WOOD PRESERVATIVE POTENTIALS OF THREE PLANT SPECIES USED LOCALLY IN NIGERIA

ABDULQUADRI SAGAYA[1*], ABDULLAHI ALANAMU ABDULRAHAMAN[1], GANIYU SHITTU OLAHAN[1], SUNDAY ADENIRAN[1]

Wood extractives are one of the main reasons for the resistance of wood against termite and fungal attacks. The chemical composition of aqueous leaf extracts of *Ocimum gratissimum*, *Azadirachta indica* and *Vernonia amygdalina* were used as wood preservative against termite and fungal infestation in *Daniellia oliveri*, *Parkia biglobosa* and *Ceiba pentandra*. The leaf extracts were screened quantitatively and qualitatively for phytochemicals. The extracts were used to treat woods from *D. oliveri*, *C. petandra* and *P. biglobosa* that were exposed to termites (*Macrotermes bellicosus*) and fungal attacks in the field. *Aspergillus sp; Rhizopus sp; Penicillum spp; Neurospora spp; Mucor spp; Saccharomyces spp; Candida spp.* were the fungi species isolated from the decayed woods; with *Geotricum spp.* being absent only in the decayed wood of *Parkia biglobosa*. It was observed that leaf extracts used as preservatives in this study improved the resistance of less durable wood samples to termite and fungal attack, compared to the control. It was also observed that there was an insignificant difference between the potency of the leaf extracts and the synthetic wood preservatives used in this study. These extracts can therefore be used as bio-preservatives for woods against termite and fungal attack.

Keywords: fungi infestation, plant extract, termite attack, wood species.

INTRODUCTION

Wood products are important to the socio-economic development of any nation. Wood has been used in carpentry, production of sports equipment, building, fuel industries; etc. It is also the basic raw material for pulp and paper production, plywoods, panel boards, and veneers. Despite all its numerous usefulness, one of its limitations is deterioration. Wood is liable to attack by degrading agents especially during packaging, storage, and service leading to deterioration. Wood being a biological material is easily degraded by bacteria, fungi, and termites (Walker, 1993; Schultz and Nicholas, 2002a). However, some wood species are resistant to these degrading agents while others are very susceptible to deterioration (Kityo and Plumptre, 1997). Those that are susceptible must be treated with preservative chemicals to increase their shelf life. Wood preservation is a process of reducing

[1] Applied Plant Anatomy and Wood Technology Laboratory, Department of Plant Biology, Faculty of Life Sciences, University of Ilorin, Ilorin, Nigeria *Correspondence: sagaya.aa@unilorin.edu.ng; +2348063052975.

ROM. J. BIOL. – PLANT BIOL., VOLUME **67**, Nos. 1–2, P. 47–63, BUCHAREST, 2022

and/or preventing attack by wood deteriorating agents thereby increasing the shelf life of wood (Barnes, 1992).

There are wood species that are naturally resistant to bio-deterioration agents; this resistance is mainly due to the accumulation of extractives in the heartwood some of which are decay inhibitors (Kityo and Plumptre, 1997). It is these extractives that render the heartwood poisonous to wood destroying organisms. Haygreen and Bowyer (1996) and Milton (1995) noted that the chemical composition and amount of extractives in wood are highly variable within and between tree species and can range from 2–15% of the wood weight. Hinterstoisser *et al.* (2000) noted that the content of extractives plays a key role in the prediction of the durability of wood. The concentration of extractives varies among species, between individual trees of the same species and within a single tree. For instance, heartwood contains more extractives than sapwood and in some cases sapwood lacks these deposits completely rendering it susceptible to attack by fungi and termites. The question that needs to be asked is: 'Can naturally occurring plant extracts be used to enhance the durability of those wood species in which these extractives are lacking (susceptible to deterioration)?' Therefore, the overall objective of the study was to assess the use of natural plant extracts as wood preservatives in increasing the shelf life of susceptible timber species.

MATERIALS AND METHODS

STUDY SITE AND COLLECTION OF MATERIALS

The study site was the termitarium located at the Forestry Research Institute of Nigeria (FRIN), Jericho, Ibadan, Kappa Technology Laboratory, Amusement Park, University Road, Ibadan, Nigeria

The wood species used for this experiment were *Daniellia oliveri* (Rolfe) Hutch & Dalziel (African copaiba balsam tree, aiyafunfun), *Parkia biglobosa* (Jacq.) G. Don (locust bean, dodongba) and *Ceiba pentandra* (L.) Gaertn (kapok, sanmi). The wood species were procured from Irewolede, Sawmill, Ilorin, Nigeria. The leaves of *Azadirachta indica* A. Juss. (neem, dongoyaro), *Vernonia amygdalina* Delile (bitter leave, *ewuro*), and *Ocimum gratissimum* L. (ocimum, *efinrin*) were collected around Government Reservation Area, Tanke, Ilorin, Nigeria.

PREPARATION OF WOOD AND PRESERVATIVE SAMPLES

The wood samples were cut using a circular saw machine into 5×20 cm size, at Irewolede, Sawmill, Ilorin, Nigeria. The wood species were taken to the laboratory. From each species, 42 specimens each were obtained for the termites and fungi studies. The wood samples were weighed, and then sun-dried. Wood samples were constantly re-weighted until a constant weight was gotten. The leaves of *A. indica*, *V. amygdalina* and *O. gratissimum* were air-dried at ambient temperature until they were crispy, then ground into a powdery form using Binatone electric blender (model No.: BLG-555(MK2), sealed and then taken to the laboratory for screening.

PREPARATION OF WOOD SAMPLES

The specimens of each wood species were separated into two groups; for termite and fungal deteriorative studies. From each of the species, 3 wood samples were used as the control, 3 wood samples were treated with synthetic preservative (rocket), and 12 wood samples each were treated separately with Neem, Ocimum, and Bitter leaf aqueous extracts in four concentrations (100, 75, 50 and 25% w/v).

Dilution ratio of the extract was as follows:

T5 = 20% of the rocket preservative

T4 = 100% concentration consisting of 100% plant extract,

T3 = 75% concentration consisting of 75% plant extract + 25% distill water,

T2 = 50% concentration consisting of 50% plant extract + 50% distill water,

T1 = 25% extract is composed of 25% plant extract + 75% distill water.

