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Effect of Acetylation on Some Strength Properties of Danta (*Nesogordonia papaverifera*) and Ananta (*Cynometra Ananta)*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Dimensional stability and durability of wood can be improved by chemical modification. However, some strength properties are reduced, increased or not affected depending on the type of chemical used. Two high density tropical hardwood species, *Nesogordonia papaverifera* and *Cynometra ananta* which can be used for construction were acetylated and the impact of modification on the modulus of elasticity (MOE), modulus of rupture (MOR) and compressive strength parallel to the grain (CS) were analysed. The results indicated that the weight percentage gain (WPG) of 15.92 % and 15.20 % for acetylated *Nesogordonia papaverifera* and *Cynometra ananta* respectively had no significant change in MOE and MOR. The modification resulted in an increase in CPG by +15.71 % and +12.92 % for the modified *Nesogordonia papaverifera* and *Cynometra ananta* respectively.

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1. INTRODUCTION

Dimensional changes and durability are major factors that limit the application of wood especially when used as an engineering material. Some tropical lesser-used hardwood species which are available in the forests of Ghana in large quantities [1,2] are associated with low dimensional stability [3]. Large numbers of these wood species are also non-durable, however, chemical modification improved the durability of *Celtis mildbraedii,* a lesser-used wood species which is in large quantities in the forests of Ghana [2,3]. Most of these species are high density hardwoods that could be used for construction. According to [2], the range of total longitudinal shrinkage of some of these lesser-used species is between 0.2 % and 0.3 % and attention is therefore required when using these species as engineering materials in structural design where longitudinal stability is necessary. The range of total longitudinal shrinkage of Danta (*Nesogordonia papaverifera*) and Ananta (*Cynometra ananta*) is between 0.2 % and 0.3 % [2].

The colours of the heartwood and sapwood of *Nesogordonia papaverifera* are red to brown and pale red to brown respectively with basic density of 740 kg/m^3 and is converted into lumber, veneer and plywood. It is used for joinery, flooring, cabinet, paneling and furniture [1].

The colours of the heartwood and sapwood of *Cynometra ananta* are dark red with darker streaks and pink to brown respectively. It has a basic density ranging between 910 and 1000 kg/m3 and is used for conversion into lumber and poles [1]. It is used for flooring, heavy construction, furniture, joinery and furniture.

Acetylation is a chemical modifications process that results in a covalent bond [4] by substituting hydroxyl groups in the wood cell wall polymers and bulk the cell wall as well thereby reducing absorption of water by hydrogen bonding into the wood cell walls [4,5]. Chemical modification of wood improves durability and reduces dimensional changes [4,6,7] and some researchers have reported an improvement in some strength properties with certain anhydrides [8]. Others have also reported reduction and no effect on some strength properties of wood with some anhydrides [7]. Acetylation of hardwoods and softwood gave products with high dimensional stability, improved durability and the strength properties did not reduce [8]. According to [9], information of the impact of chemical modification on mechanical properties of wood that is important when using the modified wood as engineering material is limited. According to [7], modification of fibre boards with malic anhydride using phenol formaldehyde as a binder reduced MOR but when polypropylene was used as a binder there was a general increased in mechanical properties. Modification with acetic anhydride and succinic anhydride showed no change on MOR [7]. The objective of this work was to acetylate *Nesogordonia papaverifera* and *Cynometra ananta,* and analyse its effect on their MOE, MOR and CS.

2. MATERIALS AND METHODS

2.1 Wood Source

The trees were taken from the Bia District located in the Western region of Ghana. The trees were felled from a secondary forest and the district has average yearly temperature of 29.04^{o}C. Logs for the work were processed at John Bitar sawmill Company located in Takoradi, Ghana.

2.2 Wood Samples Preparation

Small samples free from defects were taken from the heartwood. The samples were randomly taken at 5 cm away from the sapwood. Three sets of samples were prepared for the MOE, MOR and CS tests. Each set contained 30 replicates. Tests sample dimensions for the MOE and MOR were 20×20×300 mm and for CS were 20×20×60 mm.

2.3 Wood Treatment

Modification processes described by [10] was used. Soxhlet extraction of the samples was carried out using toluene/methanol/acetone mixture in the ratio of 4:1:1 for 8 hours. The samples were oven-dried at a temperature of 103^{o}C overnight and allowed to cool to room temperature over silica gel. Samples were weighed. Weighed samples were vacuum impregnated with pyridine for 1 h at 103°C, followed by impregnated with 1M solution of acetic anhydride in pyridine at 103°C for 8 h. After 8 hours impregnation, samples were placed in cold acetone to quench the reaction. Soxhlet

extraction was carried out again to remove unreacted acetic anhydride. The modification processes were repeated but with de-ionised water for the control samples. Samples were oven-dried, weighed and the weight percentage gain due to the modification was calculated as shown in equation 1.

Percentage gain due to modification (%WPG) $= [(W_{mo} - W_{unmo})/W_{unmo}] \times 100$ (equation 1)

Where:

W_{mo} is the oven dry weight of the modified wood samples and M_{unmo} is the oven dry weight of the wood samples before modification.

