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Chemical products traceability on treated bamboo

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Abstract: Salt solutions, such as CCA (chromium-copper-arsenic) or CCB (chromium-copper-boron) are the principal chemical products employed to enhance durability of bamboos against decay, borer and termite attack. The effectiveness of these treatments was evaluated by means of the total amount of chemical products retained in bamboo culm. Strips from *Bambusa tuldoides* were soaked in CCB solutions (31.75% Cr, 13% Cu and 5.25% B) with 10 per cent concentration. Influence of the elapsed time between strips cutting and soaking was evaluated. Chemical products traceability was performed by scanning electron microscope (SEM). Results obtained confirm a non-uniform distribution of chromium and copper oxides along the bamboo anatomical elements.

Key words: Bambusa tuldoides, CCB treatment, SEM.

INTRODUCTION

Bamboo is an important raw material for several applications in tropical regions (Beraldo *et al.*, 2006). However, despite its availability, bamboo still is a non-dependable material since its engineering properties change with time and it can be severely affected by decay (CNBRC 2001). Like most lignocellulosic materials, several bamboo species show poor decay resistance. Several factors are responsible for the magnitude of the decay, such as, bamboo species, season of the year, climatic conditions (temperature and relative humidity) and applications (Hidalgo, 2003). Protection by design is a strategy to enhance bamboo durability (CNBRC 2001). Large amounts of starch (2-6%) in the parenchyma cells are attractive for fungi and powder-post beetles (Hidalgo, 2003). Green round bamboos normally are treated by soaking or by Boucherie method, while dry bamboos are treated by soaking or in vacuum process. Compared with hardwoods and softwoods, bamboo is quite different and its anatomical structure is more regular (Kumar *et al.*, 1994). The absence of the ray cells in bamboo is a drawback in terms of the effectiveness of the chemical solution transfers (CNBRC 2001). Chemical treatment effectiveness depends on several factors, mainly the bamboo

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anatomy, age (strongly correlated with starch content), thickness, length, density, moisture content, *etc.* (CNBRC 2001). Treatment performance depends on preservative penetration into the treated material. Soaking requires a long process time which is faster for green bamboo than for the dried ones (Kumar *et al.,* 1994).

Liese (1985) reported the importance of the vessels on chemical solution distribution to the surrounding tissues. Untreated pockets, mainly in the parenchyma cells, are vulnerable to attacks. Scanning electron microscope (SEM) analysis applied to pressure treated bamboo corroborated this hypothesis. A heterogeneous chemicals distribution was observed in several samples. Chemical elements were detected only in the vessels (Lee *et al.,* 2001). Axial diffusion is faster (for about 20 times in dried bamboo) than in the radial and tangential directions (CNBRC 2001). The treatability of dried bamboo is more difficult because sap can precipitate in the vessels blocking the flow. Pit channels in the parenchyma cells and the entrapped air in various bamboo tissues are responsible for the poor penetration (Hidalgo, 2003). In bamboos, average content of vessels, parenchyma cells and bundle fibers are 10 per cent, 50 per cent and 40 per cent, respectively (CNBRC 2001); for 33 bamboo species, similar results were 6.1 per cent, 52.8 per cent and 40.8 per cent, respectively (Kumar *et al.,* 1994). Despite its small variation in surface vessel diameter, average changes across the wall according to their position are: outer (28 μ), middle (87μ) and inner (98 μ). So, in a preliminary analysis it can be expected that the chemical solution flow occurs more effectively at the inner zone. This fact can be advantageous because this region, rich in starch content is attacked by decay organisms (CNBRC 2001).

In the internodes, the vessels are isolated from each other by the parenchyma cells. Treatment effectiveness depends on the magnitude of a lateral flow by penetration (diffusion) from the vessel to the other anatomical elements. Vessels are easily permeable, but lateral flow is restricted due to the absence of ray cells (Hidalgo, 2003). Pits located at vessel walls have an important function in promoting the lateral flow.

METHODOLOGY

Five-year-old green culms of *Bambusa tuldoides* Munro were selected for this study. Splits of 2 cm width and 50 cm high, from the internodes, were obtained. Splits were identified as bottom, middle, and top, according to their position along the culm. Three replicates of splits were treated by soaking in a commercial salts solution (10% concentration) of sodium dichromate (31.75%), copper sulphate (13%) and boric acid (5.25%).

