EFFECTS OF CANE PEELING AND AQUEOUS EXTRACTION ON COMPATIBILITY OF TWO RATTAN SPECIES WITH PORTLAND CEMENT

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ABSTRACT

Rattan cane is a relatively abundant lignocellulosic in Africa and Asia that could be used for wood-cement composite production. However, rattans tend to inhibit cement setting. This study investigated the effects of cane peeling and aqueous extraction on maximum hydration temperature (T_{max}) and setting time (t_{max}) rattan-cement-water systems using *Calamus deerratus* and *Lacosperma secundiflorum* rattan species. Peeling was done manually to remove the silified epidermis before hammer-milling to obtain cane particles. Portions of the particles were soaked in de-ionised cold (25^0C) and hot water (80^0C) respectively for 30 minutes. Findings showed that aqueous extraction improved the T_{max} and reduced the t_{max} of the rattan-cement mixtures while peeling caused reduction in both T_{max} and t_{max}. The two rattan species seemed more amenable to cold rather than hot water extraction. Peeling, species, aqueous pre-treatment and their interactions had significant effects on the setting time of the rattan-cement mixtures.

KEYWORDS
Rattan; pre-treatment; cement composite; hydration

INTRODUCTION

Rattans are commercial non-timber forest products employed mainly in furniture manufacture in many parts of the tropics. A major problem associated with the use of rattan for furniture manufacture, however, is the level of material wastage involved. As noted by Olorunnisola (2005), over 30% of rattan stems harvested at any particular time for furniture manufacture is wasted. Besides, only about 20% of the over 600 known rattan species produce the most sought-after fine quality canes and are, therefore, of commercial value. The remaining species with low quality canes are not utilized due to inflexibility, tendency to breakage, poor mechanical properties (Dransfield and Manokaran 1993).

One of the alternative potential uses of rattans yet to be fully explored is in the production of environmentally friendly and fire-resistant Cement-Bonded Composites (CBCs). The use of rattan canes for CBC production has been reported by Olorunnisola and Adefisan (2002); Olorunnisola *et al*, (2005) and Olorunnisola (2005). A major advantage of the use of rattan in composite panel production is the possibility of complete material utilisation, precluding the need for pre-sorting and discarding of canes as is done in rattan furniture manufacture (Olorunnisola 2005).

However, rattan canes like other woody materials tend to inhibit the setting of cement. Inhibition of Portland cement setting by many lignocellulosics is a major limitation to the development of new CBCs (Lee, 1984; Badejo, 1989; Shi *et al*., 1999, Alberto *et al.* 2000, Sutigno, 2002). Badejo (1989) and Olorunnisola (2005) reported that chemical and aqueous pre-treatment measures are two of the common methods adopted. However, chemical additives tend to be expensive. Sutigno (2002) noted that soaking lignocellulosic particles in cold water dissolves tannins, gums, sugars, and colouring matter, while hot water pre-treatment dissolves not only tannins, gums, sugars, and colouring matter, but also starches. Olorunnisola and Adefisan (2002) reported improved bond strength between cement and strands obtained from rattan cane furniture wastes pre -treated with hot water and calcium chloride ($CaCl_2$), while Olorunnisola (2005) and Olorunnisola

et al (2005) found enhanced bond strength and dimensional stability between particles of *Lacosperma secundiflorum* canes treated with 3% (by weight of cement) of $CaCl_2$. However, the effects of different aqueous pre-treatments (hot and cold water) and epidermis removal, a pre-processing step in rattan utilisation on the maximum temperature (T_{max}) and setting time (t_{max}) rattan canes have not been reported.
This work investigated the effects of aqueous extraction and removal of silified epidermis of *Calamus deerratus* and *Lacosperma secundiflorum* rattan cane species on the T_{max} and t_{max} of Portland cement.