T0 = Distilled water only

Powdery leaves of 16.5 g of *Azadirachta indica*, 17.4 g *Vernonia amygdalina*, and 18.65 g *Ocimum gratissimum* were soaked in 83.5 ml, 82.6 ml and 81.35 ml of distilled water respectively (determined by the average water content), left for 42 hours. Each mixture was filtered using a muslin cloth and concentrated to prepare 100, 75, 50, and 25% of the plant extracts. The 4 different concentrations of the plant extracts were applied to the wood samples by spraying. After treatment, the treated woods were air-dried and then oven-dried at 60°C until a constant weight was achieved. The specimens were then relabeled using, conditioned to equilibrium moisture content, and weighed to determine their initial weight W1. The wood samples were then divided into two, one part exposed to termites (*Macrotermes bellicosus*) in the field during the dry season in August when termites are most active in Nigeria, and the other part to fungi attack under a shed close to the laboratory.

Field trials were preferred to laboratory studies because they allow the collective and cumulative effects of all kinds of abiotic and biotic deterioration factors to be evaluated (Peralta *et al*., 2003).

The samples were laid down randomly inside the termite mounds, then covered with tarpaulin. The termites that attacked the specimens were collected and identified in the Department of Zoology, University of Ilorin. Test specimens in the field were inspected at four weeks interval, cleaned, and reweighted to determine the final weight (W_2) for 12 weeks. The percentage weight loss for individual test specimens was determined according to D1413 American standards (2003);

$$\text{Percentage weight loss} = \frac{(W1 - W2)}{W1} \times 100$$

Where W1 = Weight of test specimen after treatment but before exposure to termites.

W2 = Weight of test specimens after exposure.

The effect of extracts on natural durability was also tested by exposing wood samples to fungi attack following the method of Abdul Rahaman *et al*. (2018). After which, the wood was cultured in a plate for the manifestation of fungi.

Test specimens in the field were inspected at four week intervals, for the fungal count to determine final fungal concentration for 12 weeks.

PHYTOCHEMICAL SCREENING

The qualitative and quantitative phytochemical screening was conducted using some analytical methods. For the analysis of tannins, phenol, and alkaloid, using the method of Treas and Evans (1996). Saponins and terpenoids were screened using the method described by Ejikeme *et al.* (2014). Flavonoids were screened using methods described by Sofowara (1993) while cardiac glycoside was analyzed using the methods described by Hikino *et al.* (1984).

DATA ANALYSIS

One way Analysis of Variance was used on data obtained from plant extracts and wood using the Statistical Package for Social Sciences (SPSS) version 16.0. The level of significance used in F ratio was $p<0.005$, where F ratio is significant. Treatment means were separated using Least Significance Difference (LSD). Figures were plotted using origin 7.0 for Windows.

RESULTS

IDENTIFICATION OF COMPOUNDS IN PLANT EXTRACTIVES

Tables 1 and 2 show quality and quantity of different phyto-compounds present in the three plant species. The compounds detected in *O. gratissimum* extracts were terpenoids, tannins, alkaloids, flavonoids, saponins, phenolics, and glycosides. Terpenoids were the most abundant compound (876.67) compared to all other compounds, with cardiac glycoside being the least abundant compound (31.67). Tannins which are said to possess high preservative characteristics are found to be the second most abundant compound.

Alkaloids were the most abundant compounds (1348.33) found in *V. amygdalina.* Other compounds detected included terpenoids, saponins, and tannins in significant quantity. The other compounds flavonoids and glycosides occur in traces. Most compounds detected in *A. indica* were similar to those detected in *O. gratissimum* and *V. amygdalina* only that the amounts varied. The most abundant groups of compounds in *A. indica* are alkaloids in highly significant quantity with all other compounds insignificant or in trace quantity.

EFFECTS OF PLANT EXTRACTS ON TREATED WOODS

The average weight for *D. oliveri, C. petandra* and *P. biglobosa* treated with the plant extracts were 173.45, 117.45 and 187.96 gram respectively after twelve weeks of exposure to termite attack (Plate 1).

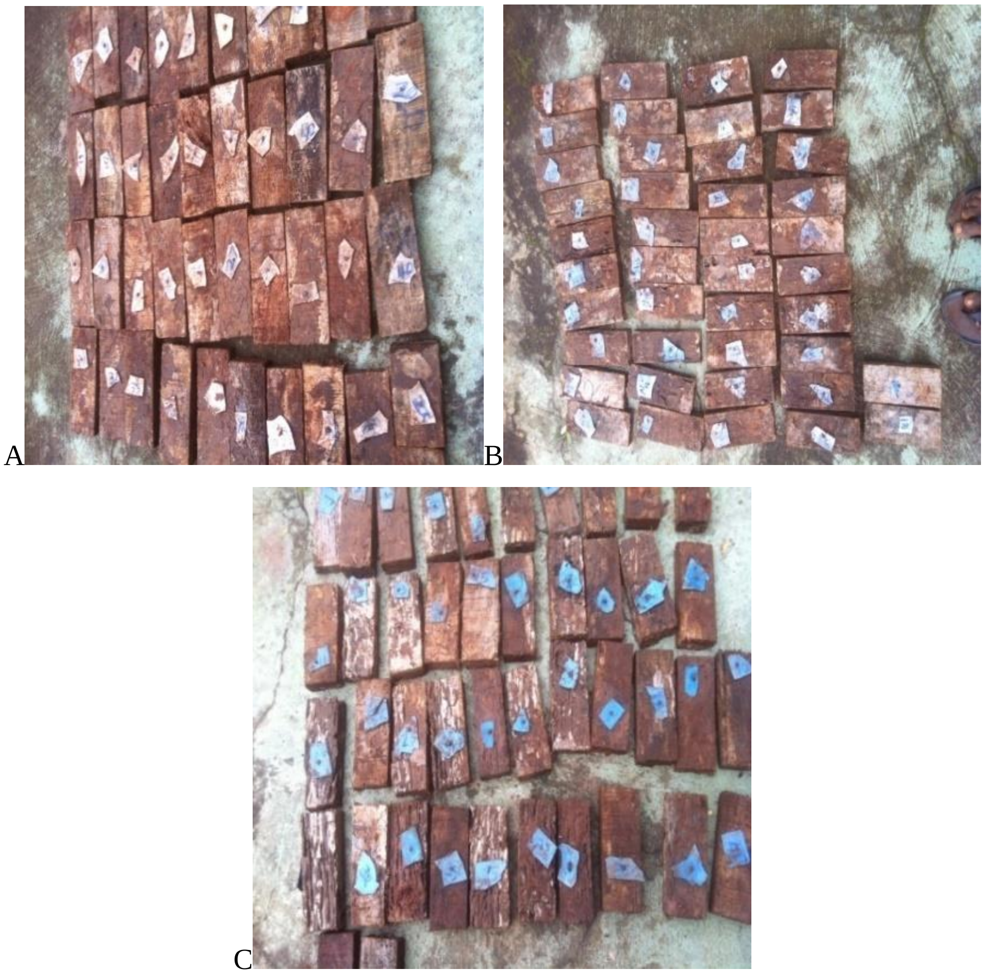

Plate 1. Wood species of (A) = *Daniellia oliveri*, (B) = *Ceiba pentandra* and (C) = *Parki biglobosa* at 12th week of exposure to termite attack.

