Journal of Bioresource Management

Volume 8 | Issue 2 Article 14

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Recommended Citation

Ajala, O. O., Adebawo, F. G., Adelusi, E. A., & Adegoke, O. A. (2021). Influence of Decay Fungi on Selected Anatomical Properties of Aningeria Robusta A. Chev. Wood, *Journal of Bioresource Management, 8* (2).
DOI: https://doi.org/10.35691/JBM.1202.0188
ISSN: 2309-3854 online
(Received: Feb 2, 2021; Accepted: Apr 4, 2021; Published: May 28, 2021)

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INFLUENCE OF DECAY FUNGI ON SELECTED ANATOMICAL PROPERTIES OF *ANINGERIA ROBUSTA* A. CHEV. WOOD

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ABSTRACT

Due to population explosion, the forest of Nigeria like most tropical forest is over exploited for choice traditional species. Therefore, need to investigate species that can substitute the species arise. Five trees of *Aningeria robusta* were harvested from Cocoa Research Institute of Nigeria. Bolts of 50cm length were obtained at the base, middle and the top; radial strips also obtained for innerwood, middlewood and outerwood. Ten test specimens of dimension 12mm x 15mm x 25mm were obtained per zone. N-hexane heartwood extracts of a 30 year old *Gliricidia sepium* diluted with kerosene using volume by volume method into 0%, 25%, 50%, 75% and 100% was used. Quantitative characterizations of fungi inoculated and uninoculated wood blocks were determined. The wood blocks were immersed in the extract for 48 hours prior subjection to *Lentinus sajor-caju and Trichoderma viride* for sixteen. Samples were laid in split plot and factorial experimental designs for the uninoculated and inoculated respectively. Data were analyzed using ANOVA and descriptive statistics. Mean proportion of vessel, fibre and ray before inoculation are 16.89%, 59.08% and 23.74% respectively. Sources of variance had significant effect on the properties at 5% probability level. There was a general reduction in all the anatomical properties after inoculation with the fungi strains. The fungi used, concentration levels adopted, sampling heights involved and radial position had significant effect on the anatomical properties after inoculation with the fungi. Conclusively, the bio-preservative could not prevent fungal growth on the anatomical properties; it could only reduce it.

Keyword: Anatomical properties, decay, fungi, A*ningeria robusta*.

INTRODUCTION

Nigerian forests like most of tropical ones are comprised of valuable resources, and are being exploited for highly valued timber species which are small proportion of the existing number. In this regard, economic timber species have reduced drastically in number and value from Nigerian forests thereby resulting in increasing dependency on lesser used wood species which were once abandoned as replacement for the valued primary timber species.Wood is subject to degradation by bacteria, fungi, insect, marine borers, climatic, mechanical, chemical and thermal factors (Greenbuilder, 2006). Degradation can affect wood of living trees, logs and products causing changes ranging from simple discoloration to alterations that can eventually render wood completely useless in appearance, structure and chemical composition. Zabel and Morrell (1992) opined that degradation by fungi could cause losses as much as 15 to 25% of marketable wood volume in standing trees and 10 to 15%in wood products during storage and conversion. Akinyemi et al., (2004) reported that thousands of cubic metres of wood are lost annually in Nigeria due to devastating effect of woodrotting basidiomycetes and other insect infestations of logs and lumber products. *Lentinus sajor-caju* (Fr.) Fries, a white rot fungus belongs to the phylum basidiomycetes, family polyporaceae, a saprophytic mushroom (Stamets, 2000) which degrades both the lignin and cellulose components of the cell, with a bleaching effect, which may make the damaged wood appear whiter than normal (Highly, 1999; Haygreen and Bowyer, 1982). *Trichoderma viride* Pers belongs to the class basidiomycetes, genera cephalosporie with elongated hyphae, conidia in heads (Stevens, 1913). The mycelia of *T. viride* can produce a variety of enzymes, including cellulases and chitinases which can degrade cellulose and chitin respectively (Volk, 2004). *T. Viride* causes digestion of middle lamella, thus causing a separation of the individual vessels (Heald, 1926). It can act as natural bioagent to protect plants from infection by soil-borne fugal pathogens (Tapwal et al., 2012).

