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DURABILITY OF *Pinus elliottii* WOOD IMPREGNATED WITH QUEBRACHO COLORADO *(Schinopsis balansae)* BIO-PROTECTIVES EXTRACTS AND CCA

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ABSTRACT

Some wood preservatives have a warning due to environmental restrictions and risks to man health. The aim of this study is to determine the performance of non impregnated and impregnated wood with a CCA salt and a bio-protective made from "quebracho colorado", when facing the action of fungi responsible for white rot decay by *Pycnoporus* sanguineus and brown rot attack by *Gloeophyllum sepiarium*. Wood samples were impregnated with different solutions by vacuum-pressure method. The design was in complete blocks at random with five repetitions. The treatments were T_0: non impregnated blank sample; impregnated T_1: CCA; T_2 Colatan IPG-F, T_3: Colatan IPG-C, T_4: Colatan IPG-C, with retentions of: 6, 18, 9 and 25 kg m^{-3} respectively. The variable was wood weight loss. Preservative CCA and bio-protective Colatan IPG-C increased the resistance to fungal degradation in lab assay, changing from non-resistance to very resistant (Findlay criterion), guaranteeing the biodegradation process inhibition.

Keywords: Wood protection, white rot, brown rot, tannin, acquired durability.

INTRODUCTION

Pinus elliottii tree is widespread in Corrientes and Misiones provinces forestations and on a smaller scale in other provinces of Argentina. The *P. elliottii* wood has different uses: the thinning crop is used in the cellulose pulp industry, chipboard panels and boards of MDF (Medium Density Fiberboard) kind. The main part of the wood harvest is set for sawmill.

The physico-mechanical, aesthetic and natural durability properties determine the uses assigned for the wood (Keil *et al*. 2006). Wood of naturally low durability is treated with different protective agents to increase its resistance to degradation and it allows to broaden its uses. This practice of wood protection is defined as acquired durability (Zabel and Morrell 1992).

Wood durability may be calculated in a lab by means of standardized assays of accelerated degradation using the soil block technique (IRAM 9518, 1962; ASTM - D 2017, 1981).

Wood protection is a practice that allows increasing its durability in use and to reduce the maintenance costs caused by the frequent replacement of spoiled pieces of wood (FAO 1986).

Some of the substances used as chemical preservatives have warning due to environmental restrictions and thus there is a search for alternative techniques which can extend wood service life and which are, at the same time, less harmful to the environment and the man.

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With regard to tannin, there is no evidence that tannin has a specific function in the metabolism of plants, though its importance in the plant defense mechanisms against insects and rot fungi is acknowledged (Pearce 1996). The enzymatic attack derived from the metabolism of the fungi or bacteria colonizing wood may be substantially inactive or diminished in the presence of tannin (Gonzalez Laredo 1996).

The aim of this study was to determine the performance of *P. elliottii* wood without protectives, either and impregnated with CCA salt solution type c and "quebracho colorado" extract (due to its tannin content) based bio-protectives strengthened with minerals against, the actions of the white rot fungus *Pycnoporus sanguineus* and the brown rot fungus *Gloephyllum sepiarum* in lab tests.

MATERIALS AND METHODS

The wood used for the construction of test tubes was obtained from a 26 years old *P. elliottii* plantation, on sandy soil, located in San Miguel district, Corrientes province, Argentina (27º59'11" S and 57º26'38" W). From five trees were sawed five boards of 2.5 x 7 x 50 cm. The stove drying took place until 25 % humidity content.

The protectives used were: 1) CCA type c aqueous solution at 5%. 2) Colatan IPG–F and Colatan IPG-C. Natural hydro soluble products made with "quebracho colorado" extract strengthened with mineral salts as the basic ingredient and tannin fixer to avoid wash out. Colatan IPG is a trademark product of UNITAN SAICA.

The wood boards were impregnated by the vacuum pressure method by means of the Bethell method (traditional full cell) in a lab autoclave. A loading dozer was made for each impregnation, weighing the volume and weight of each piece of wood and the concentration of the preserving solution in order to determine the individual retention. The working conditions were: initial void: 600 mm Hg during 30 min., filling up the autoclave, 5 min. pressure cycle: 5.5 kg cm^{-2} during 30 min. Autoclave draining: 5 min. final void: 580 mm Hg 20 min.

