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WEIGHT LOSS AND COMPRESSIVE STRENGTH OF CASTOR OIL-TREATED *Pinus caribaea* (Morelet) WOOD EXPOSED TO FUNGI

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Abstract:

The need for environmental sustainability calls for a radical change from the use of synthetic wood preservatives which persist in the environment even after wood has been taken out of service. There has therefore been a growing interest in the development of efficacious biocides from plants, prompting the exploration of castor seed oil as a potential wood antifungal in this study due to its reported antimicrobial properties. Thus, this study aimed at evaluating the resistance of castor oil treated P. caribaea wood against two strains of wood basidiomycetes.

Five trees of Pinus caribaea were harvested at Shasha Forest Reserve, Osun State. Wood samples were obtained from the top, middle and base of the trees. The samples were conditioned and treated with four formulated fungicides prepared from mechanically extracted oil of castor seeds. The treated and control samples were inoculated with Sclerotium rolfsii (Brown rot) and Ganoderma lucidum (White rot) for 24 weeks. Parameters such as oil yield, preservative absorption, weight loss and compressive strength of the treated wood samples were determined. ANOVA was used in analyzing the data generated.

Results show that the oil yield of the seed of the plant is 41.75%. The preservative absorption of the wood ranged between 114.85 - 277.12 (Kgm^{-3}), weight loss (1.36 - 15.85%) and MCS// (33.05 - 48.35N/mm^2). Sampling height and preservative concentration significantly influenced weight loss of the wood ($p<0.05$). The 30% preservative concentration performed best, having the least weight loss (1.71% and 1.61%) and highest MCS// (47.06N/mm^2 and 44.65N/mm^2) after exposure to S. rolfsii and G. lucidum, respectively. The brown rot (4.12%) was more virulent than the white rot (3.66%) on the basis of wood weight loss, however, the MCS// results indicated otherwise. It is concluded that castor seed oil is effective in protecting wood against white and brown rot fungi.

Key words: *castor oil; white rot fungi; brown rot fungi; Pinus caribaea; compressive strength.*

INTRODUCTION

Wood is a hard, lignified and fibrous structural tissue found in the stem and root of trees and other woody plants (Kollmann and Cote 1968). It is a renewable resource which plays an important role in the world economy. It is a versatile material which can be utilized under any environmental condition (Hingston *et al*. 2001). However, due to its organic nature, its natural endurance is limited, as it is vulnerable to attack by bio-deteriorating agents (Sarker *et al*. 2006; Yang 2009). Hence, the rationale behind the use of preservatives in wood conservation is inherent in the great damages caused by these bio-deteriorating agents (Ogunsanwo and Adedeji 2010).

Much concerns have been raised on the use of synthetic chemicals in wood preservation due to their unavailability, cost, toxicity and negative environmental impacts (Murphy 1990; Sen *et al*. 2002; Tiilikkala *et al.* 2010). This has prompted intense research globally into the development of novel efficacious botanicals in controlling the actions of bio-degrading organisms on wood (Sen *et al*. 2002; Olajuyigbe *et al*. 2010; Thlama *et al*. 2012; Malami *et al.* 2015). Green plants have been discovered to be reservoirs possessing inexhaustible harmful fungicides/pesticides that are innocuous to man when

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compared to their synthetic counterparts (Venmalar and Nagaveni 2005). As such, the course of exploring the potentials of plants in the development of wood biocides has been vigorously pursued over the years (Goktas *et al*. 2007a; 2007b; Ogunsanwo and Adedeji 2010; Olajuyigbe *et al*. 2010; Ajala *et al*. 2014).

The Castor oil plant (*Ricinus communis*) is a flowering plant which belongs to the spurge family, Euphorbiaceae (Momoh *et al*. 2012). In Nigeria, this plant has little socio-economic value as it often grows in the wild and are most times considered a weed. Its seed oil has been reported to possess anti-microbial properties (Momoh *et al*. 2012) and efficacious towards termite control in wood (Ahmed *et al*. 2014). However, its potency against fungal attack in wood is yet to be explored. It is therefore expedient to explore the potentials of the seed oil in preserving *Pinus caribaea* wood against fungal degradation, which is reported to be a non-durable timber species (Emerhi *et al*. 2008), owing to the increasing rate of utilization of this wood species for structural applications in Nigeria.

