Development of an Experimental Drying Schedule for *Eucalyptus dunnii* Wood Aiming Further Industrial Application

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Abstract

Brazil has approximately 3 million hectares of fast growing plantation forests of *Eucalyptus*. It is known that Eucalyptus wood is very versatile, being possible its application in high value products (e.g. solid furniture and flooring). However, to get a product of high quality the processing of wood must be also of high quality, regarding to sawmilling, drying and machining. The kiln drying of wood is currently recognized as a vital element in the value of processed solid wood, with an emphasis on the improvement of its quality and costs reduction. The aim of this study was to develop and test a drying schedule for the *Eucalyptus dunnii* wood aiming further industrial use, generating wood of good quality for higher value products application. The developed drying schedule was considered appropriated for the *Eucalyptus dunnii* species, however, some improvements must be done: conditioning time must be increased once the wood charge had a wide variability of final moisture content; the drying load must be restrained with some restraining device, in order to reduce warping, mostly cupping. These modifications will reduce the defects level of the dried wood, reduce the volume losses in planing and increase the yield of dry wood. The phase of collapse recovery was efficient, even not getting the wished values of dry and wet bulb. It is important to notice that the quality of the wood, regarding to presence of knots, pith wood and resin and gum channels influence directly in drying, reducing its final quality.

Keywords: kiln drying, *Eucalyptus dunnii*, drying schedule development.

Introduction

Brazil has approximately 3 million hectares of fast growing plantation forests of *Eucalyptus*. *Eucalyptus* wood has a wide range of applications and uses even for energy production (coal), as a low price product, or furniture and flooring use, with high value products. So, *Eucalyptus* wood is very versatile and its use depends on correct technology development and quality processing.

Currently, the use of wood from planted forests has been an unavoidable world tendency, once that the society consumption demands an increasing of the wood production with quality and environmental care. The international trade of forest products, which moves 115 billion dollars per year, goes increasing and the developed countries domain this kind of trade, answering for 80% of the total amount of importations and exportations. However, some regions of Asia and South America have been becoming each time more representative (Leão, 2000). But, it is still common to find barriers to some kinds of wood, for example the genus *Eucalyptus* ones, where in majority of the times are unfairly processed which results in low quality products.

The *Eucalyptus* genus, as cited by Calori e Kikuti (1997), has a great versatility regarding to its use. In their research work they tested the physical and mechanical properties of 20 years old *Eucalyptus dunni,* and recommended this species where great mechanical resistance is demanded, such as structural use, flooring, body of trucks, handles of tools, etc. The popularity of solid wood furniture, from certificated plantations, is a tendency in the European trade which will last for a long time, and *Eucalyptus* wood has a great potential if correctly used (Assis, 1999).

However, during kiln drying, *Eucalyptus* wood low permeability contributes to a fast surface drying while the inner part is still wet, over the fiber saturation point. This is a problem which causes internal tensions due to this marked moisture gradient. As result, collapse, surface and end checks occur, defects which tend to increase as the drying temperature increases (Vermaas, 1998).

According to Campbell and Hartley (1984) *Eucalyptus* wood dries slowly and its characteristics during drying are: propensity to collapse, surface checks, high shrinkage levels, development of moisture gradient and marked drying tensions. In the majority of *Eucalyptus* species the average basic specific gravity ranges from 500 to 900 kg/m^3, being relatively impermeable and difficult to dry.

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The aim of this study was to develop and test a drying schedule for the *Eucalyptus dunnii* wood aiming further industrial use, generating wood of good quality for higher value products application.

Material and Methods

The trees used in this study were felled from a 13 years old homogeneous fast grown plantation of *Eucalyptus dunnii* Maiden, in the city of Três Barras, Santa Catarina state, Brazil. The trees were selected from an area of 37.5 hectares, with 1634 trees/hectare, with straight stem and diameter higher than 30 cm (BHD). This forest was managed for lumber production.

Physical Properties of Wood

Some most important physical properties were determined, once that these properties are related to drying. These were the evaluated properties: maximum (from green to dry) shrinkage (radial, tangential and volumetric), anisotropy coefficient (tangential/radial shrinkage) and basic specific gravity (dry weight/saturated volume). There were made specimens from boards of different trees in order to get a wide range of variability of the wood collected. These specimens were made in accordance with COPANT (1972) standard.