The impregnated wood was placed in a dry room, under ceiling and with natural air circulation until equilibrium humidity of about 18%. Fifty wood blocks, 5 per treatment, of 3 x 1 x 0.5 cm, were prepared out of this impregnated and non-impregnated wood after it had been brushed according to IRAM 9518 Regulation (1962). Only blocks without nodes, stains or any other fault (deep splits or crakes) were used.

Assay Design

The design was in complete blocks at random with five repetitions and the treatments were:

T_0 = non impregnated blank sample (control); T_1: impregnated with CCA type c with a 6 kg m^{-3} retention; T_2 impregnation with Colatan IPG-F with a 18 kg m^{-3} retention; T_3: impregnation with Colatan IPG - C with a 9 kg m^{-3} retention, and T_4: impregnation with Colatan IPG-C with a 25 kg m^{-3} retention. The variable measured was the wood blocks weight at the beginning and at the end of the experiment.

Before the impregnation process, the volume (V) was determined and the wood blocks were weighed before (Pi) and after (Pf) impregnation. The absorption values (A in kg m^{-3}) were obtained and taking into account the concentration used, the preserver retention (R in kg m^{-3}) in wood was calculated by the following formulas:

$$A = \frac{P_f - P_i}{V}, \quad R = \frac{A \times C\%}{100}$$

Fungi used and culturing

Each one strain of *Gloeophyllum sepiarium* (brown rot) and *Pycnoporus sanguineus* (white rot), was obtained from the "Instituto de Botánica del Nordeste" (CTES Conicet-UNNE).

Pre-culturing of the fungi was performed in Petri dishes with 2.5 % agar and 1.5 % malt extract at 27º C for 2 weeks.

50 ml of medium was put in 50 plastic flasks with lid; after that they were sterilized at 1,5 pressure air 30 min.

The wood blocks were stove dried at 103º C for 24 hours, set in a drier for cooling and were weighed P(i). Before inoculation they were sterilized in a stove at 103º C for during 30 min. Flasks containing each one block were inoculated with a about 1 cm^2 agar block with the mycelium under a laminar air flux, Fig. 1. The flasks were sealed and placed in a stove at 27º C for 3 months.

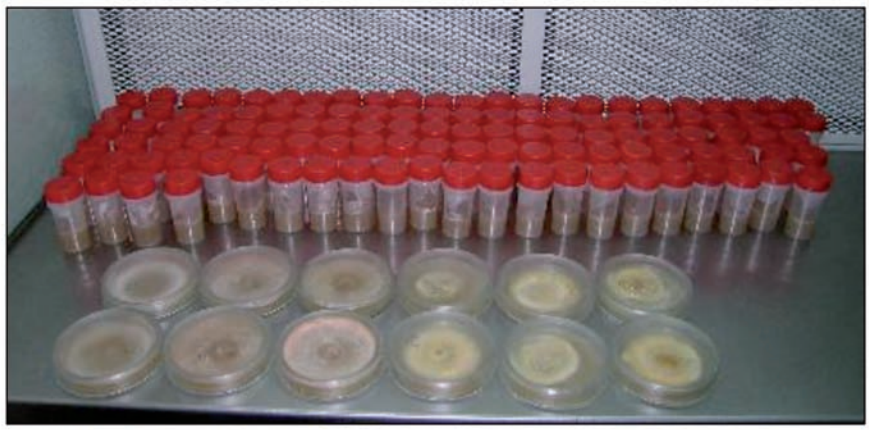

Figure 1. Fungi and culture flasks before inoculation.

Harvesting

After the set time, the wood blocks were sampled and the remnant of the mycelium was withdrawn; they were stove dried at 103º C for 24 h, placed in a dehydrator and weighed P (f). Taking into account the initial and final weight difference, the mass (weight) loss percentage caused by the fungus was determined following this formula:

$$P_P(\%) = \frac{P_i - P_f \times 100}{P_i}$$

Findlay's criterion (1951), which establishes the relation between weight loss percentage caused by fungi and the wood strength grade, was followed (Table 1).

Table 1: Wood grading according to the weight loss in % caused by xylophagus fungi and its strength grade.

Weight loss	Durability grade or Resistance Category
Lower than 5	Very resistant
5 to 10	Resistant
10 to 20	Moderately resistant
20 to 30	Not resistant
Higher than 30	Perishable or without resistance

RESULTS AND DISCUSSION

Brown Rot Decay

The brown rot fungus *Gloeophyllum sepiarium* rapidly colonized the non-impregnated wood pine blocks (T_0), those impregnated with Colatan IPG–F (T_2) and those with Colatan IPG–C as well (8 kg m^{-3} retention) (T_3). There was no colonization of the blocks with CCA type c (T_1) and Colatan IPG–C (25 kg m^{-3} retention) (T_4), (Figure 2).