GENERAL OBJECTIVE:

The main objective of this study was to evaluate the resistance of castor oil treated *Pinus caribaea* to a white rot and brown rot fungi attack.

The specific objectives were to:

1. determine the oil yield of the castor seeds;
2. determine the absorption of chemical formulations in the treated wood;
3. evaluate the fungicidal efficacy of castor oil in the protection of *Pinus caribaea* wood using weight loss;
4. assess the compressive strength parallel to grain of the castor-oil treated *Pinus caribaea* wood after exposure to a white rot and brown rot fungi.

MATERIALS AND METHODS

Sample collection

Five (5) defect-free trees of *Pinus caribaea* were harvested from a 31-year old pine plantation within Shasha Forest Reserve, Osun State, Nigeria, located between Lats. 7^0 and 7^0 30' N and Longs. 4^0 and 5^0 E. Bolts of 50cm in length were obtained from the top (90%), middle (50%) and base (10%) of the merchantable lengths of the trees. The bolts were coated with pentachlorophenol to prevent attack by blue-stain fungi before transporting them to the Department of Forest Resources Management wood workshop for further processing.

Test block preparation

The bolts were processed into 6cm x 2cm x 2cm dimensions such that the wood grains aligned with the longitudinal axis (BSI 1961). The test blocks were dried in the oven at 103^0C for 18 hours, weighed and subsequently stored in air-tight bags.

Oil extraction and yield estimation

Ripe castor seeds (*Ricinus communis var Gibsonii*) growing in the wild were sourced in large quantities within Ibadan, Oyo State. The seeds were dehauled, air-dried and grounded into paste. Oil was mechanically extracted from a known weight of the grounded seeds using a cold press until the oil stopped dripping out from the seeds. This method of extraction was utilized as the oil extracted is crude and therefore, the active ingredients present in the oil are preserved. The oil yield was determined using the formula below:

$$\boldsymbol{Oil\ Yield}\ (\%) = \frac{\boldsymbol{Volume\ of\ oil\ collected}}{\boldsymbol{weight\ of\ ground\ meal\ used}}\ \boldsymbol{x\ 100}$$

Formulation of fungicide

The fungicides were formulated using the volume-to-volume method employed by Adetogun *et al.* (2003) and Olajuyigbe *et al.* (2010). 1ml of the oil in 99mls of kerosene (diluent) is equivalent to 1% dilution. The oil extracted was therefore used to prepare the following concentrations of fungicides: 0% (kerosene alone), 10%, 20% and 30% preservative concentration levels.

Growth medium preparation

Inoculums of a *Ganoderma lucidum* (white rot) and *Sclerotium rolfsii* (brown rot) were sub-cultured on a fully solidified Potato Dextrose Agar (PDA) and incubated at room temperature (27±2^{0}C) in the laboratory.

Treatment of wood test blocks

The conditioned wood samples were completely submerged in a cold bath of the formulated fungicides for 24hrs. After treatment, each test block was removed from the formulated preservatives, drained and re-weighed to determine the preservative absorption using the method employed by Olajuyigbe *et al.* (2010) as described below:

$$\boldsymbol{Absorption\ (Kg/m^3)} = \frac{\boldsymbol{10^6\ x\ WPA}}{\boldsymbol{10^3\ x\ V}}$$

where: WPA = Weight of preservative absorbed (Kg),
V = Volume of wood sample (m^3).

Inoculation and incubation of test blocks

The test blocks were placed in Kolle flasks containing the actively growing fungi such that the test blocks were only in contact with the aerial mycelium of the fungi in order to prevent leaching of the preservative into the agar (Sarker *et al*. 2006). Each kolle flask contained 5 test blocks (replicates from individual tree treated with each fungicide concentration) and control (untreated blocks). The test blocks were incubated with *Ganoderma lucidum* (white rot) and *Sclerotium rolfsii* (brown rot) fungi at room temperature (27±2^{0}C) for 24 weeks. At the end of the incubation period, the test blocks were removed from the kolle flasks and the adhering mycelia carefully scrubbed off the wood surface without removing wood splints.

Weight loss determination

The test blocks after exposure to fungal attack were oven-dried at 103^{0}C for 18 hours and finally re-weighed to determine the weight loss. Weight loss was estimated using procedures adopted by Kumar and Dev (1993) as given below:

$$\boldsymbol{Weight\ loss}\ (\%) = \frac{\boldsymbol{W1 - W2}}{\boldsymbol{W1}}\ \boldsymbol{x\ 100}$$

where: W_1 = Oven-dry weight before incubation;
W_2 = Oven-dry weight after incubation.

