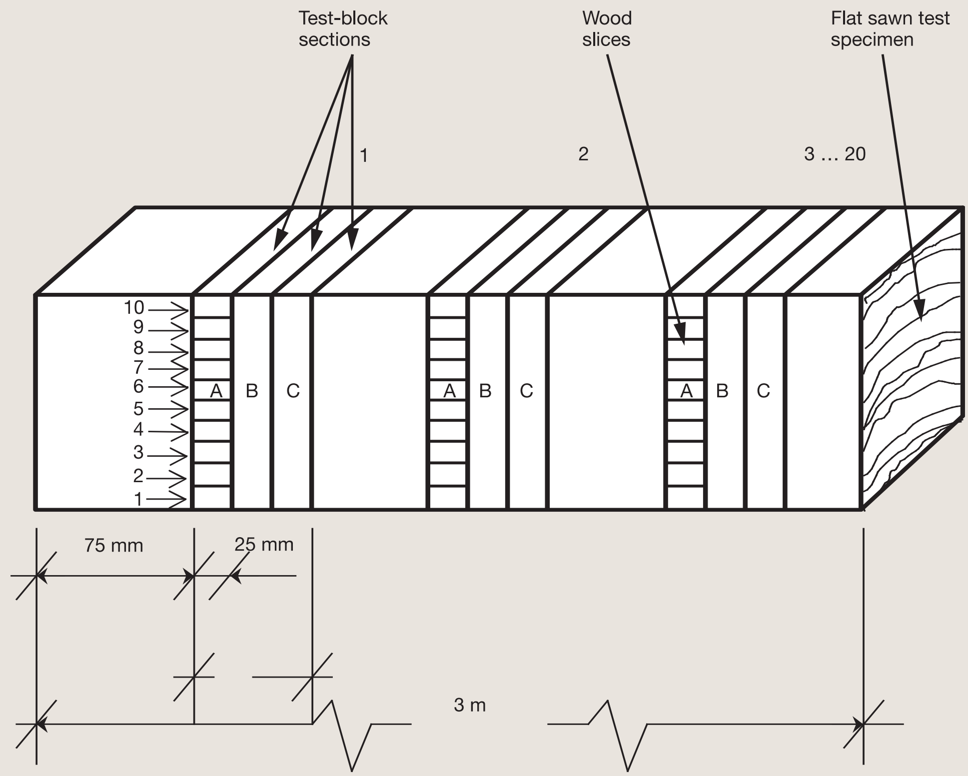

Figure 1.
Sketch showing the method used to mark test-block specimens.
Test-block section A: Slice numbers (1, 2, 3... 10) used to determine shrinkage, stress (compression and tensile) and moisture gradient distribution.
Test-block section B: determination of moisture content at each interval of the drying process.
Test-block section C: determination of case-hardening at each interval of the drying process.

Table I.
Estimation of evaporable moisture value ("E").

Schedules	Wood thickness (mm)	IMC (%)	SETS (x 10^2 mm/mm)	MC (%) SETS	EMC (%)	EM at SETS
Control	25	58.5	-9.36	41	18.6	0.23
	50	77.6	-12.00	57	18.6	0.31
Schedule 1	25	94.78	-11.00	68.19	17.1	0.66
	50	76.42	-10.00	65.13	17.1	0.81
Schedule 2	25	65.46	-6.50	28.29	13.8	0.28
	50	95.72	-17.00	48.01	13.8	0.42
Schedule 3	25		-10.50	13.54	12.1	0.04
	50	67.70	-11.00	33.11	12.1	0.38

IMC: initial moisture content; SETS: state of equilibrium tensile strain; EMC: equilibrium moisture content.

was used: board length from 2.4 to 3.0 m, board width 150 mm, board thickness 25 mm and 50 mm. The logs were sawn into boards by Ehwia Wood Products Limited in Kumasi, Ghana. The sample boards were then planed on all sides to remove any defects due to sawing variations and also to facilitate strain measurements. The sample boards were wrapped in polythene sheets, end-coated with black pitch and then stored in a cold room at 0°C to 4°C for two weeks. This was done to prevent the samples from pre-drying before the start of the experiments.