MATERIALS AND METHODS

Matured stems of *Calamus deerratus* and *Lacosperma secundiflorum* rattan canes were harvested from Gambari forest reserve Ibadan, Oyo state, Nigeria. These were identified through comparison with stocks kept in the herbarium of the Department of Botany and Microbiology, University of Ibadan. The harvested canes were separated into two parts. One part was manually peeled to remove the silified epidermis, while the other part was left intact. Both the peeled and the unpeeled canes were converted into billets of about 6cm and hammer milled. The milled particles were collected and sieved using a set of 1.18mm, 0.85mm and 0.60mm sieves. Particles that passed through the 0.85mm sieve and were retained in the 0.60mm sieve were collected.
Particles from both peeled and unpeeled canes collected were separated into two portions i.e. those to be used 'as is' and those to be subjected to pre-treatment. Pre-treatments involved soaking different portions of the particles in de-ionised cold (25^0C) and hot water (80^0C) for 30 minutes respectively, draining and re-washing with de-ionised water to remove water the soluble extractives, and air drying for 14 days to an average moisture content of 10%. Phytochemical screening of the aqueous extracts of the rattan canes was conducted in accordance with procedures adapted from Harborne (1991) and Evans (2006).
For the hydration tests, 15g of the rattan particles, 200g of ordinary Portland cement and 93ml of de-ionized water were mixed in a polythene bag to form homogeneous slurry. For the control experiment, 200g of neat cement was mixed with 90ml de-ionized water as in Hachmi *et al*. (1990). The tests were performed in a set of well insulated thermos flasks. Temperature rise was monitored for 27 hours using a T-type thermocouple. Three replicates of each mixture were prepared. The compatibility was assessed using the compatibility indices shown in Table 1.

Table 1: Compatibility Indices

S / No.	Parameter	Classification Index	Reference
1	Time to Maximum Temperature	Suitable (<15hr) Unsuitable (> 20hr)	Hofstrand *et al.* 1984
2	Maximum Hydration Temperature	Suitable ($T_{max} > 60^0$C) Intermediately Suitable ($T_{max} = 50 - 60^0$C) Unsuitable ($T_{max} < 50^0$C)	Sandermann and Kohler, 1964

RESULTS AND DISCUSSIONS

Phytochemical Properties of Extracts

The results of the phytochemical screening carried out on the cold and hot water extracts of peeled and unpeeled samples of *Calamus deerratus* and *Lacosperma secundiflorum* are shown in Tables 2 and 3. Saponins, tannins, terpenes, alkaloids and carbohydrates were noticed in the cold and hot water extracts of both *C. deerratus* and *L. secundiflorum*. Anthraquinones were absent. Tannins, terpenes, alkaloids and carbohydrates are extractives and sugars in lignocellulosics, the presence of which could inhibit setting in composites. Cold and hot water extracts of unpeeled *L. secundiflorum* indicated stronger presence of alkaloids, terpenes and saponins than those of the peeled extracts. On the contrary, stronger presence of alkaloids, terpenes and saponins were observed in the cold water extracts of peeled *C. deerratus* than in the unpeeled samples. The hot water extracts of the peeled *Calamus* species indicated stronger presence of alkaloids and terpenes than the unpeeled samples. Saponins were however more pronounced in the hot water extracts of unpeeled than in the peeled samples.

What the foregoing observations suggest is that the inhibitory compounds were more at the periphery of the stems of *L. secundiflorum* than in the core and more in the core of the stems of the *Calamus* species than at the periphery. Apkofure (1992) had noted that extractive contents have patterns. They may decrease from periphery to the centre of the heartwood; increase from the pith to the heartwood, or increase from sapwood to heartwood. Cladius (2006) also reported that the concentration of extractives in mangrove tree (*Rhizophora racemosa*) decreased from bark to inner bark (bast) to the stem depending on the locality, time of the year, height and age of the tree.