Tables 3, 4 and 5 illustrate the mean weight for *D. oliveri, C. petandra* and *P. biglobosa* after treated with plant extract concentrations (T0, T1, T2, T3, T4 and T5) over a period of 12 weeks. *O. gratissimum* extract (T1) has the highest mean weight (g) and proof to be most effective while *V. amygdalina* (T4) shows the lowest fungal count for *D. oliveri*. *A. indica* extract (T4) has the highest mean weight (g) and proof to be most effective at 100% concentration while *O. gratissimum* with 100% concentration has the least fungal count for *C. petandra*. Also *A. indica* extract is the most effective at T4 in the woods exposed to termites while 100% concentration of *V. amygdalina* has lowest fungi count for *P. biglobosa*.

Figures 1 to 6 were also in line with the tables, they illustrated the effectiveness (potency) of the concentrations of plant extracts on *D. oliveri, Ceiba petandra* and *Parkia biglobosa* attacked by termite and Figures 7 to 12 showed the effectiveness of the best concentration on fungi for each wood sample. *D. oliveri, Ceiba petandra* and *Parkia biglobosa* respectively.

Tables 6 to 8 compared the most effective plant extract with control and synthetic for *D. oliveri, C. petandra* and *P. biglobosa* respectively. Significant differences were observed only between plant extract T1 and T5 (synthetic) in *Daniellia oliveri* ($P < 0.05$) for the termite attack while the treatment of wood species with preservatives (plants extract and synthetic) increases their resistance to fungi infestation significantly at ($P < 0.05$).

Table 1

Qualitative analysis of the extracts used as preservatives

PARAMETER	NEEM	OCIMUM	BITTER LEAF
Tannins	++	+++	++
Terpenoids	++	+++	++
Alkaloids	+++	++	++++
Flavonoids	+	++	++
Saponins	++	++	++
Phenolics	+	++	++
Cardiac Glycosides	+	-	-

Legend: ++++ Very high, +++ High, ++ Medium, + Low, Very low/ trace

Table 2

Quantitative analysis of the extracts used as preservatives

PARAMETER	NEEM	OCIMUM	BITTER LEAF
Tannin (mg/100g)	221.67 ± 6.01^{c}	490.00 ± 10.41^{b}	181.67 ± 4.41^{d}
Terpenoid (mg/100g)	435.00 ± 10.41^{b}	876.67 ± 9.28^{a}	251.67 ± 10.14^{c}
Alkaloid (mg/100g)	863.33 ± 6.01^{a}	458.33 ± 6.01^{c}	1348.33 ± 19.22^{a}
Flavonoid (mg/100g)	205.00 ± 7.64^{c}	360.00 ± 8.66^{d}	270.00 ± 7.64^{c}
Saponin (mg/100g)	426.67 ± 7.26^{b}	341.67 ± 13.02^{d}	388.33 ± 4.41^{b}
Phenol (mg/100g)	18.70 ± 0.32^{d}	32.67 ± 0.12^{e}	38.57 ± 0.09^{e}
Cardiac glycoside (mg/100g)	8.33 ± 1.67^{d}	31.67 ± 3.33^{e}	13.33 ± 1.67^{e}
Total	311.2429	370.1429	355.9857

Table 3

Mean weight of each concentration on *Daniellia oliveri* attacked by termites and fungi

Wood weight				Fungi counts		
Concen-tration	Treatment			Extract		
	Ocimum gratissimum	*Azadirachta indica*	*Vernonia amygdalina*	*Ocimum gratissimum*	*Azadirachta indica*	*Vernonia amygdalina*
T4 (100%)	186.87	216.93	191.00	3232.50	7963.3	2231.7
T3 (75%)	218.64	204.84	206.03	11316.67	24033.3	11774.1
T2 (50%)	209.53	186.82	204.82	34033.33	43758.3	90250
T1 (25%)	235.68	217.40	199.46	161883.33	225333.3	235858
T0 (0%)	180.65	180.65	180.65	28400000.00	28400000.00	28400000.00
T5 (Syn)	168.43	168.43	168.43	407.75	407.75	407.75

Table 4

Mean weight of each concentration on *Ceiba petandra* attacked by termites and fungi

Wood weight(g)				Fungi counts		
Concentra-tion	Treatment			Extract		
	Ocimum gratissimum	*Azadirachta indica*	*Vernonia amygdalina*	*Ocimum gratissimum*	*Azadirachta indica*	*Vernonia amygdalina*
T4 (100%)	145.50	155.06	150.65	4073.33	13215.00	6458.33
T3 (75%)	143.03	143.13	134.50	22391.67	23891.67	27491.67
T2 (50%)	150.08	145.44	136.64	35741.67	52417.50	57783.33
T1 (25%)	135.40	153.97	136.63	112225.83	207323.33	134083.33
T0 (0%)	125.97	125.97	125.97	18892500.00	18892500.00	18892500.00
T5 (Syn)	147.00	147.00	147.00	425.50	425.50	425.50

Table 5

Mean weight of each concentration on *Parkia biglobosa* attacked by termites and fungi

Wood weight(g)				Fungi counts		
Concentration	Treatment			Extract		
	Ocimum gratissimum	*Azadirachta indica*	*Vernonia amygdalina*	*Ocimum gratissimum*	*Azadirachta indica*	*Vernonia amygdalina*
T4 (100%)	207.57	235.67	206.14	20800.00	16958.33	3897.50
T3 (75%)	182.80	228.79	211.58	66641.67	26716.67	23661.67
T2 (50%)	208.93	195.31	222.89	171750.00	100783.33	35425.00
T1 (25%)	197.05	210.18	210.43	179483.33	161641.67	266816.67
T0 (0%)	259.66	259.66	259.66	3145833.33	3145833.33	3145833.33
T5 (Syn)	239.83	239.83	239.83	308.42	308.42	308.42