The experiments were carried out with a 35 m^3 commercial kiln dryer made by Copcal International Dryer Co., Italy. Two internal axial fans were installed in the kiln chamber above an intermediate ceiling to accelerate air circulation and venting.

Four test-runs including a control run were replicated three times each. Each test run used 35 m^3 of wawa lumber comprising the two classes of board dimensions:

- 25 mm x 150 mm x 1.2, 2.4, 2.5 and 3 m;
- 50 mm x 150 mm x 1.2, 2.4, 2.5 and 3 m.

The drying experiments were carried out with 900 one-inch thick sample boards and 400 two-inch thick boards.

The sample boards were used to determine moisture gradient, moisture content and strain during drying. Some reference boards were retained whole to inspect possible degrade during the different kiln runs.

Temperature and relative humidity conditions were monitored semi-automatically. Each green test board specimen was divided and marked with an indelible ink pencil into 20 sections and three adjacent 25 mm wood block sections 75 mm in length, along the length of the board (Figure 1). On the 50 mm thick boards the outer test block sections were each marked into 10 equal sections and the outer test block section from boards 25 mm in thickness were marked into 6 equal slices. The slices were numbered consecutively, beginning at the convex side of the growth rings (Figure 1).

Measurement methods

The width of the test-board was measured between the 2 mid-points at the ends of each outer and centre slice (numbers 1/10, 2/9, 3/8, 4/7 and 5/6, Figure 1) respectively. Every marked board specimen was placed in the centre layers of stacks inside the kiln and loads were put on the stacks to simulate industrial kiln loading practices. Empty spaces around lumber stacks were baffled to ensure a uniform air flow and velocity of about 2.0 to 2.25 m/s over the surface of the test-board specimen.

The three outer sections were cut off from the specimen with a band saw and wrapped in waxed paper foil after each drying interval. The remaining test-board specimen was end-coated and replaced in the kiln. As the sample size was reduced in length, the gap was filled in with short dummy boards supported by extra stickers. The lengths of the marked slices were measured in situ in the intact wood sections before cutting into wood slices (Figure 1, sample number 1-10). The length of the wood slices after cutting was then measured and recorded.

The unit strain (expressed as mm per mm) was determined by the difference between subtracting the green dimensions (before cutting) from the kiln dried dimensions (after cutting) of each slice, and the difference expressed as a fraction of the dimensions after cutting. The unit strain measurements were determined only for the outer (1/10) and centre (5/6) slices within each marked wood section (Figure 1, number 1, 2, 3… 20). Each sliced piece of wood was immediately wrapped in waxed paper foil just before the dimensional measurement was carried out with an electrical digital calliper, to prevent heat and moisture loss. Oven-dry moisture content was determined for each slice to give an indication of moisture gradients in the board during drying. This procedure was repeated for wawa boards 25 and 50 mm (1 and 2 inches) in thickness and the average values were used to draw up tables and graphs for each test run analysed. Equalisation and conditioning were applied to ensure that both thicknesses had reached the desired moisture content of about 11% by the end of the drying process, and also to relieve drying stress in the wood prior to use.

Analysis of evaporable moisture

Evaporable moisture is defined as the value of the fraction of moisture left in the wood when stress in wood is attained either at a state of equilibrium compression strain (SECS) or at a state of equilibrium tensile strain (SETS). The values of the fraction of evaporable moisture "E" were calculated from the derived data obtained from three accelerated test runs carried out in this study. The value of "E" was determined by the formula:

$$E = (C-EMC)/(G-EMC)$$

where:
E = Fraction of evaporable moisture at SETS;
C = Approximate current moisture at SETS;
G = Initial (Green) moisture content;
EMC = Equilibrium moisture content.

The respective values are presented in Table I.

Data Analysis

The data for the drying rate and a visual inspection of the drying quality (possible wood defects developed during the drying process) were used to assess the drying conditions and thus stress developments and degrades, respectively (internal and external). Tests for significant differences in the measured data were conducted using ANOVA and the Student t-test in SPSS version 10.

Results and discussion

Drying schedules

Control schedule

The control schedule adopted from Copcal International Dryer Co (Table II) was used to determine the stress pattern for wawa test-boards 25 and 50 mm (one and two inches) in thickness. Drying time and degrade were also compared with the subsequent test runs in this study to obtain the most suitable kiln schedule for wawa.