To evaluate the effectiveness of the treatment applied to the green bamboo splits, combinations of factors, such as, culm position, time elapsed after felling the culm, and soaking duration were selected (Table 1). After soaking, splits were air-dried at

Table 1. Factors selected for the evaluation of the effectiveness of treatments

Split specimen	Position in the culm	Time after felling (h)	Treatment time (h)
#3 – 0h/6h	Bottom	0	6
#10 – 0h/24h*	Bottom*	0	24
#21 – 0h/48h	Bottom	0	48
#29 – 0h/168h	Bottom	0	168
#47 – 24h/24h	Bottom	24	24
#57 – 24h/48h	Bottom	24	48
#13 – 0h/24h*	Middle*	0	24

room temperature during two months, to fix the preservative. One specimen (#01) without treatment was selected as reference for SEM analysis. From each treated strip, one sample specimen measuring 4.0 cm in length, 1.5 cm in width and 0.5 cm in height was cut. The samples were divided into 4-6 parts parallels to the fibers direction, using a sharp blade (Fig.1).

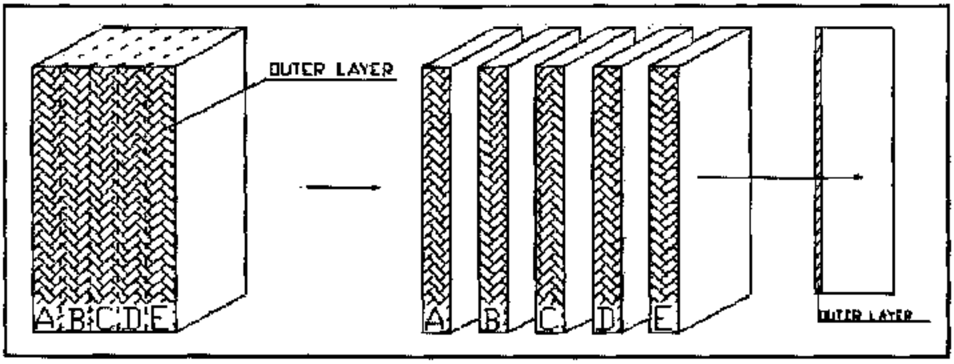

Figure 1. Preparation of samples for SEM analysis.

For preparing the bamboo strips for the SEM studies, they were coated with a thin gold film and the analysis was performed in a LEO - 430 apparatus. Samples were analyzed along the direction parallel to the fibers. Three to seven points corresponding to different anatomical constituents (vessels, parenchyma and fibers) were selected for each image. Then percentage of chemical elements was detected automatically at these points by the software. SEM analysis was applied to detect the chemical solution concentration across the bamboo sample and used as a qualitative comparison. Boron compounds were not detected by this procedure.

RESULTS AND DISCUSSION

Bamboo treatment effectiveness is not so simple to explain in terms of the chemical elements traceability, because the variability of the culm in terms of its anatomical elements (vessels, parenchyma and fibers) and the effect of other parameters, such as, age, sampling position (bottom, middle and top), time elapsed after felling of the culm, drying duration, *etc*. SEM analyses of the bamboo samples were automatically reported by the software as oxides contents. For each layer. five to seven points were selected according to the image contrast. Figure 2 shows the bamboo strip employed as reference. CO_2 content is over 90 per cent for all of the selected points. Calcium and magnesium oxides were also detected in some points. Potassium (0.82%) and phosphorus (0.16%) oxides were also presented in the analysis reported by Kumar *et al.* (1994). Gold oxide contents (1% to 6%) were detected due to the SEM sample preparation (Table 2). Table 3 shows a comparison of the treatments applied to the bamboo samples. In general, non-homogeneous distribution of chemical products was detected in almost all the samples evaluated.

Table 2. Oxides contents on *B. tuldoides* reference at layer A

Points	P1	P2	P3	P4	P5	P6	P7
CO_2	93.90	97.51	97.95	97.88	92.96	96.01	98.43
MgO	-	0.47	0.12	0.12	-	0.19	0.12
CaO	1.52	0.22	0.05	0.08	0.20	0.10	0.04
Au_2O_3	3.00	1.60	1.82	1.77	5.95	3.40	1.28

Analysis of samples

Samples #3 - 0 h/6 h

The potassium content detection can be explained as a contaminant present in sodium dichromate used in the solution or as a natural compound present in bamboo, as reported by Kumar *et al.*, 1994. Therefore, it seems to be more adequate to perform the analysis based on the presence of the other metal oxides. Chromium and copper oxides were scarcely detected mainly in points at layer C.