Table 6

Statistical summary to compare treatments used on *Daniellia oliveri*

Termite		Fungi
Treatment	Mean	Mean
T1(*Ocimum gratissimum*)	$215.58^{a} \pm 16.99$	$2898.33^{a} \pm 1057.50$
T0(Control)	$180.65^{ac} \pm 10.51$	$28400000.00^{b} \pm$ 1E+07
T5(Synthetic)	$168.43^{c} \pm 22.61$	$403.75^{a} \pm 80.71$
Total	188.22	9467767.3611

Table 7

Statistical summary to compare treatments used on *Ceiba petandra*

Termite		Fungi
Treatment	Mean	Mean
T4(*Azadirachta indica*)	$145.50^{a} \pm 14.17$	$4073.33^{a} \pm 1172.05$
T0(Control)	$125.97^{a} \pm 15.24$	$18892500.00^{b} \pm 4428223.38$
T5(Synthetic)	$147.00^{a} \pm 16.74$	$425.50^{a} \pm 56.01$
Total	139.49	6298999.61

Table 8

Statistical summary to compare preservatives used to preserve *Parkia biglobosa*

Termite		Fungi
Treatment	Mean	Mean
T4(*Azadirachta indica*)	$235.67^{a} \pm 12.29$	$3875.00^{a} \pm 718.81$
T0(Control)	$259.66^{a} \pm 22.15$	$3145833.33^{b} \pm 1296438.28$
T5(Synthetic)	$239.83^{a} \pm 23.12$	$308.42^{a} \pm 74.53$
Total	245.22	1050005.58

Appendix 1. Identified fungi species

Wood species	Isolated organism
Daniella oliveri	*Aspergillus sp; Rhizopus sp; Penicillum spp; Neurospora spp; Mucor spp; Saccharomyces spp; Candida spp; Geotricum spp.*
Parkia biglobosa	*Aspergillus spp; Rhizopus spp; Penicillum spp; Saccharomyces spp; Neurospora spp; Mucorspp; Candida spp; Saccharomyces spp.*
Ceiba petandra	*Aspergillus spp; Rhizopus spp; Penicillum spp; Saccharomyces spp; Neurospora spp; Mucor spp; Candida spp; Geotricum spp.*

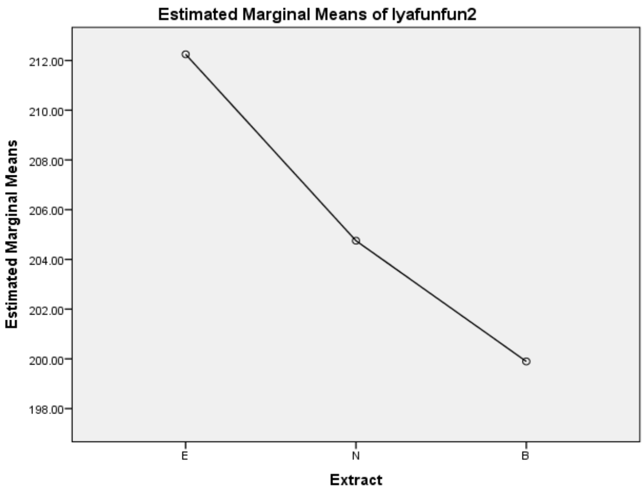

Fig. 1. Effectiveness of the plant extracts on *Daniellia oliveri* attacked by termites.

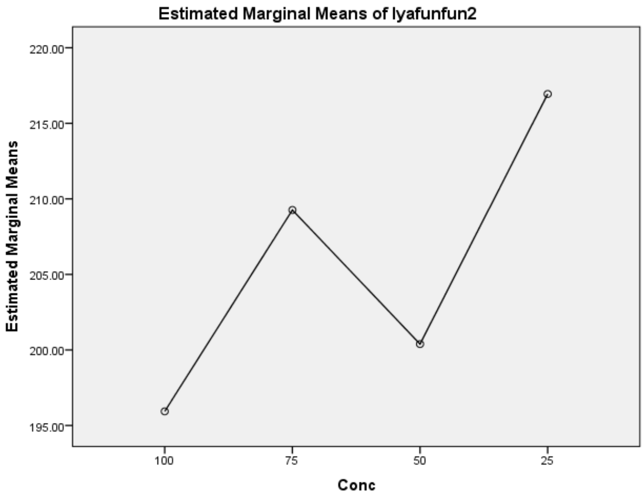

Fig. 2. Effectiveness of the concentrations of *Ocimum gratissimum* (efinrin) on *Daniellia oliveri* attacked by termites.

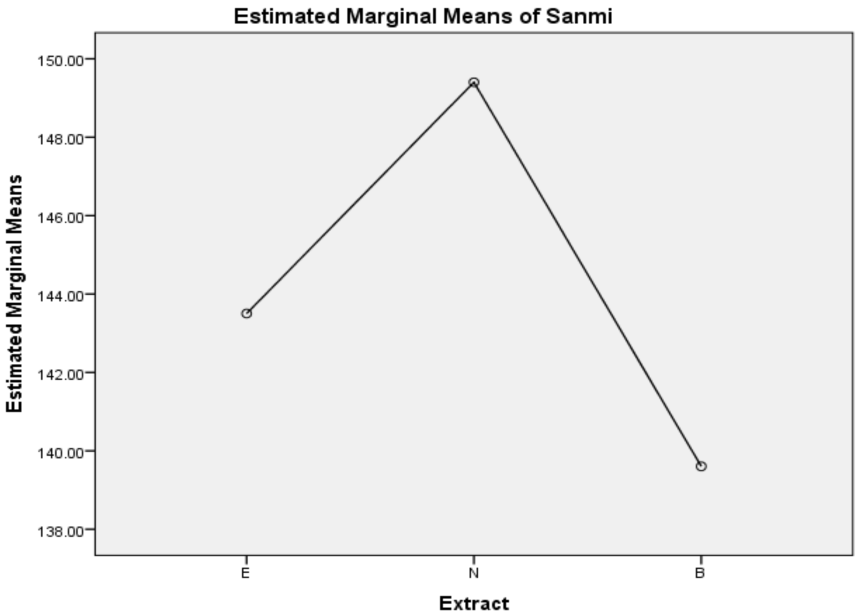

Fig. 3. Effectiveness of the plant extracts on *Ceiba petandra* attacked by termites.