Maximum compressive strength parallel to grain test (MCS//)

After weight loss estimation, the compressive strength of the samples were tested in accordance with BS 373 (1957) using the Instron 3369 model Universal Testing Machine (UTM).

RESULTS AND DISCUSSION

Oil yield of castor seed

The oil yield of the mechanically extracted seeds of *Ricinus communis var Gibsonii* was 41.75%. This value is similar to the oil yield of 45% reported by Gupta *et al.* (1951) and Ogunniyi (2006) for mechanically extracted seed oil of the same plant, but higher than the 33.2% reported by Akpan *et al.* (2006) for the solvent extracted oil. It has been reported that solvent extraction method results in greater oil yield than mechanical extraction (Tsaknis *et al.* 1999). The low value reported by Akpan *et al*. (2006) therefore may possibly be due to difference in the variety used, as the castor plant is reported to have about 36 different varieties in Brazil (Ramos *et al.* 1984). According to Ikhuoria *et al.* (2008), high oil content in plant seeds would be economical when they are processed for oil. The yield observed in this study shows that the castor seed is a high oil-yielding plant as it compares favourably with the oil yield reported by Rossel (1987) for some commercial plant oils such as olive (17%), soyabeans (18%), and corn (3.4%). Based on its high yield, the seed oil of *Ricinus communis var Gibsonii* can be of commercial value in the wood industry for use as a preservative.

Absorption of chemical formulations

The mean preservative absorption values are shown in Table 1. The mean absorption by the wood samples based on the sampling height ranged from 122.75kg/m^3 to 169.48kg/m^3. An inconsistent variation in preservative absorption was observed from the base to the top, with wood samples from the middle having the least absorption, while those from the base had the highest. Differences in the observed preservative absorption among the axial wood positions is possibly due to the anatomical differences in the wood samples obtained from the different positions of the tree (Ulvcrona *et al.* 2006; Larnøy *et al*. 2008). This result is in agreement with the findings of Ogunsanwo and Adedeji (2010) who also observed the highest absorption from wood samples at the base for *Triplochiton scleroxylon* treated in a cold bath of four different concentrations of *Erythrophleum suaveolens* bark extract.

Based on the preservative concentrations, absorption values ranged from 128.16kg/m^3 to 177.70kg/m^3. The 0% concentration had the highest absorption while the least was recorded for the 10% concentration. An increasing trend in absorption was though observed as the concentration increased from 10% to 30%, except for the 0% which had the highest. There was no significant difference ($p > 0.05$) in the effect of concentration, sampling height nor interaction effect of the two factors on preservative absorption (Table 2). The highest preservative absorption observed in the solvent alone (0%) must have been as a result of its lesser viscosity and its ability to easily permeate into the cell walls of the wood better than the other preservatives. On the other hand, the increasing trend in absorption with increasing preservative concentration suggests that more of the oil got introduced into the cell wall as the concentration increased, indicating that the viscosity of the 30% preservative was still within a permissible level to facilitate good absorption into the wood. The preservative absorption range observed in this study is considerably higher than that reported (45.1kg/m^3) by Venmalar and Nagaveni (2005) for rubber wood treated in a cold bath of neem oil for 24hrs. This wide contrast may possibly be due to the viscosity of the preservative (Owoyemi 2010) or the anatomical differences between both wood species. Kazemi *et al.* (2006) reported that solvent type as well as the viscosity of the chemicals used influence preservative penetration in wood.

Weight loss of wood

The mean percentage weight loss of the *P. caribaea* samples exposed to *Sclerotium rolfsii* (brown rot fungi) after twenty four weeks is presented in Table 3. Mean percentage weight loss of the control samples ranged between 7.65% - 15.85%, with an increasing trend noted from the base to the top. Percentage loss in weight for the samples treated with kerosene (0%) ranged between 3.75% - 4.21%, with an inconsistent trend in weight loss observed along the tree bole. Wood samples treated with the 10% and 20% preservative recorded weight losses which ranged between 1.84% - 2.07% and 1.45% - 2.13%, respectively. For both treatments, percentage weight loss increased from base to the top. At 30% preservative concentration, mean percentage weight loss of wood samples was between 1.47% - 2.06%, with an inconsistent trend in weight loss observed from base to top.