Aningeria robusta (A. Chev.) is a lesser known tropical species (LKTS); belongs to the family of Sapotaceae, a hardwood, referred to as agengre in Cote d'ivoire, Landosan in Nigeria and Osan in Uganda (TRADA, 1979); Mukali in Angola, Mukangu in Kenya (Chudnoff, 1980); Asafonia in Ghana (Okai 2003). Its wood performs excellently well in the production of joinery and furniture (Chudnoff, 1980; Ajala, 2006) and it is gaining recognition among wood users both locally and internationally in the last decades. Despite this, the wood is non-durable with little resistance to decay fungi and termites infestation (TRADA, 1979; Chudnoff, 1980; Scheffer and Morrell, 1998; PROTA, 2010). Its fibres are simple with minutely bordered pits, vessels are diffuse–porous in nature, axial parenchyma diffuse in aggregate with narrow bands, ray cells procumbent with 2-4 rows (Lemmens, 2007).

The wood cellular structures which include the proportions of fibres, vessel elements axial and ray parenchyma cells are very germane in the evaluation of mechanical strength of wood species and thus tend to influence its end uses. Therefore, a sound knowledge of the wood micro structural properties is a prerequisite for choosing wood species for particular end uses. Information on the anatomical characterization of wood after exposure to agents of deterioration is essential as it has potentials to reveal information on the effects of cell damage on properties such as specific gravity and compression strength.

The known properties and utilisation of tropical hardwood species had been a formidable force behind their trade. Some African countries dwell on this and had their annual wood export volumes increased by 30% as in the case of Ghana in the 1970's on lesser-known timber species, while Cote d'ivoire and Nigeria had 40% and 5% contribution from the same source noted Owonubi (1999). Jayanelti (1998); Eastin et al.,(2003); Barany et al.,(2003), opined that where lesser known timber species are used as substitute for traditional economic timber species, such products suffers from non-recognition and acceptance in international markets. Lesser-used species are thus considered important components of the future forest ecosystem which must be given special attention now in forest management policy making opined Coleman (1998); Barany et al., (2003); Eddowes (1980). However, for this to be realised, Eddowes (1980) disclosed that adequate data on the properties of concerned wood species must be readily available. This will help inefficiently utilising the diverse species available for us in the tropical forest thereby reducing pressure on the species, which are already popular in the market. In view of dearth of information in the literature evaluating the influence of fungi on wood cellular structures of *A. robusta*, this study therefore investigated the effect of fungi infestation on the cellular structure of wood of *A. robusta*, a LKTS with and without treatment with N-hexane extract of *Gliricidia sepium*.

MATERIALS AND METHOD

Study Area

Materials for the study (five trees of *Aningeria robusta)* were obtained from a forest within Cocoa Research Institute of Nigeria, Oyo State, South-West, Nigeria. The Institute is located within latitude 07°25ˡN and longitude 3°53ˡE between River Ona in the West and the main motor road from Ibadan to Ijebu-Ode on the East.

Sample Collection

The trees were selected based on absence of reaction tendencies i.e with clear and straight bole and absence of dead knots. They were felled with power saw and samples were collected at the base, middle and top of the merchantable height (Table 1). At each sampling height, bolts of 50cm long were obtained and partitioned radially into 3 positions viz: innerwood, middlewood and outerwood on the basis of position from the pith.

Preparation of Heartwood Extract

N-hexane heartwood extract of *Gliricidia sepium* (GHE) was obtained in accordance with T2 0403-76 standard (Kazemi et al., 2006) using soxhlet apparatus. Fungicidal formulation used was volume method after Adetogun (1990) where 1ml of heartwood extract in 99ml of solvent (kerosene) is equivalent to 1% dilution. Five concentration levels were used viz: 0% (kerosene alone), 25%, 50%, 75% and 100%. Dipping impregnation method (FAO, 1986; Adetogun, 1998) was adopted. Two sets of *A. robusta* test blocks were used; a set was not exposed to fungi at all while another was conditioned and completely immersed in cold bath of fungicides' (heartwood extract) various concentrations for 48hours in accordance with (BCMAFF, 1993) so as to obtain maximum absorption before exposure to fungi.

Table 1: External Characteristics of the Sampled Trees of *A. robusta.*

Characteristics	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Mean
Age (Years)	25	28	32	30	29	28.8
Total Height (m)	30.49	33.53	36.60	35.96	34.14	34.14
Merchantable Height (m)	23.60	26.40	28.20	27.30	26.70	26.44
Base (cm)	50.00	50.00	50.00	50.00	50.00	50.00
Middle (m)	11.80	13,20	14.10	13.65	`3.35	13.22
Top (m)	23.00	25.50	27.50	26.50	26.00	25.70

NB: Sampling heights are percentages of merchantable height.