2.4 Determination of MOR, MOE and CS

The [11] standards used for determination of maximum load using small clear samples were used for the determination of MOE, MOR and CS. After the strength tests, moisture content of the samples were checked and moisture content of samples different from 12% were recorded.

Strength values for samples with moisture content above or below 12 %, were corrected using the formula by [12] as shown in equation 2

$$\varphi 12 = \varphi n \{1 + \delta (N_2 - 12)) \quad \text{(equation 2)}$$

where:

$\varphi 12$ = strength at 12% moisture content (N/mm^2), φn = strength at moisture content different from 12% (N/mm^2), δ = constant value for relationship between strength and moisture content (δ = 0.05, 0.04, 0.02,) for CS, MOR, and MOE respectively. N_2 = moisture content during test (%).

3. RESULTS AND DISCUSSIONS

3.1 Evaluation of MOE, MOR and CS of Modified and Unmodified *Nesogordonia papaverifera and Cynometra ananta*

Table 1 shows the MOE, MOR CS of unmodified and modified *Nesogordonia papaverifera* with acetic anhydride.

3.2 Evaluation of MOE

The WPG of *Nesogordonia papaverifera* and *Cynometra ananta. were* 15.90 % and 15.20 % respectively. The modified and unmodified *Nesogordonia papaverifera* had MOE of 11,400 and 11,530 respectively and there was no statistical difference. The modified and unmodified *Cynometra ananta* also had MOE of 16.406 and 16.720 with no statistical difference. However, the MOE of the modified and unmodified *Nesogordonia papaverifera* were lower than the MOE of both modified and unmodified *Cynometra ananta.* According to [13], changes in mechanical properties of wood due to acetylation were inconsistent with one another, depending on wood species, treatment method, and WPG obtained by wood. The mechanical properties of beech wood were less influenced by acetylation [14].

3.3 Evaluation of MOR

The MOR of the modified and unmodified *Nesogordonia papaverifera* were 178.70 and 182.34 respectively whilst the MOR of *Cynometra ananta* were 159.23 and 164.30 respectively. The results indicated that there were no significant differences in MOR of the modified and unmodified *Nesogordonia papaverifera* and *Cynometra ananta* samples at WPG of 15.90 and 15.20 % respectively. The result show no significant deviation in MOR of the modified samples from the unmodified. This was in agreement with [7] report, that modification of wood with acetic anhydride had no significant change in MOR.

3.4 Evaluation of CS

The percentage change of the modified samples showed +15.71 % and +12.92 % positive change in the CS over the unmodified samples of *Nesogordonia papaverifera* and *Cynometra ananta* respectively which agrees with [8] that acetylation improves strength properties of wood. According to [15], at a comparable WPG of approximately 15 %, the compressive strength of Scots pine wood treated with acetic, propionic, butyric, valeric, hexanoic anhydrides increased with the molecular size of the substituent groups, indicating the improved compressive strength is due to degree of substitution rather than with the cell wall bulking. According to [16], the shear strength parallel to the grain of acetylated wood of about 20 % WPG decreased by 24 %, but various wood species exhibited different degree of changes in their mechanical properties after modification [16, 17]. Whilst the percentage change in CS of the modified *Nesogordonia papaverifera* samples showed +15.71 % positive change, that of *Cynometra ananta* showed +12.92 % positive change which is agreement with [16, 17].

Table 1. Mean values MOE, MOR, CS and WPG of *Nesogordonia papaverifera* and *Cynometra ananta*

	WPG	MOE	MOR	CS
***Nesogordonia papaverifera* modified (N/mm2)**		75.21[a]	78.70[a]	75.21[a]
Percentage change after treatment (%)		- 1.13	- 0.20	+15.71
***Nesogordonia papaverifera* unmodified (N/mm^2)**		11,530[a]	182.34[a]	65.00[b]
***Cynometra ananta* modifierd (N/mm^2)**		159.23[b]	159.23[b]	89.00[c]
Percentage Change after treatment (%)		-1.88	- 3.09	+12.92
***Cynometra ananta* umodified (N/mm^2)**		16,720[c]	164.30[b]	78.82[d]
***Nesogordonia papaverifera* (%)**	15.90			
***Cynometra ananta* modifierd (%)**	15.20			

**Means superscript with the different letters on a column are significantly different at P < 0.05*

4. CONCLUSIONS

Two tropical lesser-used hardwood species, *Nesogordonia papaverifera* and *Cynometra ananta*, were modified using acetic anhydride. The weight percentage gain of the modified *Nesogordonia papaverifera* and *Cynometra ananta* were 15.92 % and 15.20 % respectively. The modification resulted in no significant change of their MOE and MOR but improvement in their CPG by +15.71 % and +12.92 % for *Nesogordonia papaverifera* and *Cynometra ananta* respectively. *Nesogordonia papaverifera* and *Cynometra ananta* are recommended for improvement of their compressive strength parallel to the grain through acetylation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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