Overall, percentage weight loss increased from the base to the top, while loss in wood weight largely tended to reduce with increasing preservative concentration, though with the exception of the 20% preservative. Thus, while the result shows that the diluent (kerosene) was able to impart some form of inhibition to decay by the fungus, its high weight loss in comparison to the other preservative treatments show that it was only able to confer a temporary fungal resistance on the wood samples as it evaporated with time. The most severe attack was observed in the control samples (11.14%), while the 30% preservative reduced weight loss by 85% when compared to the control samples, indicating its efficacy in conferring substantial resistance on the wood samples to fungal attack.

The observed axial trend in weight loss in this study is consistent with findings of Ashaduzzaman *et al.* (2011) for wood samples of *Acacia auriculiformis* and *Dalbergia sisso* exposed to a white rot fungi (*Schizophyllum communie*), but is in contrast to that reported by Emerhi *et al*. (2008) for *Pinus caribaea* wood exposed to some white rot and brown rot fungi, where they observed an inconsistent variation in weight loss along the tree bole. While the more or less decreasing weight loss with increase in preservative concentration observed here is in conformity with the work of Adetogun *et al*. (2009), it however is in dissonance with reports of both Ogunsanwo and Adedeji (2010) for treated wood samples of Obeche treated with bark extracts of *Erythrophleum suaveolens* and exposed to a brown rot fungus (*Fomitopsis pinicola*), and Goktas *et al*. (2007a) for samples of beech wood and Scots pine treated with *Sternbergia candidum* extract and exposed to a brown rot fungus (*Postia placenta*). According to both Goktas *et al*. (2007a) and Ogunsanwo and Adedeji (2010), they stated that the reason for such an occurrence may be due to the ease with which effective

preservative components dissolve at lower concentrations thereby becoming more toxic at such low concentrations to the fungus.

The mean percentage weight loss of the *P. caribaea* samples exposed to *G. lucidum* (white rot fungi) after twenty four weeks is presented in Table 3. Mean percentage weight loss of the control samples ranged between 6.98% - 10.15%, with an increasing trend observed from the base to the top. Percentage loss in weight for the samples treated with kerosene alone ranged between 3.52% - 4.55%, with an inconsistent trend in weight loss observed along the tree bole. Wood samples treated with the 10% preservative recorded weight loss which ranged between 1.76% - 1.92%, with a decreasing trend observed from base to top. For the 20% and 30% preservative, mean percentage weight losses recorded ranged between 1.56% - 2.15% and 1.36% - 1.79%, respectively, with an inconsistent trend in weight loss observed from base to top in both cases.

A similar trend of weight loss observed for the brown rot fungi was equally observed for the white rot fungi, with an increasing weight loss from base to top and a seemingly decreasing weight loss with increasing preservative concentration, with the exception of the 20% preservative treatment. In the same vein, the most severe attack was observed on the control samples (8.85%), while weight loss was minimal for wood samples treated with the 30% preservative (1.61%). It is noteworthy that the efficacy of the 30% preservative in resisting attack to white rot fungi is beyond reasonable doubt as it reduced weight loss in *P. caribaea* wood exposed to *G. lucidum* by 82% when compared to the control samples.

The axial pattern of variation in weight loss for the white rot fungi is similar to the pattern observed for the wood samples exposed to *S. rolfsii*. The trend of weight loss in relation to preservative concentration is equally similar to that obtained for wood samples exposed to *S. rolfsii*. While this observation is similar to that reported by Adetogun *et al*. (2009), it is however in contrast to reports by Goktas *et al*. (2007b) for treated beech wood and Scots pine exposed to a white rot fungus (*Trametes versicolor*) where they observed an increasing trend in weight loss with increasing preservative concentration. Goktas *et al*. (2007b) ascribed their observation to the fact that some botanicals do possess some organic materials which constitute the nutrition for the fungus and thus, increasing its concentration will only increase the nutritive components in the wood, culminating in an increase in wood weight loss.