After treatment the blocks were drained and reweighed to determine absorption level using the British Standard Institute (BSI) 1961) formula:

$$Absorption = \left(\frac{TA \times C \times 10}{VW \times NS}\right) Kg/m^3$$

Where;

TA = Total absorption per test block

C = Concentration
VW = Volume of the wood
NS = Number of sample

Fungi Preparation and Test Block Inoculation

Fungi species *Lentinus sajor-caju* (white rot) and *Trichoderma viride* (brown rot) used for the study were obtained and cultured on potato dextrose agar at the pathology section of the Forestry Research Institute of Nigeria, Ibadan after which they were introduced to the test blocks of *Aningeria robusta* that were treated with the heartwood extract in petri dishes for sixteen weeks (AWPA, 1997). After sixteen weeks the mycelia growths on the surfaces of the blocks were cleaned with dry cotton wool and the anatomical properties of the two sets of test blocks were determined by boiling them in water for 48 hoursafter which sections were cut with a sledge microtome. The slides were observed under a microscope for quantitative characterization. This was done by placing 2.5mmx2.5mm grid squares over a visopan microscope such that it cut across the growth rings. The principles of stereological counting described by Ifiju (1983); Ogunsanwo (2000) was adopted using the point count procedure, that is structural element falling on each grid point was recorded and estimated. Test blocks treated and exposed to fungi was a factorial design while those not exposed was a split-plot because the treatments consists of all possible combinations of the levels of the factors considered. Data were analyzed using ANOVA and descriptive statistics in both cases. The wood anatomical terms used are in accordance with the IAWA Committee (1989).

RESULTS AND DISCUSSION

Vessel Proportion

The mean vessel proportion before inoculation with fungi strains was 16.89%; it ranged from 16.05% to 18.47% along the radial axis and from 15.99% to 17.47% along the axial plane while an inconsistent pattern of variation was recorded along the axial plane as shown in Table 1. The trend in axial plane is at variance with the findings of Leitch (2001) who reported an increase in vessel frequency along the length of *Eucalyptus globulus* stem. The inconsistent pattern observed in axial plane is in consonant with the type (b) variation pattern of vessel proportion reported by Panshin et al., (1980); Akachuku (1980); Ogunsanwo (2000). In radial axis, vessel proportion was constant initially but latter increased from the middlewood to the outerwood as shown (Table. 2). Earlier studies by Stokke and Manwiller (1994) reported a vessel mean of 10.5% in *Quercus laurifolia*, 26.6% in *Q. macrocarpa and* 13.5% in *Quercus velutina* while Lei et al.,(1996) reported 12% and 27% in a juvenile (less than 10 years) and mature (greater than 30 years) woods of *Q. garryana* respectively. Ogunsanwo (2000) in a similar study on *Triplochiton scleroxylon* reported a vessel proportion of 15.40% while Bhat and Priya (2004) reported 9% in a 21year old but 11.9%-14.9% in a 65 year old provenance of teak respectively. In the work of Uetimane et al., (2009) on *Sterculia appendiculata* mean vessel volume of 6% was reported. In a similar study on lesser-used species from northern Nigeria, Ogunwusi (2012) reported vessel volumes of 11.3%, 7.83%, 10.01%, 4.60% and 14.8% for *Butyrospermum paradoxum, Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka* respectively. Variations observed could have been attributed to species involved, sampling technique, age of species and geographical location among others. Ogunwusi (2012) opined that wood species with high volume of vessels will result in mechanical weakness during load application while in service. Huda et al., *(*2012) noted that mechanical weakness caused by such wood species with high vessel proportion and high lumen area might be mitigated by high fibre proportions and cell wall fractions. Number of trees, sampling heights and radial position had significant effect on vessel proportion at 5% probability level (Table 3). Follow-up test revealed the sampling heights to be different from one another while the innerwood is not different from the middlewood but different from outerwood (Table 4). Before inoculation with the fungi strains the anatomical features of the wood of *A. robusta* showed that the vessel is solitary and multipores with paratracheal parenchyma (Plate 1).Before inoculation with the fungi strains the anatomical features of the wood of *A. robusta* showed that the ray is multiserated, the fibres are thin walled, the vessel is solitary and multipores with paratracheal parenchyma (Plate 1).

Table2: Mean vessel proportion of *Aningeria robusta* wood along and across the bole before inoculation with fungi.