Figures 2a and b show that the control schedule's compression and tension strains were lower in magnitude than the other schedules in this study. This is probably due to the low temperatures and high relative humidity (RH) and equilibrium moisture content (EMC) used for this schedule as compared to high temperatures, low RH and EMCs for the other test schedules. The control schedule took 12 days to dry the wood to about 11% final moisture content, with defects acceptable to the Ghana Timber Grading Standards for Square-edged Sawn Wood (1995).

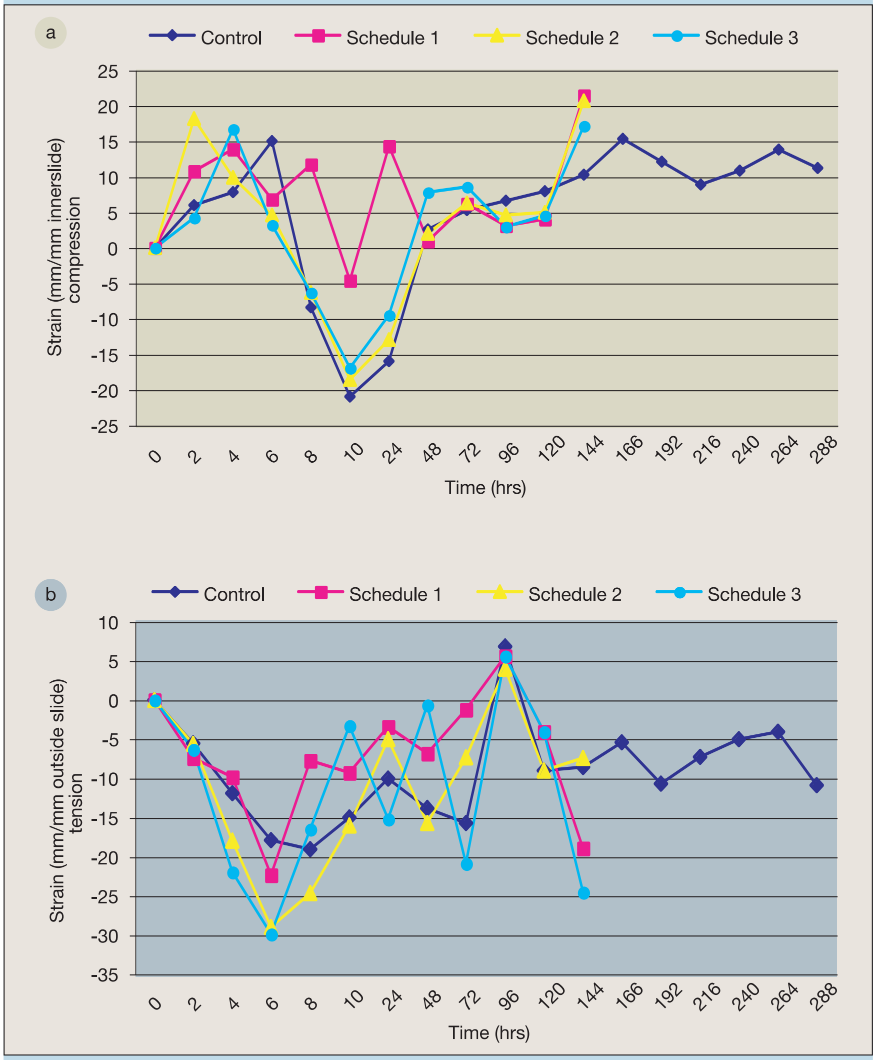

Figure 2.
a. Internal compression strains during wood drying according to different schedules. The temperature profile shown was followed for all schedules.
b. External tension strains during wood drying according to different schedules. The temperature profile shown was followed for all schedules.

Schedule 1

Based on the results obtained from the control test run, modifications were made to improve the drying time while eliminating or reducing the defects. Temperatures were increased to speed up drying, which resulted in reductions in both RH and EMC during the drying process as a whole (Figures 3a, b and c). The results show that compression and tension strains with this schedule were higher in magnitude than with the control schedule (Figures 2a and b). This may be due to the increase in temperatures and lower RH and EMC, which created high moisture gradients and speeded up the drying process. These findings confirm previous studies on Dahoma (*Piptadeniastrum africanum*) and Celtis (*Celtis mildbraedii*) species (Sagoe, 1993). The defects observed with this schedule were slightly higher than with the control schedule but remained within acceptable limits. Drying time was 6 days. There were short equalisation and conditioning periods for both the 25 and 50 mm (1 and 2 inches) boards to achieve the same 11% moisture content and also to relieve some stresses in the wood.