Figure 2. View on the blocks 3 months after inoculation with Gloeophyllum sepiarium.

Three months after the inoculation, the wood degradation in the control was simply observed with naked eyes (Figure 3) and there was no evidence of degradation symptoms of the tissues of wood impregnated with the different protective solutions. With the help of a magnifying glass, the woody tissue degradation was observed in detail (Figure 4).

As it was expected, the greater weight loss 38.80% was registered in the control blocks, with statistically significant differences ($p< 0,05$) regarding the rest of the treatments. Bobadilla *et al*. (2007) found similar values in *P. taeda* L. The results obtained are in accordance with the IRAM 9600 (1998) regulation that classifies the resinous pine wood as Class 3: not very durable against fungi. According to Findlay scale, ASTM D-2017 (1981), wood with fungal weight loss > to 30 % (Table 1) is classified as perishable or without resistance.

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Figure 3. Brown rot effects on the different blocks after 3 months.

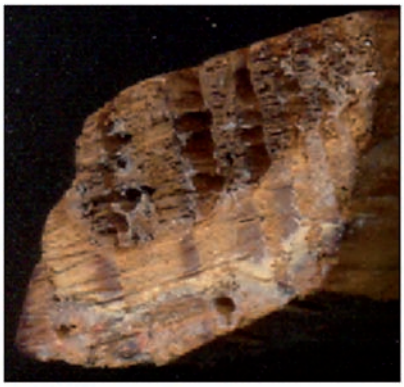

Figure 4. Details of degradation by *Gloeophyllum sepiarium* on non-impregnated pinewood (T_0).

The Colatan IPG-F treatment showed weight loss of 29.26%, with significant differences as regard the rest of the treatments. This substance reduces the weight loss for 9,54 % with regard to the blank sample, achieving an increase in wood durability. According to Findlay scale, ASTM D 2017 (1981) wood turns to be non resistant (weight loss between 10 to 30%).

A smaller weight loss of 0.72 % was registered with the CCA type c treatment variation index was 28.92%. This treatment (T_1) and the ones with Colatan IPG–C (T_3 and T_4) did not show significant differences (Table 3).

Pine wood impregnated with CCA type c, Colatan IPG–C in was highly resistant to degradation (weight loss rate 0 – 10%) when exposed to the brown rot fungus.

The protection observed due to the weight loss (less than 5%) would allow the use of this wood in high risk conditions when confronting to brown rot fungi.

Table 3. Treatments, protectives, retentions, weight losses and variation index of pine wood after brown rot attack and durability grade (Findlay 1951).

Treatments	Protectives	Retention Kg m^{-3}	Average Weight Loss %	Variability Index (CV%)	Durability Grade
T_0	Control	0.00	38.80 c	21.45	Non-resistant
T_1	CCA type c	6.00	0.72 a	28.92	Very resistant
T_2	Colatan IPG-F	18.00	29.26 b	5.92	Non-resistant
T_3	Colatan IPG-C	9.00	4.31 a	20.94	Very resistant
T_4	Colatan IPG-C	25.00	4.68 a	3.82	Very resistant

Different letters indicate significant differences *(p< 0,05)*.

White Rot Decay

The white rot fungus *Pycnoporus sanguineus* colonized the wood rapidly and grew abundantly on the non-impregnated pine wood blocks. It colonized the Colatan IPG–F and Colatan IPG–C blocks (9 kg m^{-3} retention) in a lesser grade. There was no colonization of blocks impregnated with CCA type c and Colatan IPG–C (25 kg m^{-3} retention) (Figure 5).

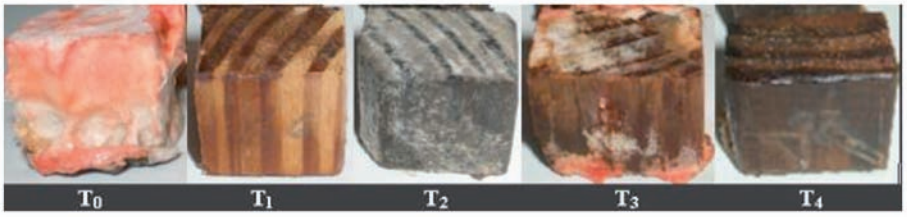

Figure 5. View on the test tubes after 3 months of culture with *Pycnoporus sanguineus*. Abundant colonization in the pinewood without impregnation (T_0).