Parameter	WT/SH	Base (%)	Middle (%)	Top %)	Mean (%)
Vessel	Inner wood	16.00	14.40	17.75	**16.05±1.68**
	Middle wood	16.92	16.67	14.82	**16.14±1.14**
	Outer wood	19.48	16.89	19.04	**18.47±1.38**
	Mean	**17.47±1.80**	**15.99±1.38**	**17.20±2.16**	**16.89±0.39**

Table 3: Analysis of variance for the vessel of *Aningeria robusta* before inoculation.

Sources of variation	df	Sum of Square	Mean Square	F-cal	F-tab
Tree (Blocks)	4	77.79	19.45	14.96*	2.8
SH	2	38.45	19.22	14.78*	3.4
Major Plot Error	8	91.8	11.48		
RP	2	44.1	22.05	16.96*	3.4
Interaction (SH*RP)	4	12.64	3.16	2.43*	2.8
Sub-Plot Error	24	31.27	1.3		
Total	**44**	**296.05**			

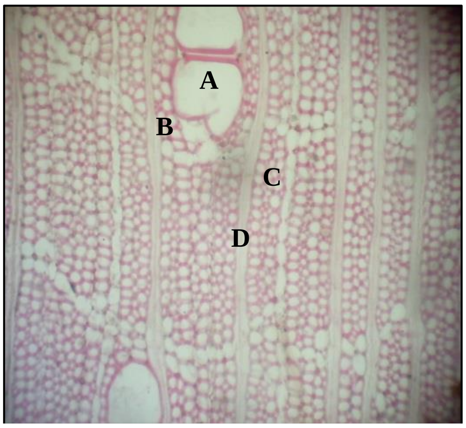
*Legend: * Significant at α = 0.05. ns: Not Significant; SH =Sampling Height, RP= Radial Position*

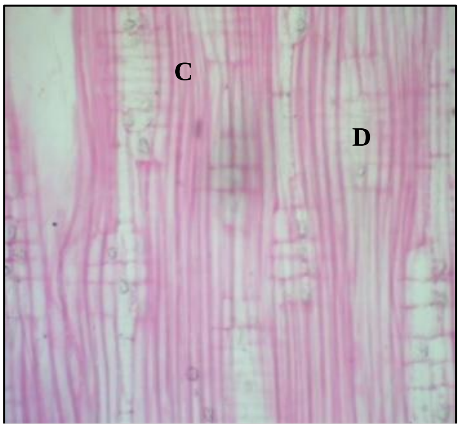
Table 4: Follow-up Test on vessel proportion of *A. robusta* before inoculation.

Tree number	Sampling Height	Radial Position
2 - 15.03a	M - 15.99a	I - 16.05a
4 - 15.63	B - 17.46b	M - 17.15ab
5 - 17.52	T - 18.21c	O - 18.47b
3 - 8.04		
1 - 18.87		

Means with the same letter are not significantly different
Legend: B=Base, M=Middle, T= Top, I= Innerwood, M- Middlewood, O= Outerwood

I **II**





Legend: A- Vessel, B- Parenchyma, C- Fibre, D- Ray.

Plate 1: Anatomical features at Transverse (I) and Radial Longitudinal ; (II) Sections respectively before inoculation of untreated samples of *A. robusta.*

After inoculation there was a slight reduction in the proportion of vessels in both species of fungi used at all concentration levels except 50% as shown in Table 5. Preservative concentration levels and sampling heights had significant effect on the vessel proportion after inoculation (Table 6). Further test by Duncan Multiple Range Test revealed that all the sampling heights are different just as concentration levels are different from one another (Table 7).

At 25% HEG, the vessels are partly blocked by *T. viride* hyphae (Plate 2) whereas the blockage is more pronounced at 50% HEG (Plate 3). At 75% HEG, the entire vessels were blocked (Plate 4). It can be deduced from these that the fungi hyphae were able to penetrate and block some vessels, which means that the preservative could not prevent the growth of the fungi absolutely. The untreated wood samples were badly infested by the two fungi strains.