Table II.
Kiln dry table for *Triplochiton scleroxylon* adapted from Copcal International Dryer Co.

Moisture content (%) of wettest timber	Dry bulb temperature (°C)	Drying gradient content (%)	Equilibrium moisture content (%)	Final moisture
Green	60	2.6	15	10
40	70	No data	No data	No data

Schedule 2

Having established data for schedule 1, further modifications were made to improve on schedule 1. Temperatures were increased to speed up drying within the first 10 hours whilst RH and EMC were reduced (Figures 3a, b and c). Drying was monitored from the green to the fibre saturation point (FSP) to reduce or avoid degrades. Moisture contents in this schedule decreased steadily (Figure 4). Once the moisture content was below the FSP, temperatures were further increased and both RH and EMC were arbitrarily reduced to speed up drying (Figure 3a, b, and c), The above changes in temperature, RH and EMC in this drying process were applied because at the point when moisture content was observed to be below the FSP, further defects were not likely to appear. Figures 2a and b showed further increases in strain levels of both compression and tension as compared to the control and schedule 1. This schedule took 5 days to dry the wood to the final moisture content of about 11%.

Accelerated schedule 3

After comparing with previous data and using the results as a guide for further development, a new and faster schedule was developed. With the new schedule 4 days were required to dry the 25 and 50 mm thick wawa boards without serious defects. This was a considerably shorter time than the 12 days obtained with the control schedule developed by Copcal as shown in Table II. A 67% reduction in conventional drying time was achieved. This was possible when 33.8°C dry bulb temperature and 71% RH schedule were applied (Figures 2a and b) in the initial drying phase. The temperature was boosted successively from 63 to 71.2°C in the second phase and from 72.3-81.6°C final drying phase while RH reductions were made arbitrarily in the last two phases.

Before conducting the experiments, the conventional schedule for 50 mm wawa boards (Table II) was used as a control to help determine the stress pattern for the subsequent

