Modulation of Moisture Content and Grouping of Wood from Fast-growth Tropical Species in Plantation

Róger Moya
Escuela de Ing. en Forestal, Instituto Tecnológico de Costa Rica
CIIBI, Apartado 159-7050, Cartago, COSTA RICA.
Email: rmoya@itcr.ac.cr

Erika Urueña
Facultad de Ing. en Forestal, Universidad de Tolima
A.A. 546 Ibagué, COLOMBIA
erikajohana18@hotmail.com

Cynthia SALAS and Freddy MUÑOZ
Escuela de Depto. Ing. en Forestal, Instituto Tecnológico de Costa Rica
CIIBI, Apartado 159-7050, Cartago, COSTA RICA.
cysalas@itcr.ac.cr, fmunoz@itcr.ac.cr

Abstract

Exotic and native species had wide been planted in reforestation program in several tropical countries, with excellent developed in tree diameter and productivity. However, some problems are noted: wood properties and industrial performance are different when wood came this condition. There was began a research about dry behavior of drying time of wood from species growing in fast growth plantation. The main objective was to determine a model lineal of moisture content (MC) variation of wood obtained from MC measured by gravimetric method. High power precision (R^2>0.90) was found in *Alnus acuminata*, *Tectona grandis* and *Terminalia oblonga*. *Vochysia guatemalensis*, *Swietenia macrophylla*, afterwards *Cupressus lusitanica*, *Swietenia macrophylla*, *Terminalia amazonia* and *Vochysia guatemalensis* varied their R^2 from 0.80 to 0.87. The lowest value of R^2 was found in *Acacia magnium*. The linerized model from $moisture\ content = a * \varepsilon^{-time*b}$ was utilized for grouping wood species. Five groups were established from a longest and shortest dying time. The first and second group is colleted *A. magnium* and *V. guatemalisis* respectively. In the third ones, *C. lusitanica* and *T. grandis* were group and the flowing one *S. macrophylla*, *T. amazonia* and *T. oblonga*. And last group with shortest drying time is compost for *A. acuminata.*

Keywords: Dry, moisture content, tropical species, wood quality

Introduction

Costa Rica posses a great stock of hardwood timber for sawmilling both from natural and plantation forests (Moya 2004), however species growing in fast growth plantation condition had reached large commercial importance. On others the hand, few species have acquired commercial importance in reforestation projects due to a reduced knowledge on their genetic, reproductive, and silvicultural management (Mora 2002). By year 2000, only 50 000 ha of timber species were counted for forest plantations with production purposes, limiting the establishment of a sustainable wood trade market.

An advantage of planted species is the uniformity of the product processes, not only the sawnwood but also the drying process, (Moya, 2004). Many tropical species from natural forest in the trade market must be dried in the same place and time of these planted species because of the small volume of the first one (De Souza Mendes et al., 1995, Jankwowsky and Gonçalves, 2006). As same time, conventional kiln drying is the most common method for drying lumber around the world. A different drying schedule are implemented in conventional kiln drying according to lumber characteristics as dimensions, specific gravity, tendency to show defects or degrade and desired quality standards.

Few studies on wood properties or behavior in industrial process of fast growth species from tropical climates are reported in the literature and are limited to a reduced number of characteristics. The aim of the present study was to established the relationships moisture content measured current moisture content eight (*Acacia magnium*, *Alnus acuminata*, *Cupressus lusitanica*, *Swietenia macrophylla*, *Terminalia amazonia*, *Terminalia oblonga*, *Tectona grandis* and *Vochysia guatemalensis*) species growing in fast growing plantation condition in a tropical region of Costa Rica. And this information utilized for grouping of those species.

Material and Methods

Plantation description and tree sampling: eight different pure plantations located at several part of Costa Rica were utilized. The initial planting density was 1111 trees/ha (3x3 m spacing); at the moment of evaluation the stands aged 9-18 years and presented a density of 495-575 trees/ha (Table 1). A second thinning was applied in representative plot of all species, approximately were felled 60 trees in one hectare. 3 or 4 logs with 2.5 m in length were extracted for each thinning, approximately 60 log with 3.5 m^3.