Fibre Proportion

The mean fibre proportion before inoculation was 59.08%. It ranged from 58.30% to 59.72% radially and 58.13% to 60.40% along the vertical axis (Table 8). Stokke and Manwiller (1994) reported a mean of 40.8% *in Quercus velutina.* Lei *et al.*, (1996) also reported a range of 59% to 61% in *Quercus garryana.* Bhat and Priya (2004) reported a range of 59.7% to 66.7% and 58.6% to 60.2% in a 21year and 65 year old teak respectively. In the work of Uetimane et al., (2009) on *Sterculia appendiculata* mean fibre volume of 22% was reported. Ogunwusi (2012) also reported fibre volume of 54%, 36.1%, 29.3%, 39.1% and 26.6% for *Butyrospermum paradoxum*, *Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka* respectively which are also lesser-used species. Along the radial plane, fibre decreased from innerwood to outer wood while it increased gently from the base to the middle and then decreased gently to the top. Akachuku (1980) and Onilude and Ifju (1992) observed the same trend in their works on *Gmelina arborea* and *Populus deitodes* respectively although, that of Akachuku (1980) was very similar to this study in that it was not significant (Table 9). Ogunwusi (2012) observed that relatively high fibre volume is an indication that such species is good for structural application; that is the higher the fibre volume, the better the species for structural purposes.

Table 5: Mean Values of vessels proportion per concentration level after inoculation.

CL/FT (%)	***Lentinus sajor-caju* (White) V (%)**	***Trichoderma viride* (Brown) V (%)**
0	13.21	17.75
25	14.59	15.43
50	21.9	14.44
75	16.52	15.98
100	16.7	17.21
Control	17.3	20.00
Mean	16.7	16.8

Legend: CL=Concentration level, FT=Fungi Type

Table 6: Analysis of variance for vessels of *Aningeria robusta* after inoculation.

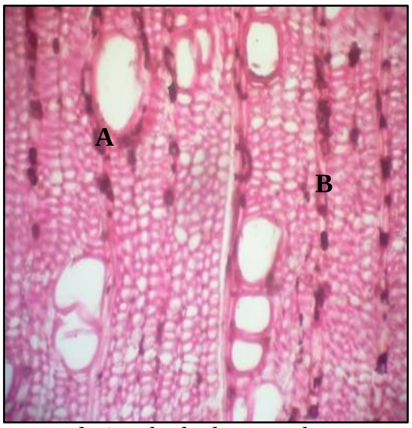
Sources of variation	**df**	**Sum of Square**	**Mean Square**	**F-cal**	**F-tab**
Fungi	1	0.42	0.42	0.29ns	3.86
Concentration Level	5	991.16	198.23	141.55*	2.23
Sampling Height (SH)	2	37.76	18.88	13.48*	3.02
Radial Position (RP)	2	4.37	2.18	1.56ns	3.02
Fungi * Conc. Level	5	1884.68	376.94	269.16*	2.23
Fungi * SH	2	2.16	1.08	0.77	3.02
Conc * SH	10	64.42	6.44	4.60	1.85
Fungi * Conc. SH	10	73.67	7.37	5.26	1.85
Fungi * RP	2	7.35	3.67	2.62	3.02
Conc * RP	10	10.96	1.10	0.78	1.85
Fungi * Conc * RP	10	14.96	1.50	1.07	1.85
SH * RP	4	3.32	0.83	0.59	2.39
Fungi * SH * RP	4	4.88	1.22	0.87	2.39
Conc* SH* RP	20	64.46	3.22	2.30	1.6
Fungi*Conc* SH* RP	20	66.82	3.34	2.39	1.6
Error	432	604.99	1.40		
Total	**539**	**3836.36**			

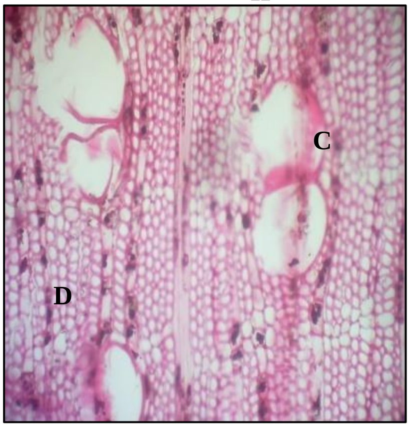
*Legend: * Significant at α = 0.05. ns= Not Significant, SH=Sampling Height; RP=Radial Position*

Table 7: Follow-up Test on vessel proportion of *A. robusta* after inoculation.