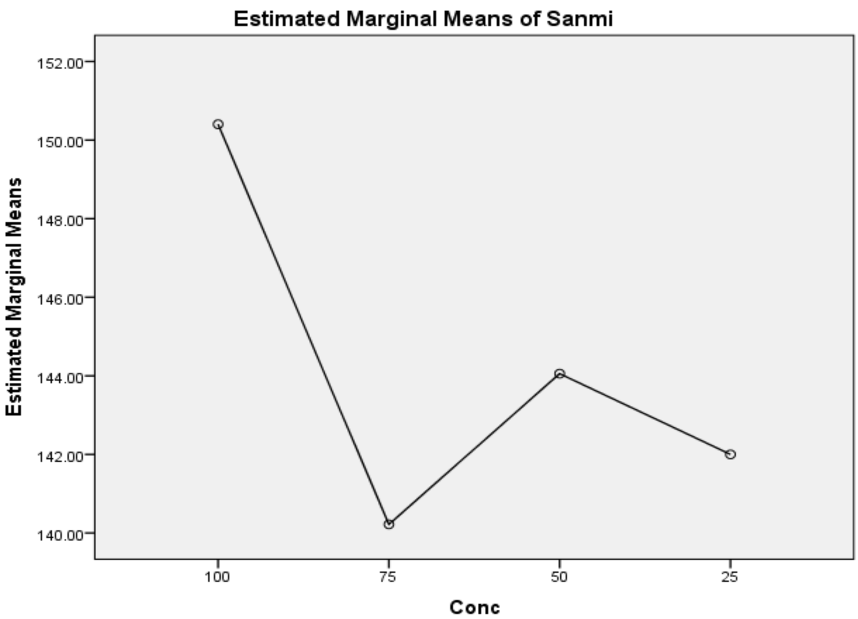

Fig. 4. Effectiveness of the concentrations of *Azadirachta indica* (neem) on *C. petandra* attacked by termites.

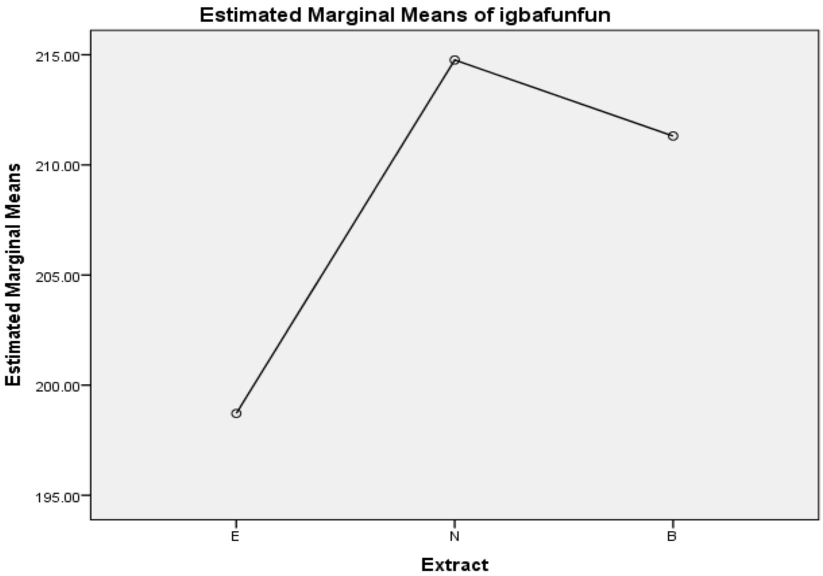

Fig. 5. Effectiveness of the plant extracts on *Parkia biglobosa* attacked by termites.

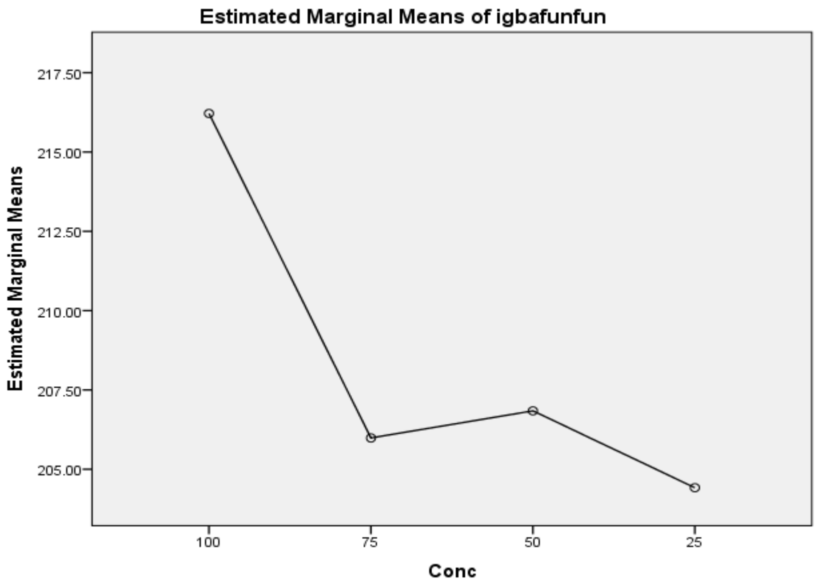

Fig. 6. Effectiveness of the concentrations of *Azadirachta indica* on *Parkia biglobosa* attacked by termites.

Key: E= *Ocimum gratissimum* N= *Azadirachta indica* B=*Vernonia amygdalina*

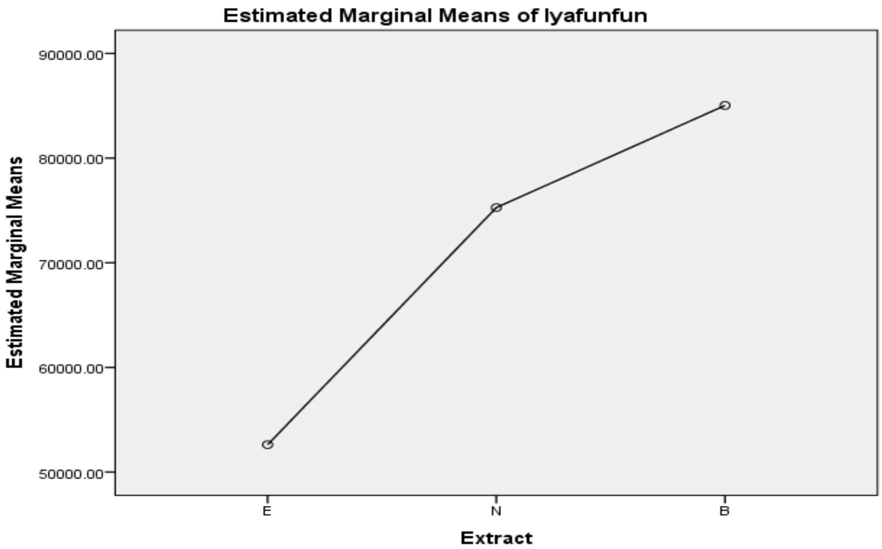

Fig. 7. Effectiveness of the various plant extracts on *Daniellia oliveri* infested by fungi.