Sawing pattern: Logs were sawn using a pattern described in figure 1. This pattern was designed to produce boards with different orthotropic directions commonly used in Costa Rica to obtain wood for furniture industry. Each board was 2.5 cm thick and boards with bark were processed using an edger. Approximately 250 boards were obtained from different log/species.

Table 1. Information on the conditions and management of the plantations used.

Specie	*Acacia magnium*	*Alnus acuminata*	*Swietenia macrophylla*	*Terminalia oblonga*	*Terminalia amazonia*	*Tectona grandis*	*Cupressus lusitanica*	*Vochysia guantemalisis*
Age (Years)	9	9	10	10	14	13	18	8
Density (trees/ha)	556	338	480	495-575	452	475		515
Total height (m)	20.7	19	16.7	-	21.40	21.85		22.7
DBH (cm)	20.5	36.7	21.5	-	22.59	25.2		18.5
Gravity specific	0.45	0.34	0.51	0.55	0.49	0.57	0.43	0.32
Initial MC (%)	134.49	75.5	42.42	52.57	66.61	106.39	91.91	176.9
Final MC (%)	17.28	9.46	13.3	9.11	12	10.8	11.8	7.58
Drying time (Hours)	376	52	147	159	183	237	274	227
Drying rate (% / hrs)	0.31	1.27	0.20	0.27	0.30	0.40	0.29	0.75
Dry schedule*	T2-D4 & T6-D2	T10-E3	T6-D4	T3-C2	T3-C2	Schedule H (Adjust)	T3-C2	T2-D4
Dry groups**	1	5	4	4	4	3	3	2

*Sydney et al. (1988).
**Dry groups utilized in linearized model

Drying and moisture content control: The drying process was carried out in a small NARDI® 2 m^3 capacity dry kiln. The drying schedule used was according different references for wood (Table 1). The pilot kiln had six moisture probes, which were located at different heights and depths of the package. These probe measurements were used as reference to make changes to both the temperature and relative humidity inside the kiln. MC was also monitored using six kiln samples located at different pile heights. The probes measurements were located in the same boards (Fig. 1b). The kiln sample was weighted twice time per day and simultaneously was recorded the MC displayed for moisture probes.

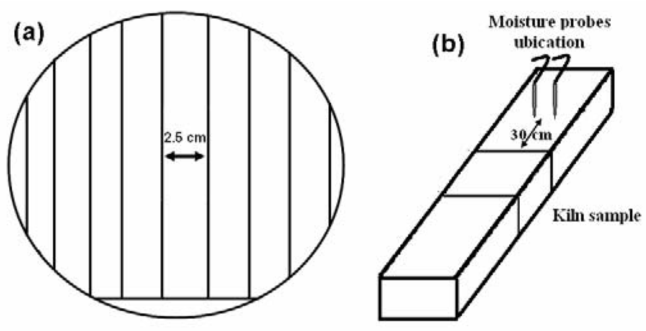

Figure 1. Sawing pattern and kiln samples obtained from boards

Results

Large average initial moisture content was found for different fast growth plantation species, from 52.57% to 134.49%. Besides, large initial MC was measured different kiln samples in all different species (Fig. 2a), except in *T. oblonga* where the differences between maximum and minimum MC of samples was only 9%. Although, the main objective of ours work was not established grouping species for kiln dry, three different group can be separate according initial MC (Fig. 2a); (I) lower initial MC, *S. macrophylla* and *T. oblonga* are grouped it; (II) moderate initial MC; *A. acuminata*, *C. lusitanica*, *T. grandis* and *T. amazonia* can be include and (III) with higher initial MC, that incorporates *A. magnium* and *V. guatemalensis*.