Furthermore, comparisons of the wood weight losses between both fungi type indicates that the brown rot fungus (*S. rolfsii*) was more destructive than the white rot fungus (*G. lucidum*), with the brown rot fungus causing a weight loss of 4.12%, and that of the white rot being 3.66% (Table 4). Divergent results have been reported on the virulence of brown rotters and white rotters. Similar to the observation in this study, Green and Highley (1997), Adetogun *et al.* (2006), Goktas *et al*. (2007b), Emerhi *et al*. (2008) and Ogunsanwo and Adedeji (2010) all reported higher virulence by brown rot fungi on wood than white rot fungi. This may be attributed to the fact that brown rotters degrade cellulose and hemicellulose in wood which are the major constituents of wood by proportion, compared to white rot fungi which degrade mainly lignin, or possibly because of the preferential invasion of conifers by brown rotters (Gilbertson 1980). Contrary to this observation however are the reports of Venmalar and Nagaveni (2005), Goktas *et al*. (2007a), Badejo (2009), Ajala *et al*. (2014) where it was observed that white rot fungi were more virulent than brown rot fungi.

The average weight loss for the white rot and brown rot fungi imposed on the wood of *P. caribaea* in this study in comparison to that reported by Emerhi *et al*. (2008) for the same species is considerably low. This perhaps is due to the difference in age of the trees for both studies. While Emerhi *et al*. (2008) used ten year old *P. caribaea* species, which can be termed a juvenile wood, a matured *P. caribaea* wood (31 year old) was used in this study. Thus, it is suggested that the juvenile tree of this species lacks adequate heartwood which, to an extent, repels fungal attack, as well as some extraneous substances in the form of resins which has been reported to confer some form of protection on the wood. The average weight loss of the control samples in this study for both the white rot and brown rot fungi (6.98% - 15.85%) falls within the range of weight loss for resistant species (11% - 24%) under the ASTM (1989) classification of wood resistance to biodeterioration. It can therefore be gleaned from this that the wood is moderately durable to fungal attack, contrary to the assertion of Emerhi *et al*. (2008) for *P. caribaea* wood grown in Nigeria.

Statistical analysis revealed that sampling height and interaction effects of fungi-concentration on wood weight loss were significant ($p<0.05$), while effect of concentration and interaction effects of concentration-sampling height on wood weight loss was highly significant ($p<0.001$) (Table 5). Fungi type on the other hand had no significant effect on weight loss ($p>0.05$) (Table 5). Post mortem analysis for sampling height shows that weight loss for wood samples at the top were significantly greater than those at the base, while weight losses for wood samples at the middle and base were not

different from each other (Table 6). For the preservative concentration, the weight loss in the control samples differed from the other treatments. Similarly, the weight loss in the 0% preservative differed from other treatments while the 10%, 20% and 30% preservatives showed similar weight losses (Table 7).

Table 1

Mean percentage preservative absorption of *P. caribaea* wood at different axial positions

	Sampling Height			
Concentration	**Top (Kg/m^3)**	**Middle (Kg/m^3)**	**Base (Kg/m^3)**	**Mean**
0%	136.79	119.19	277.12	**177.70**
10%	128.02	129.70	126.76	**128.16**
20%	138.96	127.25	120.49	**128.90**
30%	128.50	114.85	153.55	**132.30**
Mean	**133.07**	**122.75**	**169.48**	

Table 2

ANOVA for preservative absorption of *Pinus caribaea* wood

Source of variation	Df	Mean square	P- Value
Sampling Height	2	12053.542	0.14ns
Concentration	3	8657.854	0.235ns
Sampling Height x Concentration	6	9256.435	0.176ns
Residual	48	5893.904	
Total	59		

"*" denotes "significant at (p<0.05)"; "ns" denotes "not significant at (p>0.05)"

Table 3

Mean percentage weight loss of treated *P. caribaea* wood at different axial positions after exposure to *Sclerotium rolfsii* and *Ganoderma lucidum*

Concentration	Fungi Type	Top (%)	Middle (%)	Base (%)	Mean
Control	*S. rolfsii*	15.85	9.90	7.65	**11.14**
	G. lucidum	10.15	9.40	6.98	**8.85**
0%	*S. rolfsii*	3.83	3.75	4.21	**3.93**
	G. lucidum	4.11	4.55	3.52	**4.06**
10%	*S. rolfsii*	2.07	1.96	1.84	**1.96**
	G. lucidum	1.76	1.82	1.92	**1.83**
20%	*S. rolfsii*	2.13	1.98	1.45	**1.85**
	G. lucidum	2.15	1.56	2.10	**1.93**
30%	*S. rolfsii*	1.61	2.06	1.47	**1.71**
	G. lucidum	1.67	1.79	1.36	**1.61**
Mean	***S. rolfsii***	**5.10**	**2.06**	**1.47**	
	G. lucidum	**3.97**	**3.82**	**3.18**	