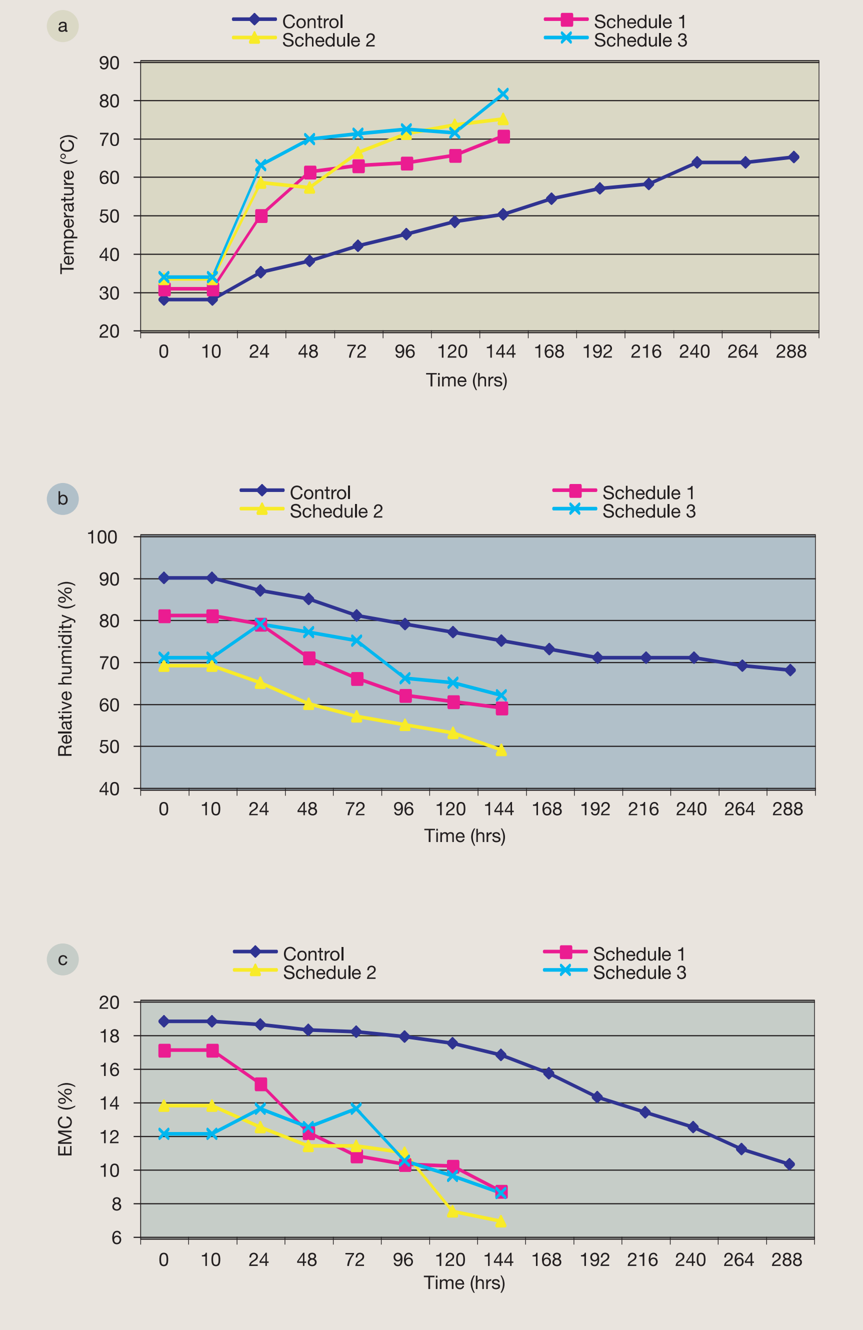

Figure 3.
a. Drying schedules based on temperature.
b. Drying schedules based on relative humidity. The temperature profile shown was followed for all schedules.
c. Drying schedules based on equilibrium moisture content (EMC).
The temperature profile shown was followed for all schedules.

development of an accelerated schedule for wawa boards of the two sizes. Drying took 12 days with the control test run and 6, 5 and 4 days respectively with schedules 1, 2 and 3, without producing defects as defined in the Ghana Timber Grading Standards for Square-edged Sawn Wood (1995).

Defects

During the entire research, no serious defects were observed as set out in the Ghana Timber Grading Standards for Square-edged Sawn wood (1995)(Table III). The total defects observed in the test runs were minimised as a result of the adaptations of the correct drying techniques proposed by PRATT and STEVENS (1974) in their work on *Pinus* species. This research was considered successful because drying degrades were less than 4%, which conforms to RAYMOND, RIETZ (1971) studies on Red oak *(Quercus rubra)*.

Moisture content

The control and accelerated test runs showed similar drying pattern during the drying process. Figure 4 provides the detailed moisture data for all schedules. All schedules differ significantly at p = 0.001 level except schedule 1 and control, where significance is at p = 0.005. Differences between the schedules were significant at p = 0.001 level except between schedules 2 and 3 when significance was at p = 0.005. During the warming stage, which took 10 hours for the study as observed in Figures 3a, b and c, temperature, EMC and RH were all stabilised. This was to ensure that all the stacks in the load were evenly warmed across the entire cross-section of the wood and also to allow the moist wood to heat up to a uniform surface temperature. A steady moisture gradient was maintained between the core and the outer shell so as to prevent cell collapse and honeycomb formation as far as possible. A further reason was to maintain maximum strength in the fibres near the surface of the wood and help protect them from temperature shock that could lead to the development of surface checks and stresses causing end checks in the outer shell of the lumber. In contrast, the moisture content (MC) decreased.

During drying above the fibre saturation point (FSP), temperature was increased (Figure 3a) whilst EMC, RH and MC (Figures 3b, c and 4) were reduced. This was to allow continuous removal of free water from the cell luminar and the larger cavities. DINWOODIE (1981) reported that at this period, increasing the temperature and lowering RH and MC helps to vent out moist air and allow fresh dry air to pick up moisture from the surface of the wood, which in turn increases the rate of drying. Below the FSP, the temperature was increased to allow more kinetic energy to break the hydrogen bonds in the cell walls and more moisture to escape, thus speeding up drying. This was observed in the study (Figure 4) and conforms to the findings of TORGESON (1959), PRATT and STEVENS (1974) and SAGOE (1993).