Kiln Drying Preparation

In this study there were tested five loads of *Eucalyptus dunnii* wood. For each kiln drying load there were used 44 wood pieces of 750 x 150 x 27 mm cut from long original boards. Before drying, each piece was weighed and had its real width and thickness measured.

Between each wood sample, from the original board, it was taken a sample of 50 mm to determine the initial moisture content (IMC) of the load (Fig. 1). The IMC was calculated by the gravimetric method (weight of water in wood/weight of dry wood and water x 100).

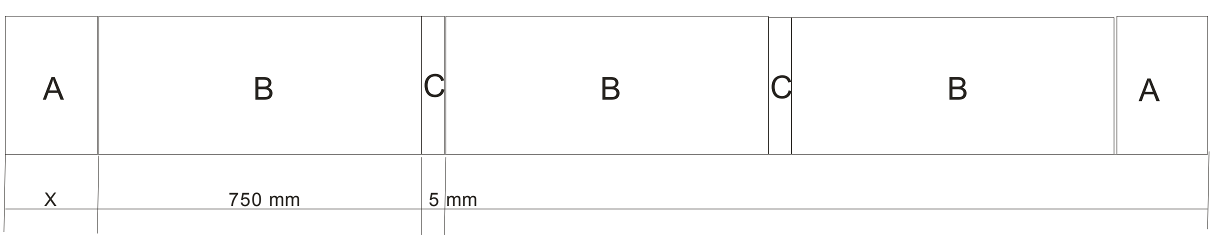

Figure 1. Sampling scheme for kiln drying: A – discarding; B – kiln drying; C – IMC.

Conventional Dry Kiln

Figure 2. Laboratory conventional dry kiln

The conventional dry kiln used in this work was provided with an automated system of management and data collection. Figure 2 presents the kiln truck with the stack on it, and gives an overview of the laboratory dry kiln used in this work.

Kiln Drying Evaluation

After kiln dried all pieces were measured and weighed again to evaluate the volumetric shrinkage reduction in thickness and width. The drying defects such as warping, shrinking and collapse were also evaluated

It was also evaluated the moisture gradient of some pieces/load in order to verify the conditioning efficiency.

After this evaluation, some pieces/load were machined in order to plain and trim, looking for the best yield of the pieces. After planed, the pieces were measured one last time, so it was quantified the volume drying losses (shrinkage plus planing). All evaluations were made after 24 hours the drying had ended.

Drying Schedule

Table 1 presents the drying schedule used in this study. This schedule was based on the studies of Rocha (2000) and Severo (2000).

PHASE	MOISTURE CONTENT (%)	DRY BULB (°C)	RELATIVE HUMIDITY (%)	DRYING POTENTIAL	TIME (HOURS)
Warmup	-	42	100	-	3
1	Green to 50	42	77	3.5	-
2	50 – 40	44	76	3.5	-
3	40 – 35	46	69	3.5	-
4	35 – 30	48	57	3.5	-
5	30 – 25	50	51	3.5	-
6	25 – 17	54	42	3.5	-
7	Collapse recovery	100	100	-	5
8	17 – 14	58	37	2.8	-
9	14 – 10	62	34	2.6	-
Conditioning	-	62	66	1.0	6

Table 1. Drying schedule

According to the literature consulted, this program can be considered medial to accelerate regarding to its severity. It was used a drying potential (wood moisture/equilibrium moisture content) of 3.5 along the whole process of drying. It was done an intermediary conditioning, suggested by other authors, in order to recover the collapse when wood was at an average moisture content of 17%. The air flow was kept constant with an average of 2.5 m/s along the whole drying.

Results and Discussions

Physical Properties

Table 2 presents the results of the physical properties of *Eucalyptus dunnii* wood.

STATISTICS	IMC (%)	BSG (g/cm³)	MAXIMUM SHRINKAGE (%)		
			TANGENCIAL	RADIAL	VOLUMETRIC
AVERAGE	115.82	0.45	11.47	5.16	16.08
STANDARD DEVIATION	13.04	0.03	0.92	0.91	1.12
VC (%)	11.26	7.10	8.02	17.59	6.98

Table 2. Physical properties results

The average basic specific gravity (BSG) was 0.45 g/cm³ and the average maximum volumetric shrinkage was 16.08%. These results are lower compared to those obtained by Severo (2000) and Rocha (2000). The average anisotropy coefficient was 2.22, which is considered medium to high, once it is long associated to shrinkage and to the irregular grain of wood. The high volumetric shrinkage, associated to the low permeability affect directly the drying time, slowing it down. In accelerated drying conditions the final wood quality is severely reduced.