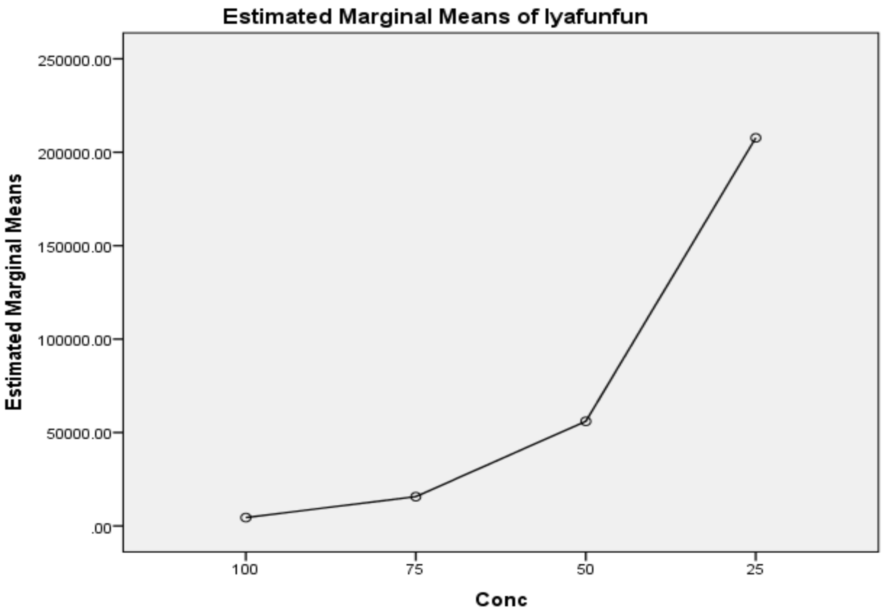

Fig. 8. Effectiveness of the various concentration of *Vernonia amygdalina* on *Daniellia oliveri* infested by fungi.

Key: E= *Ocimum gratissimum* N= *Azadirachta indica* B=*Vernonia amygdalina*

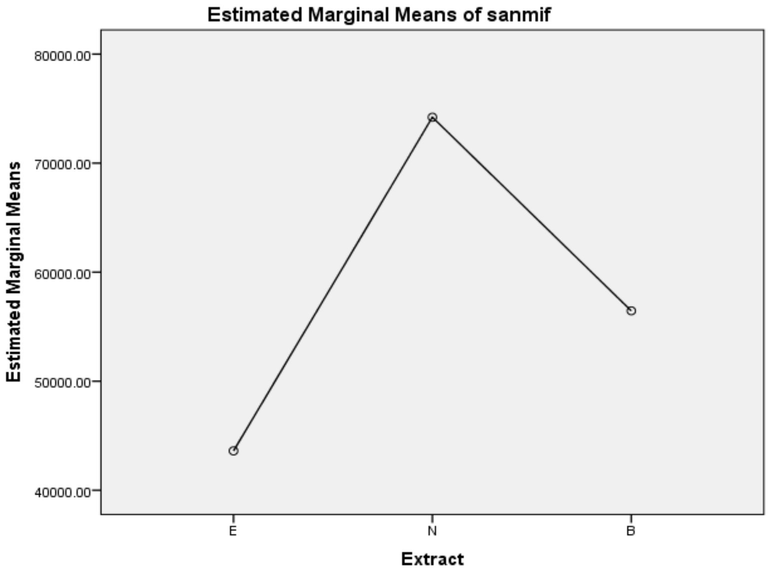

Fig. 9. Effectiveness of the various plant extracts on *Ceiba petandra* infested by fungi.

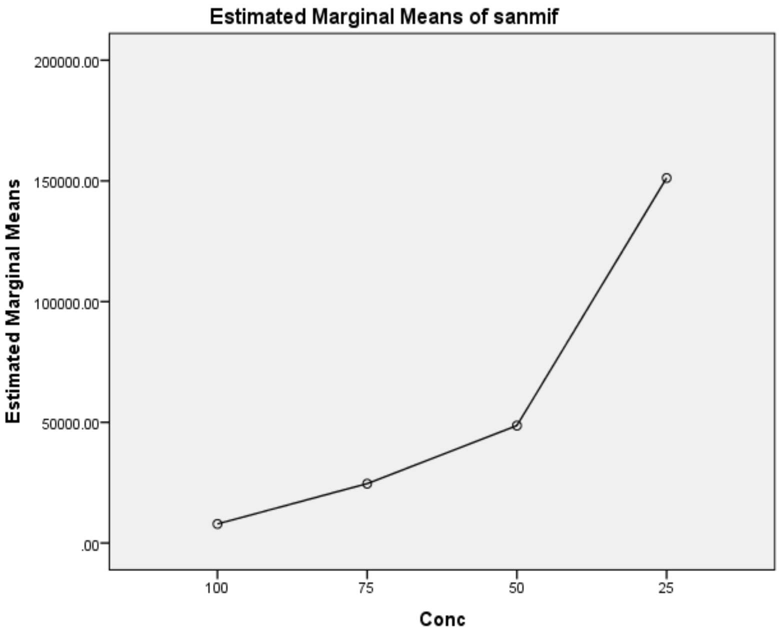

Fig. 10. Effectiveness of the various concentrations of *Ocimum gratissimum* on *Ceiba petandra* infested by fungi.