At the end of the assay, tissue degradation symptoms in the control treatment were observed at a glance.

Pinewood resistance assayed in the different treatments before white rot attack *(Pycnoporus sanguineus)*, measured according to the weight loss of the wood blocks is shown in Table 4.

The greatest weight loss was measured for the controls T_0, with a 25.84 %, with statically significant differences *(p< 0.05)* regarding the rest of the treatments (Table 4). Moreno *et al*. (2002) registered in Caribbean pine wood boards 18.51 % weight loss by white rot fungi. Bobadilla *et al*. (2007) found 34.63 % weight loss in *P. taeda* L. wood. These percentages are high taking into consideration that conifers contain only guayacil lignin (Highley 1983; Blanchette *et al*. 1990) and that *Pycnoporus sanguineus* has preference for hardwoods that have lignin of the syringyl type (Eaton and Hale 1993) that is more easily degraded than conifer lignin (Eriksson *et al*. 1990).

Similarly, the minor attack of the white rot fungus can be explained by the fact that the pine has lignin of the guayacil type.

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The IRAM 9600 (1998) regulation classifies the resinous pine wood *(P. elliottii and P. taeda)* as not very durable with an estimated service life of 5 and 10 years, taking into account the heartwood against fungi (Class 3). The results of the controls are in accordance with this classification. When compared to Findlay's scale (1951) the results show that pinewood is not resistant to white rot.

Table 4. Behavior of pinewood samples impregnated with different protectives and retentions against a white rot fungus, and the durability grade (Findlay 1951).

Treatments	Protectives	Retention Kg m^{-3}	Average Weight Loss %	Variability Index (CV%)	Durability Grade
T_0	Control	0.00	25.84 c	15.81	Non-resistant
T_1	CCA type c	6.00	2.02 a	14.78	Very resistant
T_2	IPG-F	18.00	7.94 b	23.35	Resistant
T_3	IPG-C	9.00	3.78 a	24.84	Very resistant
T_4	IPG-C	25.00	3.57 a	14.98	Very resistant

Average values followed by different letters indicate significant differences (Tukey, $p<0.05$)

The T_2 series of Colatan IPG–F showed 7.94 % weight loss differing from the control and the other treatments.

The T_1, T_3 and T_4 treatments did not show significant differences among themselves, with weight losses of 2.02 %, 3.78 % and 3.57 % respectively.

Pinewood impregnated with protectivesT_1, T_2, T_3 and T_4 behaved in the assay conditions as resistant to very resistant the fungal degradation (weight loss 0 – 10%) when being exposed to the white rot fungus. The weight loss in the treatment with CCA type c disagrees with the values obtained by Bobadilla *et al*. (2007), with a weight loss of 9.51 %.

None of the assayed fungal strains degraded significantly the wood treated with CCA and Colatan IPG–C. In Colatan IPG-C low concentrations, colonization of the wood was observed but there were no symptoms of tissue degradation.

The CCA type c and IPG-C effectiveness to protect the *P. elliottii* wood was high for the treatments with 6 and 25 kg m^{-3} retention. These values assure the effectiveness of the substances in their protective function when applied to pine wood in an industrial way.

CONCLUSIONS

Non-impregnated *Pinus elliottii* wood turned out to be more susceptible to a brown rot fungus than to a white rot fungus, behaving as not very durable wood when attacked by xylophagus fungi.

The CCA type c salt with 6 kg m^{-3} retention and the "quebracho colorado" extract based bio-protective reinforced with Colatan IPG–C mineral salts, at 25 kg m^{-3} retention in *Pinus elliottii* wood, increased resistance to fungal degradation by *Gloeophyllum sepiarium* and *Pycnoporus sanguineus* in lab assay conditions from non-resistant to very resistant, improving the inhibition of the biodegradation processes.

The protection observed would allow the use of this wood in high-risk conditions when it is impregnated with CCA type c, Colatan IPG–C (with the previously indicated retentions).

Colatan IPG–C bio-protective with a 9 kg m^{-3} wood retention, showed the same performance when compared to 25 kg m^{-3} retention, with the difference that surface mycelium growth was observed.

Colatan IPG–F bio-protective did not influence change pinewood resistance when confronting the brown rot fungus. However, it increased the type of resistance into resistant against the white rot fungus.

The "quebracho colorado" extract based bio-protective reinforced with mineral salts represents a viable and a more environmentally friendly alternative for protection and may extend the productive life of low durability wood against xylophagus fungi.

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