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Section 1 Biology

Possible durability transfer from durable to non durable wood species
The study case of teak wood

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Teakwood is well known for its excellent natural durability, mostly due to its high proportion of extracts. Amongst these extracts, quinones, and more precisely some naphtoquinones (such as lapachol) and anthraquinones (such as tectoquinone) appear to play a crucial role in the resistance to wood decay organisms.
At a laboratory scale, sawdust from malaysian teak heartwood has been extracted under different temperatures. These extracts, as well as solutions of commercialised lapachol and tectoquinone were used to treat pine sapwood mini blocks. Such treated and leached samples were used for accelerated fungal tests using basidiomycetes. The results have shown that protection against fungi was achieved through these treatments. Nevertheless, laboratory extracts from teakwood and commercial quinones performed differently, arousing then questions on this way of preserving non durable wood species.

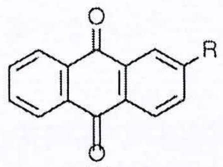
Keywords: Teak (*Tectona grandis* L.fil), natural durability, extractives, "natural" quinones, "commercial" quinones, accelerated fungal tests.

Introduction

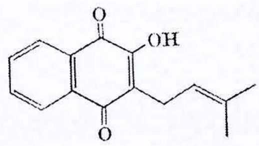
Teak (*Tectona grandis* L.fil) is one of the world's most valuable hardwood. Teakwood has a wide range of end-uses and performs extremely well indoor and outdoor, even in drastic conditions. Beyond its beauty, colour and decorative grain, teak's versatility is mainly due to its unique technological properties (Simatupang & Yamamoto, 2000 ; Steber, 2000 ; Vernay, 2000). Teakwood shows a medium density and considerable mechanical performances, it is a high strength timber without heaviness. It is easy to process and does not warp, crack, or turn black in contact with metals. It is also resistant to abrasion and harsh chemicals. And while sapwood and pith are susceptible to decay, teak heartwood is dimensionally stable and naturally durable against both fungi and termites.

Teakwood durability appears to be mainly linked to the amount and nature of extractives (Da Costa et al, 1958 ; Rudman & Da Costa, 1959 ; Dadswell & Hillis, 1962 ; Sandermann & Simatupang, 1966). Amongst these extractives, quinones (and more precisely naphtoquinones such as lapachol, and anthraquinones such as tectoquinone) (figure 1) play a major role in the resistance against wood destroying organisms (Da Costa et al, 1958 ; Sandermann & Simatupang, 1966 ; Thompson, 1971). Some other extractives (terpenes, fatty acids) and other factors, such as the high lignin and low pentosan contents, and the occurrence of caoutchouc, partly responsible for the dimensional stability, take also part in the natural durability (Sandermann & Simatupang, 1966 ; Yamamoto et al., 1998).

The aim of this work was to extract teak heartwood and assess whether the obtained solutions could protect non durable timber. As a comparison, commercialised quinones where also used for the same purpose. The efficacy of such treatments has been evaluated by some accelerated fungal tests.



(1)



(2)

Figure 1. Structure of some quinones of teakwood (Thompson, 1971).
(1) R=H, anthraquinone ; R=CH_3, tectoquinone ; (2) lapachol (naphtoquinone).

Experimental

Wood extraction
A small piece of teak heartwood was reduced to sawdust in order to be extracted. Apart from its provenance (plantation tree from Malaysia), no other characteristic of the wood piece was known (tree age, tree size, localisation of wood sample within the tree, etc...). The sawdust was extracted according to an accelerated solvent extraction technique (ASE 200, Dionex) : 4 g of anhydrous sawdust are submitted to 3 consecutive cycles of 5 minutes at 100 bars, with acetone as extraction solvent. Extractions have be proceeded at different temperatures : 40°C, 60°C, 70°C, and the extracts obtained were named E_{40}, E_{60}, E_{70}, with extraction yields of 4.53%, 7.14% and 10.7% respectively. Extracts were then concentrated to dryness. Chromatography on cellulose layer (solvent : acetic acid 1% v/v) showed the presence of both tectoquinone (Rf = 0.11) and lapachol (Rf = 0.54) in each extract.

Wood treatment
Replicate pine (*Pinus sylvestris*) sapwood specimens of dimensions 50x5x15 mm were treated under 20 min at –1 bar followed by 2 hrs at atmospheric pressure. The following treatment solutions were used :

- 2-methyl-anthraquinone (tectoquinone) (Sigma) at 0.05% w/v and 0.1% in ethanol (Prolabo) ;
- 2-hydroxy 3-[3 methyl-2-butenyl] 1,4 naphtoquinone (lapachol) (Sigma) at 0.05% and 0.1% in ethanol ;
- extract E_{40} at 0.1% in ethanol ;
- extract E_{60} at 0.1% in ethanol ;
- extract E_{47} at 0.1% in ethanol ;
- ethanol.