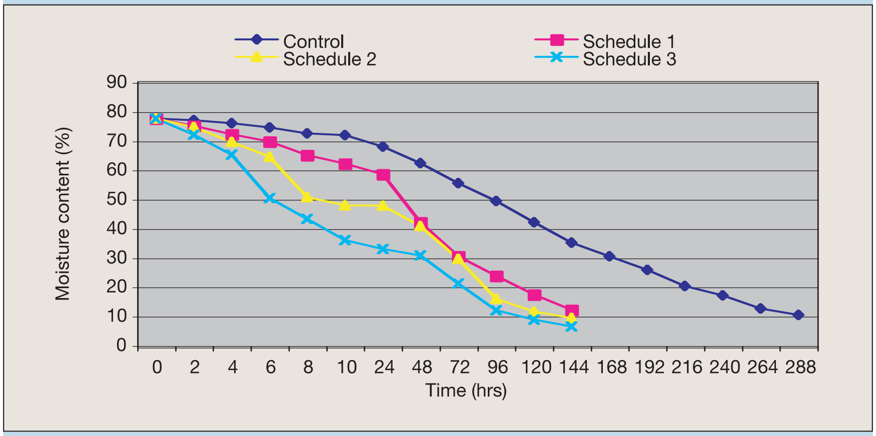

Figure 4.
Drying curve (moisture content) of drying schedules for kiln-dried wawa hardwood. The temperature profile shown was followed for all schedules.

Table III.
Assessed defects for the schedule in kiln dried wawa lumber.

Type of defects	Control schedule		Schedule 1		Schedule 2		Schedule 3	
	Board length (1.2 - 3.0 m) 900 pcs	Kiln defects (%)	Board length (1.2 - 3.0 m) 900 pcs	Kiln defects (%)	Board length (1.2 - 3.0 m) 900 pcs	Kiln defects (%)	Board length (1.2 - 3.0 m) 900 pcs	Kiln defects (%)
Checks	4	-	9	-	7	-	6	-
End splits	5	-	7	-	5	-	9	-
Cup	3	-	2	-	3	-	4	-
Twist	-	-	-	-	6	-	9	-
Bow	4	-	1	-	4	-	7	-
Total	-	1.7	-	2.1	-	2.7	-	3.8

Stress development

Stress development is shown in Figures 2a and b for the different drying schedules. Differences in both compression and tension stress were insignificant between all schedules and the control; however, significant differences arose when comparing compression between schedules 2 and 1, and between 3 and 1. Significant tension differences were observed only between schedule 1 and control (all tested with t-test $p = 0.05$). Each single strain recovery value from the test boards constitutes an average value determined from the results of two slices equidistant from the centre. The tensile and compression strains as used in this research represent recoverable strain that results from the released tension and compression stresses in the wood slices as they are cut from wawa test board samples.

The strain patterns observed in Figures 2a and b were consistent with those found earlier by Torgeson (1940), McMillen (1955a, b) and Sagoe (1993) when they worked on one and two-inch blackgum (*Nyssa silvatica*), red oak (*Quercus rubra*), dahoma (*Piptadeniastrum africanum*) and celtis (*Celtis mildbraedii*), respectively. The strain recovery levels shown in Figures 2a and b continued to decline insignificantly to zero (t-test $p = 0.05$) from the initial maximum compression and tension, even with increasing temperature and decreasing relative humidity. As the wood began to dry, the outer surface went into tension and the inner section went into compression. Stresses set in and developed to maximum levels. The stresses then declined in magnitude to zero. As drying continued the stresses reversed. This continued until the end of drying. The magnitude of the tensile strain was greater than the compression strain. This confirms the findings of Rietz (1950), when he reported that, if end and surface checks do not occur at this stage, there is no likelihood that any serious defects will occur later.

Chain saw operator get specific directives to cross cut logs to the required length.
Photo Pr Forstnutzung.

Sawing wawa logs into lumber for the study with a vertical band saw mill.
Photo Pr Forstnutzung.