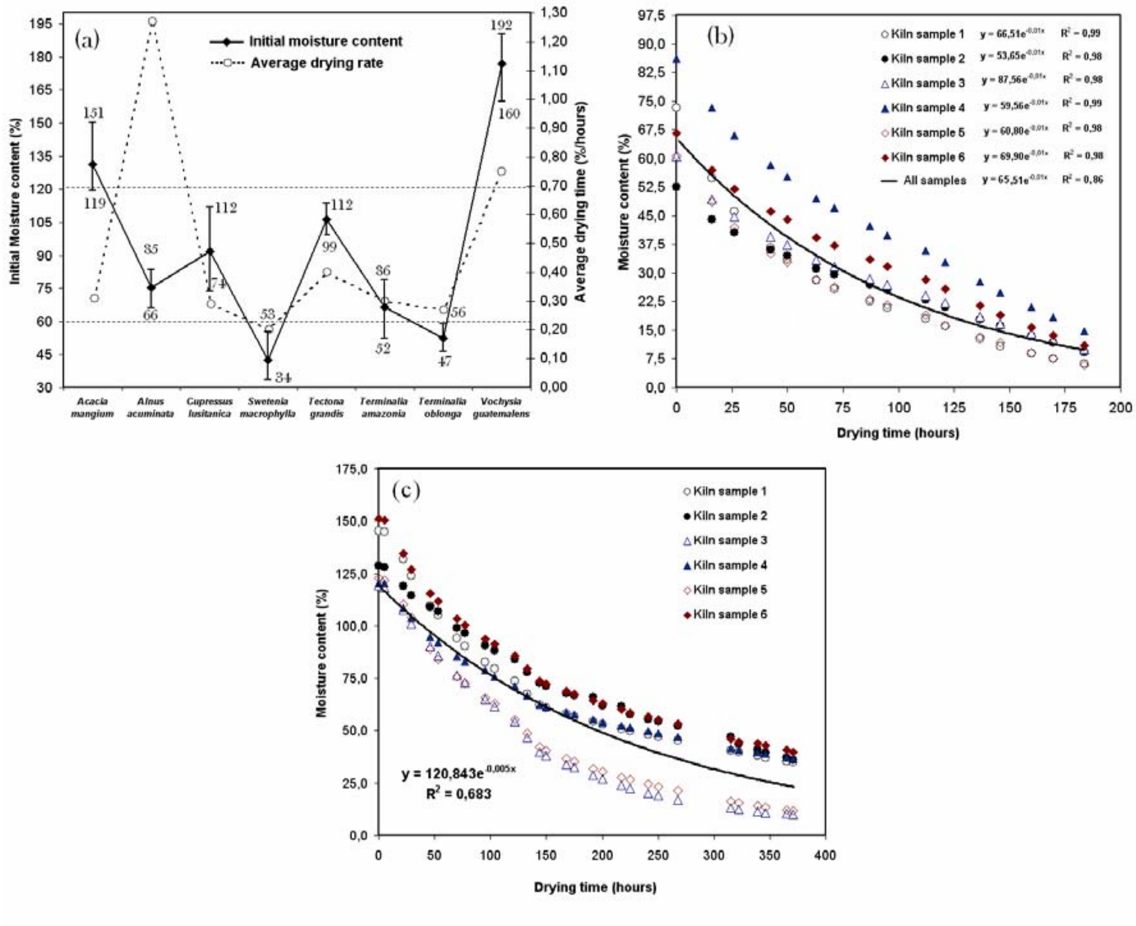

Figure 2. Initial MC and average drying rate for different fast-growth plantation species (a) and variation of MC with drying time in Terminalia amazonia (b) and A. magium (c).

The final MC varied between 9.11% to 17.28. It was also found that wet pocket presence was presented in 4 kiln samples of *A. magnium*, varying from 34 to 39% (Fig. 2c), so these samples affected the final average MC (Table 1). On the other hand, the time to reach final MC varied from 52 to 376 hours. Boards of *A. magnium* required a greater number of hours for reaching final MC than others plantation species (Table 1). *C. lusitanica* required 274 hours, following by *T. grandis* and *V. guatemalensis*. While, intermediated period was found for *S. macrophylla*, *T. oblonga* and *T. amazonia*. *A. acuminata* was the lowest drying time with 52 hours (Table 1). As a general rule, drying time increases with specific gravity (Tschermitz and Simpson 1977). However, a comparison of the specific gravity data with dying time, show one significant deviation from general rule. *V. guatemalensis* which has the lower specify gravity, it also has the lower MC; besides, *T. grandis* and *T. oblonga* are species with very different drying time. This behavior could be affected for many other factors as tyloses presence in the vessels, which interrupt the good circulation of the water in the wood (De Souza et al. 1975)