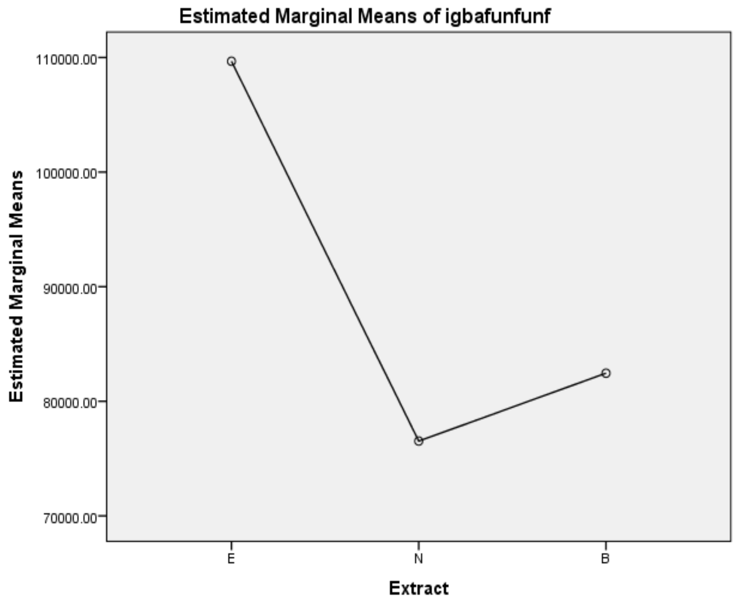

Fig. 11. Effectiveness of the various plant extracts on *P. biglobosa* infested by fungi.

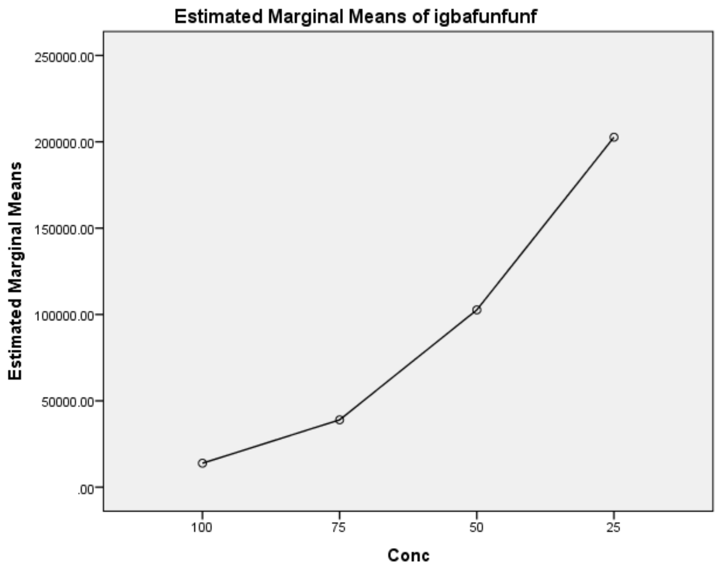

Fig. 12. Effectiveness of the various concentration of *Azadirachta indica* on *Parkia biglobosa* infested by fungi.

Key: E= *Ocimum gratissimum* N= *Azadirachta indica* B=*Vernonia amygdalina*

DISCUSSION

Phytochemicals also known as phytonutrients are naturally occurring substances found in plants (Ugwu *et al*., 2013). The result of the phytochemical screening of the aqueous extract of plant species showed presence of tannins, terpenoids, alkaloids, flavinoids, Saponins, phenolics and cardiac glycosides. Similar compounds were reported for each of the three plants (Usunobun and Okolie, 2016; Gupta *et al.*, 2011; Ujah *et al.*, 2021). Most alkaloids have a strong bitter taste and are very toxic and for these reasons they are used by plant to defend themselves against herbivores, and attacks by microbial pathogens and invertebrate pests (Harbone, 1998). Tannins are widely distributed in many species of plants, where they play a role as pesticides and plant growth regulation (Katie *et al.*, 2006). These two among others are well reported in many literatures for their uses as preservatives for perishable and non-perishable materials (Ohmura *et al*., 2000; Schultz and Nicholas, 2002).

Plant extracts were found to increase resistance to termite and fungi in *D. oliveri*, while the effects were more seen on fungi infestation in *C. petandra* and *P. biglobosa.* Similar results were reported by Goktas *et al.* (2007) who reported that plant extract enhance decay resistance. The synthetic preservative, which was a control, was also effective in increasing resistance to fungi infestation in the three wood species during fungi infestation but increase in resistance during termite attack was insignificant, while there was significant increase in resistance of *P. biglobosa* to both fungi and termite attacks. The most effective preservatives against termite infestation were *A. indica* at 100% concentration for both *P. biglobosa* and *C. pentandra*, and *O. grattisimum* at 25% concentration for *D. olivera*. The effectiveness of *A. indica* and *O. grattisimum* may be due to higher concentrations of alkaloid and tannin respectively present in their extracts and these justify the claim reported by Abdul Rahaman *et al.* (2018) that higher concentration of alkaloids reduces devastating effect of termite and fungi on economic trees and tannins give room for boron to remain within the wood for a longer period and consequently to extend its life (Tondi *et al*., 2012). The resistance of wood with aqueous extract to termite attack was significantly higher than that of synthetic preservative. These plant extracts were found to be the most effective in retarding termite attack. Thus, it can be deduced that plant extract contains compounds that are either toxic or non-palatable to the termites, thereby, are effective in preserving the three wood species.

The most effective preservatives against fungi infestation were *V. amygdalina* at 100% concentration for both *D. Olivera* and *P. biglobosa*, and *O. grattisimum* at 100% concentration for *C. pentandra*. The resistance of wood with aqueous extract was insignificantly higher than that of synthetic preservative. *V amygdalina* was the extract with a higher concentration of alkaloid showing its effect in preventing fungi growth on the two woods. The potential of *V. amygdalina* as preservative had been earlier reported by Dienye *et al.* (2017) in preserving catfish against fungi deterioration. Okon-Akan *et al.* (2019) also reported the potential of *V. amygdalina* in preventing brown rot fungi (*Sclerotium rolfsii*) on *Astonia boonie* wood.

It was noted that *A. indica* extract is an effective treatment in the *C. petandra* attacked by termite but it is the least effective in preserving wood infested by fungi. This may be attributed to the ability of the fungi to degrade/convert the toxic composition of *A. indica* to their benefits. Therefore, resistance of these woods to termites and fungi attack after preservation could be due to the extracts' repellent characteristics. The repellent characteristics could be due to the toxic chemical composition of the various plants extract. This is inline with Taylor *et al.* (2006) who in their study suggested that the methanol-soluble extractives of *Thuja plicata* and *Chamaecypari snootkatensis* play an important role in heartwood resistance to attack by *Coptotermes formosanus* and *Postia placenta.* They further noted that methanol soluble extractives of the heartwood of those tree species were positively correlated with both termite and decay resistance.