Table 4

Mean percentage weight loss of treated *P. caribaea* wood for the two fungi species

Fungi Type	Weight loss (%)
S. rolfsii	4.12
G. lucidum	*3.66*

Table 5

ANOVA for weight loss of *Pinus caribaea* wood after exposure to fungi

Source of Variation	Df	Mean square	P- Value
Sampling Height	2	20.56	0.001**
Fungi Type	1	8.03	0.09ns
Conc Level	4	376.29	0.000**
Fungi x Conc level	4	7.92	0.03*
Fungi x Sampling height	2	4.2	0.22ns
Conc. Level x Sampling height	8	5.6	0.000**
Fungi x Samp height x Conc level	8	4.97	0.09ns
Residual	120	2.77	
Total	149		

"**" denotes "significant at (p<0.001)"; "*" denotes "significant at (p<0.05)"; "ns" denotes "not significant at (p>0.05)"

Table 6

LSD of Sampling height for weight loss of *Pinus caribaea* wood

Sampling Height	Means
Top	4.53^{a}
Middle	3.88^{ab}
Base	3.25^{b}

Means with the same superscript are not significantly different at p<0.05

Table 7

LSD of Preservative concentration for weight loss of *Pinus caribaea* wood

Preservative concentrations	Means
Control	9.99^{a}
0%	3.99^{b}
10%	1.89^{c}
20%	1.89^{c}
30%	1.66^{c}

Means with the same superscript are not significantly different at p<0.05

Maximum compressive strength of wood parallel to grain (MCS//)

According to Raberg *et al*. (2005), strength tests are the most sensitive indices for detecting wood decay. The MCS// of the wood samples treated with different concentrations of castor oil and exposed to the fungi *S. rolfsii* and *G. lucidum* after twenty four weeks are shown in Fig. 1 and 2 below. The untreated samples (control) had the least average MCS (38.61N/mm^2) for wood samples exposed to *S. rolfsii*, while wood samples treated with the 20% preservative concentration had the least average MCS (40.89N/mm^2) after exposure to *G. lucidum*. On the other hand, the wood samples treated with 30% preservative concentration had the highest mean MCS of 47.06N/mm^2 and 44.65N/mm^2 after exposure to *S. rolfsii* and *G. lucidum*, respectively. The trend of variation in MCS with preservative concentration was inconsisent in both cases, while MCS tended to increase generally from top to base. Obviously, treating the *P. caribaea* wood with the 30% preservative concentration had a positive influence on the wood samples by increasing their resistance against the two fungi strains as evident from the higher MCS values in both cases. Explicitly, the 30% preservative

retained the compressive strength of the wood by 21.9% and 6.3% for *S. rolfsii* and *G. lucidum,* respectively when compared to the control samples, further showing an evidence of its anti-fungal property.

Furthermore, the average MCS for wood samples exposed to *S. rolfsii* was higher (43.56N/mm^2) than those exposed to *G. lucidum* (42.85N/mm^2). This observation however is unexpected owing to the higher weight loss recorded in wood samples exposed to *S.rolfsii* when compared to those exposed to *G. lucidum*, as higher weight loss results in a lower compressive strength (Adetogun *et. al*. 2003; Li *et. al.* 2006). Where strength properties of wood have been reported to be strongly correlated with the density or the amount of wood material (cellulose) in wood (Panshin and dezeeuw 1980; Onilude and Ogunsanwo 2002; Taylor *et al.* 2002), it becomes surprising to observe such an outcome. However, a possible reason for this occurrence is that the degradation of the cementing material of the wood cells (lignin) by the white rot fungus led to the easy collapse of the wood under a lower applied force parallel to the grain irrespective of the cellulose content of the wood when compared to the brown rot which degrades chiefly cellulose and hemicellulose. This observation however is contrary to the report of Ajala (2014) where he observed that wood exposed to a brown rot fungus had lower MCS than those exposed to a white rot fungus. Several studies have equally reported higher reduction in wood strength for brown rot than white rot than white rot (e.g. Zabel and Morrell 1992; Ajala 2014), which is contrary to the observation in this study. This therefore shows that weight loss may not be a reliable index for evaluating wood decay as suggested by Raberg *et al.* (2005). Nonetheless, the findings of this study supports the assertions by Wilcox (1978), Eaton and Hale (1993) and Barnes and Murphy (1995) and Adetogun *et al.* (2003) that the mechanical properties of wood are affected by wood decay; the degree of strength loss which is dependent on the fungi type and wood type.