The variation coefficients (VC%= average/standard deviation x 100) were considered fair in function of the great heterogeneity which exists normally in the wood material. The average initial moisture content was 115.82%, being considered high. The association of these results proves that the initial phases of *Eucalyptus dunnii* kiln drying must be conducted slowly, in order to avoid the creation of high moisture gradients and drying defects.

Considering these results it is possible to affirm that exist a great variability in the physical properties of *Eucalyptus dunnii* wood and these properties depend on many factors, such as genetic precedence, site, silvicultural treatments, handling, etc.

Drying Graphic

Figure 3 presents the drying graphic of *Eucalyptus dunnii* wood, which represents an average of the 5 kiln dried loads. According to that the drying process is slow, mostly in the initial phases. The applied intermediary conditioning, to recovery a possible collapse occurrence, was not well managed, because the wished dry and wet bulb temperatures at that phase (100°C) were not reached. Even in industrial practical conditions it is difficult to get these dry and wet bulb temperatures. However the most important in conditioning phase is to keep the relative humidity of air as close as possible to 100% at high temperatures, which the kiln got to control.

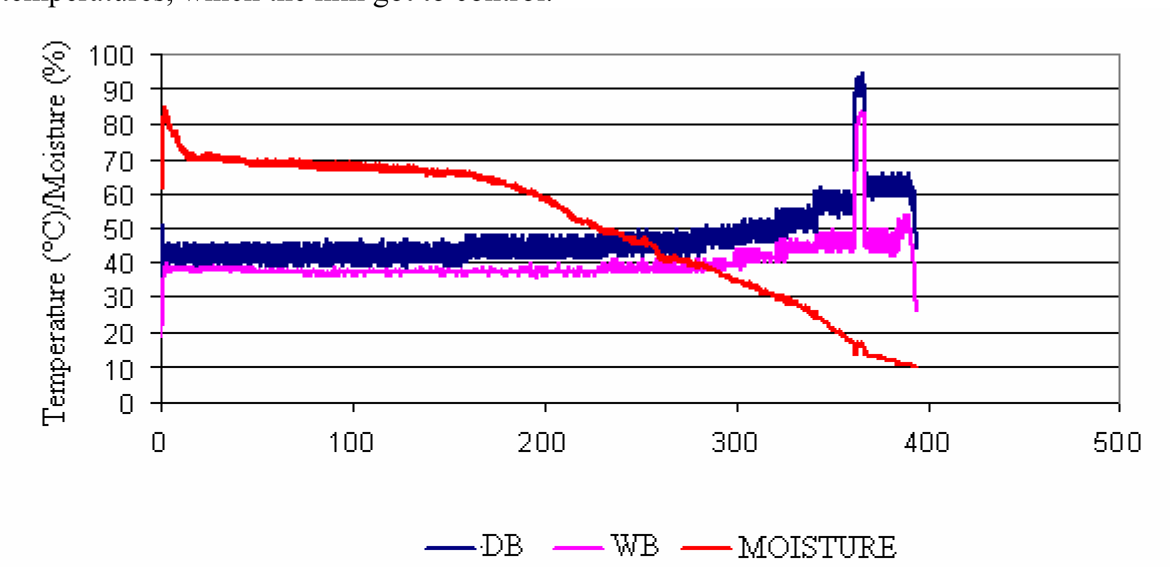

Figure 3. Drying graphic

The average total drying time was 397 hours (16.5 days), from green wood to 10% of final average moisture content. The loss of moisture happened in such a regular pace during the whole drying. This drying time is considered normal for the *Eucalyptus* species wood.

Kiln Drying Evaluation

Figure 4 presents the moisture gradient of the dried pieces.