Effect of Peeling on the Hydration Behaviour of Rattan-Cement Mixtures

As shown in Table 4, the maximum hydration temperature and the setting time of the *Calamus*-cement mixtures ranged from 37.0 to 58.6^{0}C and 3.7 to 26.5 hrs respectively, compared with those of the *Lacosperma*-cement mixtures (43.1 – 56.8^{0}C and 25.7 – 7.4 hrs respectively). Based on the classifications of Hofstrand *et al*., 1984 and Sandermann and Kohler (1964), the two rattan species

Table 2: Phytochemical Screening of Aqueous Extracts of *C. deerratus*

Phytochemical Constituents	Hot Water Extracts		Cold Water Extracts	
	Peeled	Unpeeled	Peeled*	Unpeeled
Alkaloids	Positive*	Positive	Positive	Positive
Anthraquinoes	Negative	Negative	Negative	Negative
Tannins	Positive	Positive	Positive	Positive
Terpenes	Positive*	Positive	Positive*	Positive
Carbohydrates	Positive	Positive	Positive	Positive
Saponins	Positive	Positive	Positive*	Positive

* Strong Positive Presence

Table 3: Phytochemical Screening of Aqueous Extracts of *L. secundiflorum*

Phytochemical Constituents	Hot Water Extracts		Cold Water Extracts	
	Peeled	Unpeeled	Peeled	Unpeeled
Alkaloids	Positive	Positive*	Positive	Positive*
Anthraquinoes	Negative	Negative	Negative	Negative
Tannins	Positive	Positive	Positive	Positive
Terpenes	Positive	Positive*	Positive	Positive*
Carbohydrates	Positive	Positive	Positive	Positive
Saponins	Positive	Positive*	Positive	Positive*

* Strong Positive Presence

were unsuitable for CBC production without pre-treatment. However, visual examination showed that whereas cement mixes containing particles of the *Lacosperma* species and unpeeled *Calamus* without aqueous pre-treatments formed hardened pastes, those of the peeled *Calamus* did not form cohesive bonds after 27 hours of experimentation. This observation is in line with that of Blankenhorn *et al*. (1994) who noted that some lignocellulosics contain extractives which will not only retard cement hydration but also degrade cement bonds. The differences in the observed behaviour may be attributed to anatomical differences between the two rattan species. Lucas and Dahunsi (2004) had noted differences in the anatomy between *Calamus deerratus* and *Lacosperma secundiflorum* species grown in western Nigeria. While the *Calamus* species tested contained higher proportions of parenchyma cells (storage tissues) than sclerenchyma cells (strengthening tissues), the *Lacosperma* species had higher proportions of sclerenchyma than parenchyma cells. The higher proportions of parenchyma cells in the *Calamus* species may affect the hydration behaviour when mixed with cement.

Generally, the unpeeled rattans had higher maximum hydration temperature than the peeled. However, while composites from the peeled *Calamus* had higher setting time than those from unpeeled, the setting time of the peeled *Lacosperma* were lower than those of unpeeled (Table 4). This may suggest that peeling had negative effect on the setting time of the *Calamus* species but enhanced those of the *Lacosperma* species. Higher quantities of extractives (alkaloid, terpenes and saponins) in the unpeeled *Lacosperma* (Table 3) may have resulted in higher setting time than in the peeled *Lacosperma*-cement composite. This observation again suggests that cement inhibitors are concentrated at the periphery in the *Lacosperma* species.

Table 4: Effects of Aqueous Pre-treatments and Peeling on Behaviour of Rattan-cement Mixtures

	T_{max} (^{0}C)				t_{max} (Hrs)			
	C. deerratus		*L. secundiflorum*		*C. deerratus*		*L. secundiflorum*	
Aqueous Pre-treatments	Unpeeled	Peeled	Unpeeled	Peeled	Unpeeled	Peeled	Unpeeled	Peeled
None	46.6^B	37.0^B	43.1^B	45.1^B	26.5^A	3.7^B	25.7^A	24.7^A
Cold Water	57.9^A	57.1^A	56.8^A	56.0^A	7.8^B	8.5^A	8.6^B	7.4^B
Hot Water	58.6^A	57.7^A	56.6^A	55.5^A	7.2^B	8.6^A	8.3^B	7.7^B

Means with the same letters are not statistically different

Statistical analysis revealed no significant differences ($P \leq 0.05$) between the maximum hydration temperature of unpeeled and peeled *Lacosperma* composites while the hydration temperature of the peeled *Calamus* composite was significantly different from the unpeeled. Also, significance differences existed between the setting time of unpeeled and peeled rattan composites.