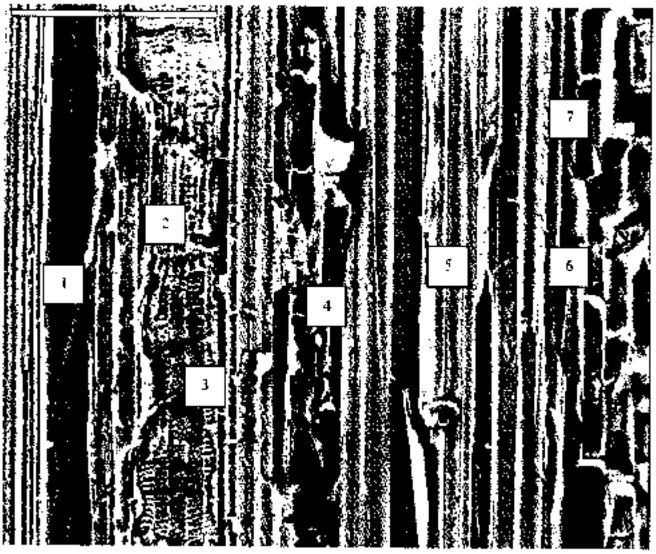

Figure 2. Sample #01 Layer A – *B. tuldoides* reference, 500X.

Table 3. SEM determined mean values of Cr_2O_3 and CuO deposited on previously selected points of the considered layers (A, C and E) for each treated bamboo sample

Sample	Oxide	A	C	E	Sample	A	C	E
#3	Cr_2O_3	0.18* (1/3)**	0.05 (2/5)	ND (0/4)	#47	0.15 (4/4)	0.53 (4/5)	0.60 (4/4)
	CuO	ND (0/3)	0.07 (2/5)	ND (0/4)		ND (0/4)	0.35 (3/5)	0.32 (2/4)
#10	Cr_2O_3	5.26 (6/6)	0.05 (2/5)	0.70 (4/6)	#57	ND (0/5)	0.14 (3/5)	0.91 (3/5)
	CuO	6.19 (6/6)	ND (0/5)	0.51 (4/6)		ND (0/5)	ND (0/5)	0.28 (4/5)
#21	Cr_2O_3	0.71 (6/6)	0.06 (2/5)	1.63 (4/6)	#13	0.57 (4/5)	0.04 (2/5)	1.18 (4/4)
	CuO	0.67 (6/6)	ND (0/5)	1.94 (4/6)		0.42 (4/5)	ND (0/5)	0.91 (4/4)
#29	Cr_2O_3	0.64 (5/5)	0.75 (5/5)	2.80 (4/4)	-	-	-	-
	CuO	0.32 (4/5)	0.20 (3/5)	4.45 (4/4)	-	-	-	-

* Means value (%)

**Number of points with oxide deposit/total number of points; ND – not detected

Sample #10 - 0 h/24 h

For layer A, analysis of chromium and copper oxides contents at point 1 (7.22 and 16.73%, respectively) and at point 4 (13.53 and 13.41%, respectively) showed greater concentration. Iron oxide at point 4 was also very high, denoting a possible sample contamination. For layer C, oxides were scarcely distributed. Small oxides contents were detected on layer F.

Sample #21 - 0 h/48 h

Copper oxide was not detected at layer C. Oxides distribution remains non-uniform, despite 48 h treatment.

Sample #29 - 0 h/ 168 h

Normally for longer treatment duration, it can be expected better oxides detection. Despite chromium and copper oxides being detected in almost all the points, the treatment would be considered as effective only on layer E, at points 1 (7.59 and 14.12%, respectively) and 2 (6.59 and 20.15%, respectively), and in smaller degree at point 5 (3.86 and 4.24%, respectively).

Sample # 47 - 24 h/24 h

For layer A (except point 3) there was a higher iron oxide content explained by a possible sample contamination. Chromium oxide was well detected for all the points in the four layers. Copper oxide was detected in all the points at layer F (0.12 to 0.38%). Despite the large occurrence of white spots at layer A, copper oxide was not detected.

Sample #57 - 24 h/48 h

Compared to the other samples, it was expected that this treatment with greater duration of time, the oxides contents would be higher. However, results obtained did not confirm this hypothesis. Copper oxide was only detected at four points at layer D (0.19 to 0.57%); chromium oxide also was poorly detected at all the layers analyzed (0.15 to 1.03%). This could be explained that culms probably were quite anatomically different or their drying time (24 h) inhibited solution absorption by the bamboo layers due to partial vessels sap blockage (Hidalgo, 2003).

Sample #13 - 0 h/ 24 h – Position: middle region of the culm

Data obtained were compared with those from sample #10 (same condition, bottom culm region). It was observed that for both conditions at layer C, oxides were not well detected. Oxides contents at layers A and E were higher for bottom than from intermediate culm position. This can be explained that greater the diameter of vessels, better the solution flows (CNBRC 2001).

CONCLUSIONS

Chemical elements traceability evaluated by SEM with respect to oxides contents showed a non-homogeneous distribution along the samples. In the majority of the cases evaluated, oxides were scarcely detected in bamboo cells. Chemical products contents analysis was not conclusive with respect to the effect of the duration of treatment or the interval after bamboo felling.

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