Table IV.
Estimated (final results) evaporable moisture value ("E").

Schedules	Wood thickness	25 mm	50 mm	Mean MC & EM (%)
Control	MC (%) SETS	41	57	49
	EM at SETS	0.23	0.31	0.54
Schedule 1	MC (%) SETS	68.19	65.13	66.66
	EM at SETS	0.66	0.81	0.74
Schedule 2	MC (%) SETS	28.29	48.01	38.15
	EM at SETS	0.28	0.42	0.35
Schedule 3	MC (%) SETS	13.54	33.11	23.33
	EM at SETS	0.04	0.38	0.21

MC: moisture content; SETS: state of equilibrium tensile strain; EM: equilibrium moisture.

Stacked wawa lumber ready for kiln-drying.
Photo Pr Forstnutzung.

Stress in drying hardwood species occurs when their outer surface reaches a state of equal strain with their internal portions. This may either be in SETS or SECS. This implies that various hardwood species have different drying characteristics and care must be taken in controlling the parameters that can speed drying to avoid degrade. Predictions of moisture content at either SETS or SECS would be a useful guide in preventing honeycomb formation. The combination of Figures 2a and b shows that the stressed condition occurred at SETS. Rietz (1950) reported that for all hardwood species, the E value should be 0.7, at which the initial reduction of relative humidity should start. An E value of 0.5 indicates that RH control in the kilns was no longer critical, because new surface checks are not likely to develop and an increase in temperature will not cause honeycomb formation. E values were computed for the control experiment and subsequently used to develop a new accelerated schedule for one and two-inch wawa.

Development of a new accelerated schedule

Based on Rietz (1950) reports on E values for hardwood species, E values and moisture contents for the control test run were computed during the drying process. In the first phase of drying, maximum tensile strain was reached, E value was 0.56 and the corresponding value of MC was 52%. In the second phase, when the initial maximum tensile started to drop in magnitude towards zero and internal strain reversed from compression to tension and vice versa, it was safer to increase temperature and lower RH arbitrarily when E value was 0.54 and moisture content 49%. The final phase, the period of SETS until end of drying, saw the final temperature boost from 70 to 76°C and subsequent reduction of relative humidity to avoid the development of peak levels of inner tensile strain and also speed up drying. The data from the control test run was used as a guide to develop a new accelerated drying schedule for one and two-inch wawa. The fastest new drying schedule had an E value of 0.21 and an average moisture content of 23.3% (Table IV). The new schedule took 4 days to dry with acceptable drying degrades instead of the usual 12 days with the conventional schedule.

This was possible when a 33.8°C dry bulb temperature and 71% relative humidity schedule were applied in the initial drying phase. Temperature boosts from 63 to 72°C in the second phase and 72.3 to 81.6°C in the final drying phase were applied successively, while RH reductions were made arbitrarily in the last two phases. Table V shows the new, fastest schedule adopted for use by kiln operators in the Ghana timber industry.

Table V.
Accelerated new drying schedule for wawa 25 and 50 mm (one and two inches) in thickness (*Triplochiton scleroxylon*).

Drying phase	Stress condition	EM	EMC (%)	Duration (hrs)	Temperature (° C)	RH (%)	EMC (%)
Phase I	To max, outer tensile strain	0.47	38.28	6	33.80	71	12.1
Phase II	To SETS	0.04	14.08	72	63 – 71.2	75	11.01
Phase III	To max, outer tensile strain	-	7.0	96	72.3 – 81.6	62.0	8.6

EMC: equilibrium moisture content; RH: relative humidity; SETS: state of equilibrium tensile strain.

Conclusions

A modified accelerated drying schedule was developed for wawa boards 25 and 50 mm (one and two inches) in thickness, based on the data obtained from the conventional 50 mm schedule and the subsequent test runs in this study. The new accelerated schedule reduced drying time for wawa by 67% compared to the conventional schedule, with degrades acceptable to Ghanaian grading standards.

In this study the prediction of an E-value of 0.21 and a pre-determined average moisture content of 23.3% for one and two-inch of wawa boards was used as a guide for timely modification of the schedule to prevent honeycomb formation. Finally, the study revealed that temperature and relative humidity variations have a significant effect on both drying time and defects from the green state to the fibre saturation point of the wood.

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