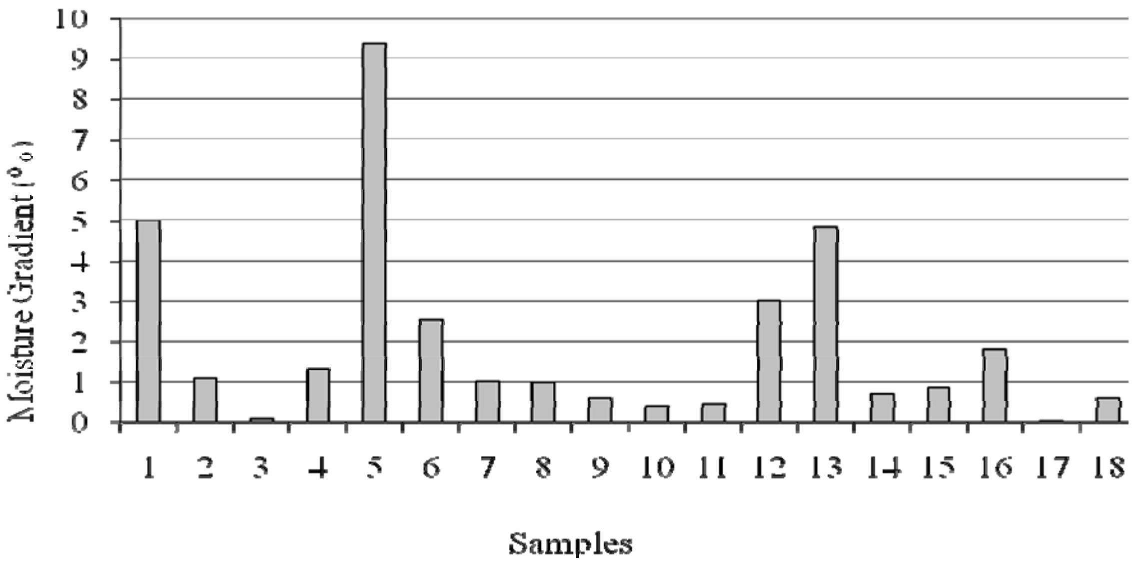

Figure 4. Moisture gradient after kiln drying

According to these results, there was a great variation of moisture gradient among the different pieces. The samples 1, 5, 6, 12 and 13 were considered high while the other pieces it was normal. The moisture gradient affects directly the machined wood in general. To reduce the moisture gradient it is necessary to apply a larger time of conditioning in kiln, in order to reduce the moisture variation in the drying load.

Drying and Planing Losses

Table 3 presents the volume losses after drying and machining of *Eucalyptus dunnii* wood.

The average total volume loss in thickness was 24.06% and 10.68% in width. Bold typed are the high variation coefficients got in width volume losses. It means a wide range of volume loss in this dimension, meaning that there were pieces with little and big volume losses.

VOLUME LOSSES	STATISTICS	THICKNESS	WIDTH	VOLUME
SHRINKAGE	AVERAGE	5.87	7.38	13.25
	STANDARD DEVIATION	1.12	1.81	1.82
	VC (%)	19.1	**24.5**	14.2
PLANING	AVERAGE	18.19	3.30	21.49
	STANDARD DEVIATION	2.46	1.19	2.53
	VC (%)	13.5	**36.1**	12.1
TOTAL	-	24.06	10.68	33.71

Table 3. Volume losses after drying and planing

Separately, the average volume reduction by shrinkage in kiln drying was 13.25%, littler than the loss in planing the pieces, which was 21.49%. This great shrinkage reduction proves the dimensional instability of the species and the planing loss indicates where the process must be improved.

Drying Defects

In 68.18% of the wood pieces it was noticed the presence of knots (dead and alive), and in 31.82% the presence of pith. These factors contributed to the high level of drying defects. Cracking was noticed in 29.5% of the pieces, but in 11.3% it was noticed heavy cracking. Cupping was present in 54.5% of the pieces and it was the most common kind of defect of *Eucalyptus dunnii* wood after kiln drying. Because of that the volume loss in planing was that big, markedly in thickness. The major cause of this high level of defect was that the stacks were not restrained. It was noticed a low level of slight collapse, in 11.36% of the pieces, proving the efficiency of the intermediary collapse recovery applied during the kiln drying. It is important to stand out this efficiency even not achieving the wished dry and wet bulb of 100°C in the collapse recovery phase (Fig. 3).

Conclusions

The drying schedule was considered appropriated for the *Eucalyptus dunnii* species. The conditioning time must be increased once the wood charge had a wide variability of final moisture content. The collapse recovery phase was efficient, even not getting the wished values of dry and wet bulb. The drying load must be restrained with some restraining device, in order to reduce warping, mostly cupping. These modifications will reduce the defects level of the dried wood, reduce the volume losses in planing and increase the yield of dry wood.

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