According with drying times, the average drying rate varied from 0.20 to 1.27 %/hours. The highest value of drying rate was *A. acuminata* and the lowest one was *S. macrophylla* (Table 1). For *A. magnium*, *C. lusitanica*, *T. grandis*, *T. amazonia* and *T. oblonga* similar drying rate was obtained, the variation was from 0.27 to 0.40 %/hours. Three different drying rates can be established according with their values obtained: the first one, with highest values (over 0.70 %/hours), can be grouped *A. acuminata* and *V. guatemalensis*. The second one, with intermediate values (between 0.25 and 0.70 %/hours), were grouped *A. magnium*, *C. lusitanica*, *T. grandis*, *T. amazonia* and *T. oblonga*. For *A. acuminata* and *V. guatemalensis* are located in the third group, with drying rate over 0.70 %/hours (Fig. 2a)

As expected, the MC decreases with time (hours) and the relationships between MC and drying time was modulated by exponential relation (Eq. 1). Figure 2b, for example, shown the relationships between MC and drying time found in different kiln samples of *T. amazonia*. The "b" values in all kiln samples was -0.01 and "b" values varied from 53.65 to 87.56: The determination coefficient was presented individual samples, however when we considered the average of all samples the determination coefficient decreased to 0.86 (Fig. 2a).

$$MC = a * \varepsilon^{-t*b} \qquad (1)$$

Where MC: moisture content, *t*: elapsed drying time and "a" and "b" are coefficients.

The "a" and "b" coefficients are estimated by linearization of equation (1), so can be written as:

$$\ln(MC) = \ln(a) - t*b \qquad (2)$$

The table 2 shows coefficients of linearized model, its determination coefficients (R^2) and empirical equation obtained for all fast growth species. *A. acuminata*, *T. grandis* and *T. oblonga* presented R^2 over 90%, afterwards *C. lusitanica*, *S. macrophylla*, *T. amazonia* and *V. guatemalensis* varied their R^2 from 0.80 to 0.87. The lowest value of R^2 was found in *A. magnium*, due to high final MC obtained for wet pocket presence in kiln samples (Fig. 2c). The percentage of error in predicting time varied from 12.05 to 34.99%. *A. magnium*, C. *lusitanica*, and *V. guatemalensis* were with highest percentage. *A. acuminata*, *T. grandis, S. macrophylla, T. amozonia* and *T. oblonga* with values in error percentage varied from 12.04 and 24.60%. McMillen and Boone (1974) and De Souza et al. (1975) found 15.8% and 14.4% in the error values of the drying time for some tropical species. Therefore, the margin of error for *A. acuminata*, *T. grandis, S. macrophylla, T. amozonia* and *T. oblonga* for the drying time prediction is within the normal requirements for drying process.

Table 2. Coefficients of linearizad model, determination coefficient and empirical equation for 8 fast growth species of Costa Rica.

Fast growth species	Coefficients of linearized model		Determination coefficients	Error (%)	Emperical equation
	b	Ln(a)			
A. manigum	-0.005**	4.794**	$R^2 = 0.683$	34.99	$y = 120.843e^{-0.005x}$
A. acuminata	-0.032**	4.392**	$R^2 = 0.923$	18.33	$y = 80.776e^{-0.032x}$
C. lusitanica	-0.009**	4.407**	$R^2 = 0.841$	31.86	$y = 82.026e^{-0.009x}$
S. macrophylla	-0.008**	3.900**	$R^2 = 0.801$	21.15	$y = 49.426e^{-0.008x}$
T. grandis	-0.011**	4.801**	$R^2 = 0.966$	14.34	$y = 121.575e^{-0.011x}$
T. amazonia	-0.010**	4.183**	$R^2 = 0.837$	24.60	$y = 65.530e^{-0.010x}$
T. oblonga	-0.007**	3.971**	$R^2 = 0.911$	12.05	$y = 53.232e^{-0.007x}$
V. guatemalensis	-0.012**	5.242**	$R^2 = 0.868$	31.66	$y = 189.076e^{-0.012x}$