CONCLUSIONS AND RECOMMENDATION

Wood resistance of tree species significantly increased after treatment with plant extracts. However, the effectiveness of both plant extracts and the synthetic preservative in protecting the wood were almost the same in both *P. biglobosa* and *C. pentandra* exposed to fungi infestation while there was significant increase in their resistivity in *D. oliveri.* Based on the results of this research, it is recommended that water soluble *A. indica* extracts at 100% should be used to preserve *P. biglobosa* and *C. pentandra* samples against termite attack and fungi infestation, and *O. gratissimum* extract at 25% and 100% for *D. oliveri* samples against bio-deterioration particularly termite attack and fungi infestation respectively.

REFERENCES

1. Abdulrahaman A.A., Ajiboye, P.O., Aderemi, M.O., Al Sahli, A.A. and Alaraidh, I.A. (2108). Comparative pesticidal properties of *Jatropha curcas*, *Jatropha gossypifolia* and *Ricinus communis* on termite and fungal infected woods. *J. Indian bot. Soc.*, 97 (3&4): 110–118.
2. Barnes H.M. (1992). *Wood Protecting Chemicals from the 21st Century*. International Research Group on Wood Preservation, Section 3. Paper Prepared for 24th Annual Conference Meeting at Orlando, Florida, USA, 16–20 May 1992, IRG/WP 93-30018, 29 pp.
3. Dienye H.E., Oladosu-Ajayi, R.N., Ajayi, C.T. and Agha, I.U. (2016). *Vernonia amygdalina* (bitter leaf) extracts as preservative for catfish (*Clarias gariepinus*). *Int J Nutr Sci & Food Tech*, *3*(1), 102–108.
4. Ejikeme C.M., Ezeonu, C.S. and Eboatau, A.N. (2014). Determination of physical and phytochemical constituents of some tropical timbers indigenous to Niger Delta area of Nigeria. *European Scientific Journal*, 10(18): 247–270. no page numbers.

5. Gupta V.K., Singh, J., Kumar, R. and Bhanot, A. (2011). Pharmacognostic and Preliminary Phytochemical Study of *Ocimum gratissimum* Linn. (Family: Lamiaceae), *Asian Journal of Plant Science*, 10(7): 365–369.
6. Harbone J.B. (1998). Methods of extraction and isolation. *Phytochemical Methods*. *3*: 60–66.
7. Haygreen J. G and Bowyer, J.L (1996). Forest Products and Wood Science: An Introduction, 3rd Ed: Iowa State University Press, Ames, Iowa. pp. 198–199.
8. Hikino H., Kiso, Y., Wagner, H. and Fiegi, M. (1984). Antihepatotoxic actions of flavonoids of flavonoligans. *Planta Medica*, 5:248–250.
9. Hinterstoisser B., Stefke, B. and Schwanninger, M. (2000). Wood: Raw material- material-source of energy for the future. *Lignovisionen*, 2: 29–36.
10. Katie Jr., Thorington, E.F. and Squirrels, R.W. (2006). *The Animal Answer Guide*. Johns Hopkins University Press, Baltimore, London, p. 91.
11. Kityo P.W and Plumptre, R.A. (1997). *The Uganda Timbers Users Handbook.* A Guide to Better Timber Use. Common Wealth Secretariat, London.
12. Milton F.T. (1995). *The Preservation of Wood. A Self Study Manual for Wood Treaters*. Minnesota extension service. University of Minnesota Collage of Natural Resources.
13. Ohmura W., Doi, S., Aoyama, M. and Ohara, S. (2000). Antifeedant activity of flavonoids and related compounds against the subterranean termites *Coptotermes formosanus. Journal of Wood Science*, 64, 711–715.
14. Okon-Akan O.A., Abiola, J.K. and Okanlawon, F.B. (2019). Effects of *Xanthorrhoea preissii* and *Vernonia amygdalina* leaf extracts against *Sclerotium rolfsii* on *Astonia boonie* (DE. WILD). International Journal of Applied Research and Technology. 8(10): 167–173.
15. Peralta R.C.G., Menezes, E.B., Carvalho, A.G. and Menezes, E.L.A. (2003). Feeding preferences of subterranean termites for forest species associated or not to wood decaying fungi. *Floresta e Ambiente*, 10(2): 58–63.
16. Schultz T.P. and Nicholas, D.D. (2002). Naturally durable heartwood: evidence for a proposed dual defensive function of the extractives. *Phytochemistry*, 54, 47–52.
17. Schultz T.P. and Nicholas, D.D. (2002a). Development of environmentally-benign wood preservatives based on the combination of organic biocides with antioxidants and metal chelators. *Phytochemistry*, 61: 555–560.
18. Sofowora A. (1993). *Medicinal Plants and Traditional Medicinal in Africa*. University of Ife Press 2nd Ed. 320 pp.
19. Tondi G., Wieland, S., Lemenager, N., Petutschnigg, A., Pizzi, A. and Thevenon, M. (2012). Efficacy of Tannin in fixing boron in wood: fungal and termal resistance. *Jor. Acad. Bio. Res.* 7(1): 1238–1241.
20. Trease G.E. and Evans, W.C. (1996). *Phenols and Phenolic Glycosides in Trease and Evans Pharmacology and Bikere*. Tindall, London. pp. 832–836.
21. Ugwu O.P.C., Nwodo, O.F.C., Joshua, P.E., Bawa, A., Ossai, E.C. and Odo, C.E. (2013). Phytochemical and acute toxicity studies of *Moringa oleifera* ethanol leaf extract. *International Journal of Life Sciences Biotechnology and Pharma Research*, 2(2): 66–71.
22. Ujah I.I., Nsude, C.A., Ani, O.N., Alozieuwa, U.B., Okpako, I.O. and Okwor, A.E. (2021). Phytochemicals of neem plant (*Azadirachta indica*) explains its use in traditional medicine and pest control. *GSC Biological and Pharmaceutical Sciences*, *14*(2), 165–171.
23. Walker J.C.F. (1993). *Primary Wood Processing. Principles and Practice*. Chapman and Hall.