The samples were left at 20°C and 65%RH until weight stabilisation. For the above treatments, the samples were leached by placing each in 50 ml distilled water at 20°C under stirring. The water was changed everyday for 5 days. The samples where then conditioned 1 month at 20°C and 65%RH prior to biological testing.

Biological testing
For each treatment, 6 leached samples and the relative controls where exposed to fungal attack on agar medium Petri dishes already inoculated with *Gloeophyllum trabeum* or *Poria placenta*. The test was carried out for 6 weeks (20°C, 65%RH). The grade of protection was measured by the samples mass loss and express as a protection coefficient (PC):

$$PC(\%) = \left(1 - \frac{\text{Mean mass loss of treated and leached samples}}{\text{Mean mass loss of controls}}\right) \times 100$$

Results

The results of the fungal tests are given in table 1.

Table 1. Protection coefficient against decay given by treatment solutions made of teak extracts or commercial quinones.

Treatment	Protection coefficient (%)	
	Poria placenta	*Gloeophyllum trabeum*
Tectoquinone 0.05%	65	64
Tectoquinone 0.1%	77	72
Lapachol 0.05%	81	69
Lapachol 0.1%	93	83
E_{40} 0.1%	55	83
E_{60} 0.1%	66	70
E_{70} 0.1%	48	57
Ethanol	1.64	0.8
Controls	mass loss : 21.4%	mass loss : 21.9%

All treatment solutions had a protective effect against both fungi, and this, even after the leaching of the treated pine samples. Tectoquinone protects the wood only to a certain extend, compared to lapachol that performed much better, especially when used at 0.1%. It was rather unexpected to find such results with tectoquinone, as this compound is known to have no anti-fungal properties but repulsive effect towards termites (Sandermann & Simatupang, 1966 ; Thompson, 1971 ; Simatupang & Yamamoto, 2000). The extracts from teakwood E_{40} and E_{60} appear to be more efficient than the E_{70} extract. This can be explained by the higher temperature that could induce a degradation of some molecules extracted. The most "homogeneous" protection of the wood samples is given by the extract E_{60}. These extracts from teakwood certainly contain other extractives than tectoquinone and lapachol (caoutchouc excepted), but probably less concentrated than 0.1% or 0.05% (concentrations of two commercial solutions used).

The results obtained in these few experiments tend to prove that teak extracts could be considered as a potential basis for wood preservatives. The interesting thing is that their efficacy remains after the leaching of the treated samples. This could be attributed to the nature of extractives : some extractives present a hydrophobic nature (fatty acids, …), and teak extracts (ethanol and hot water extracts) have a bulcking effect that contribute to the wood dimensional stability (Simatupang & Yamamoto, 2000).

Nevertheless this work is rather partial and it would have been worthwhile to :

- evaluate the durability of teakwood from which sawdust came from (in the same experimental conditions) ;
- use mixtures of the two commercial solutions of quinones ;
- use a range of concentrations for the teak extracts in order to find out a fungal threshold.

Concluding remarks

This kind of method to preserve non durable timber can appear promising, however many parameters have to be closely looked at, in order to evaluate whether this approach is realistic or not.
It is envisage to extract teak wood wastes (from sawmill mainly), wood wastes supply is the one of the first things to take into consideration. Teak is a renewable resource and is widely grown in plantations, the actual demand is high and is projected to rise dramatically (Steber, 2000). Thus it is probable that wood wastes supply is a condition that will be fulfil.
Then, the extraction method have to be optimised : extraction of the most effective extract, high yield extraction and low cost. A quality control of the obtained extracts is crucial as there is a variability in the quantity, a to a much lesser extend in the quality, of teak extractives between trees and within a tree (Da Costa et al, 1958 ; Rudman & Da Costa, 1959).
It will also have to be considered if these extracts will be effective enough to be used on their own, or if they will be integrated in a formulation with other active ingredients. The final wood preservative formulation will have to go through eco-toxicological tests. One have to bear in mind that what is "natural" (i.e. from a natural resource) is not always synonym of low or non-toxic. As a matter of fact, some naphtoquinones (lapachol, and more especially deoxylapachol) can cause contact allergy (Simatupang & Yamamoto, 2000), and it has also been shown that emissions from some naturally durable woods into the aquatic compartment can present a certain toxicity profile (Van Eetvelde et al, 1998).

The use of teak extractives as a basis for wood preservatives is of interest, but a lot of work still have to be done, in the scientific field, as well as in the economic evaluation.

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