Statistical analysis shows that none of the factors significantly influenced the MCS// of the wood samples ($p>0.05$) as shown in Table 8.

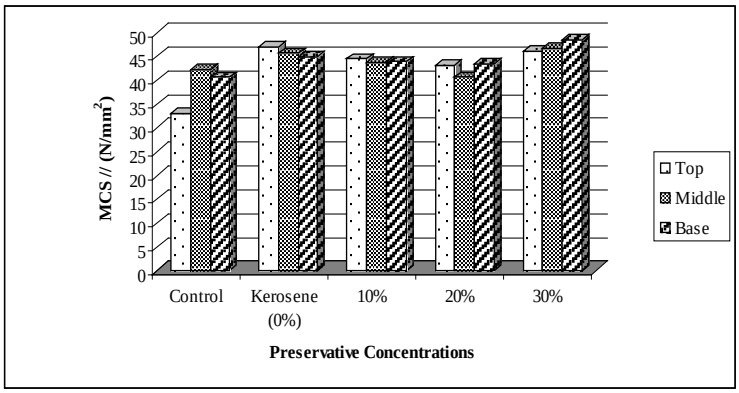

Fig. 1.
Maximum compressive strength of treated wood exposed to Sclerotium rolfsii.

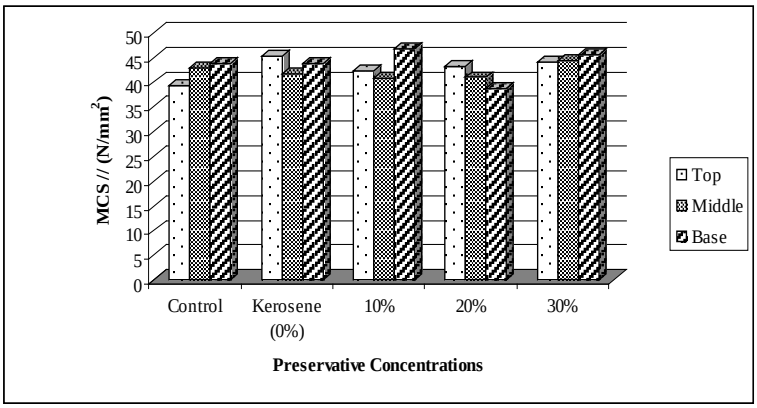

Fig. 2.
Maximum compressive strength of treated wood exposed to Ganoderma lucidum.

Table 8

ANOVA for MCS of treated *Pinus caribaea* wood after exposure to fungi

Source of Variation	Df	Mean square	P- Value
Sampling Height	2	20.24	0.73ns
Fungi Type	1	19.39	0.58ns
Conc Level	4	151.22	0.06ns
Fungi x Conc level	4	43.05	0.62ns
Fungi x Sampling height	2	10.23	0.85ns
Conc. Level x Sampling height	8	43.38	0.71ns
Fungi x Samp height x Conc level	8	15.29	0.98ns
Residual	120	64.44	
Total	149		

"*" denotes "significant at (p<0.05)"; "ns" denotes "not significant at (p>0.05)"

CONCLUSION

This study has demonstrated the potentials of castor seed oil (*Ricinus comunis var Gibsonii*) as a wood preservative. The high oil yield of its seeds, coupled with its ubiquitous nature makes it a sustainable and attractive source of wood biocide in Nigeria, especially due to its low socio-economic value in this part of the world. Overall, the 30% preservative concentration performed best in improving the resistance of *P. caribaea* against fungal attack. Sampling height on the other hand strongly influenced weight loss in the wood, which shows that there is more concentration of accessible food at the juvenile region of the wood when compared to the matured region. Also, this study has also expatiated on the need to examine weight loss in tandem with strength properties of decayed wood as some wood strength properties may not be completely sensitive to detecting decay in wood. In addition, *P. caribaea* can be described as a moderately resistant timber species in Nigeria based on the ASTM (1989) classification, contrary to the reports by Emerhi *et al*. (2008). Notwithstanding, the wood species requires preservative treatment in order to extend its shelf-life during service. Further studies is suggested on the effect of higher concentrations of the oil on resistance of non-durable wood species against wood basidiomycetes.

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