Effect of Aqueous Pre-treatments on the Hydration Temperature and Setting Time of Rattan-Cement Mixtures

Aqueous pre-treatments generally resulted in improved hydration temperature and reduced setting time in the rattan-cement mixes. Composites from the *Calamus* species subjected to hot water extraction had higher hydration temperature and lower setting time than those from the *Calamus* particles soaked in cold water. However, cold water extraction resulted in higher hydration temperature and lower setting time in the *Lacosperma*-cement mixes than hot water. This indicates that while hot water extraction improved the compatibility of the *Calamus* species, particles of the *Lacosperma* species were more amenable to cold water extraction.
Significant differences ($P \leq 0.05$) existed in the hydration temperatures and setting times of the untreated rattans and those subjected to aqueous extraction. However, there was no significant difference between the maximum hydration temperatures and setting times of composites from the two rattan canes subjected to

cold and hot water extraction (Tables 5), an indication that the two rattan species were more amenable to cold water extraction. Photochemical screening of the aqueous extracts (Tables 2 and 3) tallied with this observation that the extractives of the two rattan species were readily soluble in cold water.

Table 5: Duncan's Multiple Comparison of the Effect of Aqueous Pre-treatments on the Behaviour of Rattan-Cement Mixtures

	T_{max}		t_{max}	
Aqueous Pre-treatments	*Calamus species*	*Lacosperma species*	*Calamus species*	*Lacosperma species*
None	41.8^{B}	44.1^{D}	15.1^{A}	25.2^{C}
Cold Water	57.5^{A}	57.4^{C}	8.1^{B}	8.0^{D}
Hot Water	58.2^{A}	56.0^{C}	7.9^{B}	8.0^{D}

Means with the same letters are not statistically different

Table 6: Multiple comparison of the effects of Pre-processing, Species and Aqueous pre-treatments on the behaviour of Rattan-cement Mixtures

Factors	T_{max}	t_{max}
Peeling		
Unpeeled	53.3^{A}	14.0^{A}
Peeled	51.7^{A}	10.1^{B}
Aqueous Pre-treatments		
None	43.0^{B}	20.1^{A}
Cold Water	57.4^{A}	8.1^{B}
Hot Water	57.1^{A}	8.0^{B}
Species		
C. deerratus	52.5^{A}	10.4^{B}
L. secundiflorum	52.5^{A}	13.7^{A}

Means with the same letters are not statistically different

Comparison of Composites from the two Rattan Species

Though no significant differences existed between the maximum hydration temperatures of the two rattan species, the setting times of the species were significantly different with the *Lacosperma* species having higher setting time (Table 6). Also, the interactions of aqueous pre-treatment and pre-processing (removal of silified epidermis) had significant effects on the setting time of the *Calamus* species. However, peeling, aqueous extraction, species and their interactions had significant effects on the setting time of the rattan-cement mixtures.

CONCLUSIONS

The effects of aqueous extraction and cane peeling on the maximum temperature and setting time of cement composites from *Calamus deerratus* and *Lacosperma secundiflorum* rattan cane species were investigated. The following conclusions were drawn from the findings:

(i) The *Calamus* species inhibited cement setting more than the *Lacosperma* species due to differences in the anatomical structure.

(ii) Peeling affected the setting time of the two rattan species and the hydration temperature of the *Calamus* species

(iii) Aqueous extraction improved the maximum hydration temperatures and the setting times of the rattan-cement mixes.

(iv) The rattan particles were more amenable to cold water extraction than hot water extraction with a practical implication of low capital investment during board manufacture.

(v) Aqueous extraction improved the setting time of *Calamus* species more than the *Lacosperma* species

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