** Statistically significant to α=0.01

The drying time can be used as a criterion for grouping species. To test this criterion, it was compared "a" and "b" coefficients of linearized model (Fig. 3a). The "a" coefficient was same values for *S. macrophylla*, *T. amazonia* and *T. oblonga*, all of them with the lowest values. It was found not significant difference between *C. lusitanica* and *A. acuminata* and between *T.grandis* and *A. magnium* for "a" coefficient. The highest values were found for *V. guatemalensis* (Fig. 3a). Different "b" coefficient was found in *A. acuminata* and *V. guatemalensis*. Although, an intermediate group can be established with "b" values from -0.028 to -0.006, some differences among species were found (Fig. 3b). For example, *V. guatemalensis* was not statistically significant *T. grandis* but it was statistically different other species. And not significant difference was found between *C. lusitanica*, *S. macrophylla* and *T. amazonia*.

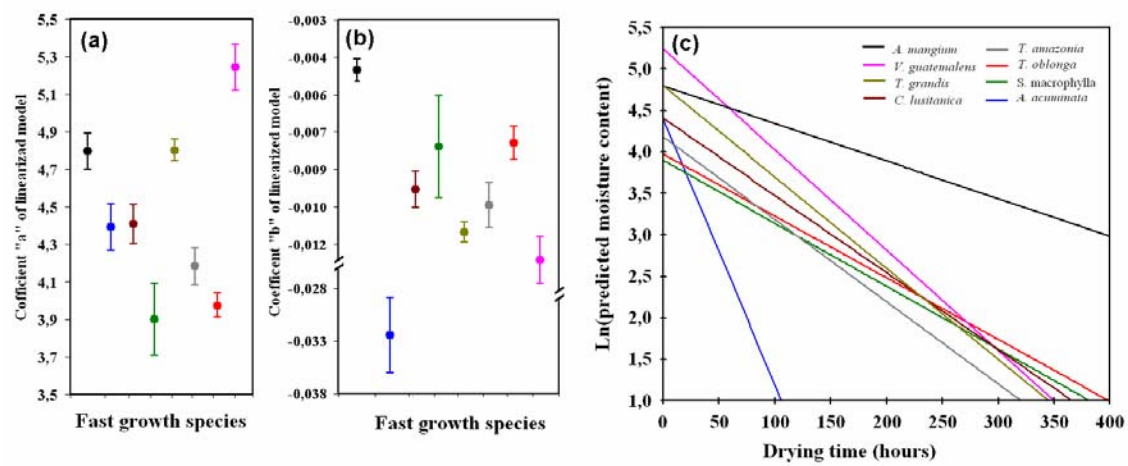

Figure 3. "a" and "b" values of linearized model (a and b) and regression slop of predicted drying time for different fast-growth plantation species (c).

Figure 3c represents the slope of predicted or linearized model as was described by Equation (2).

A 5 group are possibly visualized: the first one is formed *A. magnium* only, and it is the longest drying time. V. guatemalensis (with moderate longer drying time) could be divided of rest of fast growth species because had different linearized model and can be collated in the second group. It had statistical differences between "a" and "b" coefficient and the rest specie (Fig. 3a and 3b). The third group is formed for C. lusitanica and T. grandis. However, according with "b" coefficients values, this value was higher in T. grandis than C. lusitanica (Fig. 3a), which could affect if they are group (Fig. 3b). The fourth group could be establish with 3 species: S. macrophylla, T. amazonia and T. oblonga. For example, found among species (Fig. 3a and 3b). The last group with a shortest drying time is colleted A. acuminata only (Fig. 3c).

Conclusions

The fast growth species utilized in the reforestation in Costa Rica have different drying time. However, it possible groups some of them according drying time. Five groups were established from a longest and shortest dying time. The first and second group is colleted *A. magnium* and *V. guatemalisis* respectively. In the third is set for *C. lusitanica* and *T. grandis*, the flowing group for: *S. macrophylla*, *T. amazonia* and *T. oblonga*. And last group with shortest drying time is compost for *A. acuminata.*

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