Concentration Level (%)	**Mean**	**Sampling Height**	**Mean**
0	15.49b	Base	16.45a
25	15.00a	Middle	16.75b
50	18.17e	Top	17.10c
100	16.94d		
75	16.28c		
Control	18.77f		

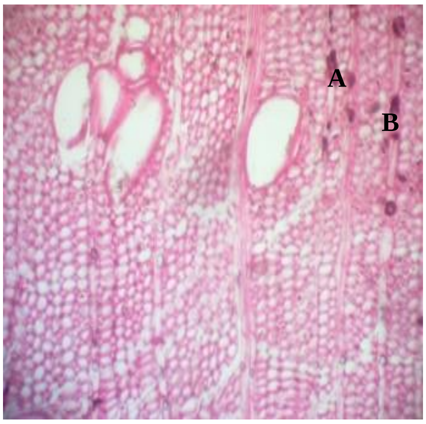
Means with the same letter are not significantly different

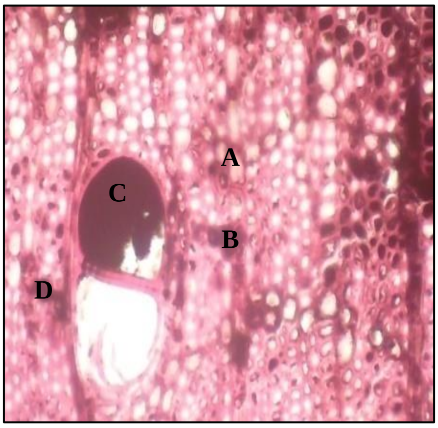




Legend: A- Blocked Parenchyma, B-Blocked Ray, C- Blocked Vessel,D-Blocked Fibre

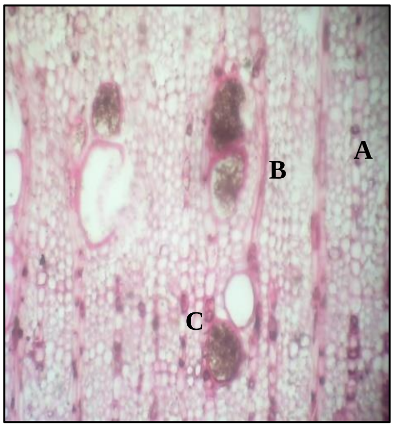
Plate 2: Extent of fungal infestation of *Lentinussajor-caju* (I) and *Trichodermaviride* (II) inoculated wood of *A. robusta* at 25% concentration level.





Legend: A- Blocked Fibre, B- Blocked Ray, C- Blocked Vessel, D- Blocked Parenchyma.

Plate 3: Extent of fungal infestation of *Lentinus sajor-caju* (I) and *Trichoderma viride* (II) inoculated wood of *A. robusta* at 50% concentration level.



Legend: A- Blocked Ray, B- Blocked Vessel, C- Blocked Fibre

Plate 4: Extent of fungal infestation of *Trichoderma viride* inoculated wood of *A. robusta* at 75% concentration level.

Table 8: Mean fibre proportion of *Aningeria robusta* wood along and across the bole before inoculation with fungi.

Parameter	WT/SH	Base (%)	Middle (%)	Top %)	Mean (%)
Fibre	Innerwood	61.56	60.60	56.90	**59.72±2.48**
	Middlewood	58.15	60.50	59.00	**59.22±1.19**
	Outerwood	56.42	60.01	58.49	**59.30±1.81**
	Mean	**58.71±2.62**	**60.40±0.35**	**58.13±1.09**	**59.08±11.16**

Table 9: Analysis of variance for the fibre of *Aningeria robusta* before inoculation.

Sources of variation	df	Sum of Square	Mean Square	F-cal	F-tab
Tree (Blocks)	4	97.35	24.34	9.51*	2.8
SH	2	43.88	21.94	8.57*	3.4
Major Plot Error	8	140.69	17.59		
RP	2	16.71	8.36	3.27ns	3.4
Interaction(SH*RP)	4	66.22	16.55	6.46*	2.8
Sub-Plot Error	24	61.49	2.56		
Total	**44**				

*Legend: * Significant at α = 0.05. ns= Not Significant, SH= Sampling Height, RP= Radial Position*

Awoyemi (1984) observed a significant effect of sampling height on the proportion of fibre in *Triplochiton scleroxylon* whereas in this study replicate effect (tree number) and sampling heights were significant at 5% probability level. Further test by DMRT revealed that both top and base are different from the middle while tree number 3 and 4 are not different from one another but certainly different from 1 and 2 (Table 10). Before inoculation with the fungi strains, the anatomical features of the wood of *A. robusta* showed that the fibres are thin walled (Plate 1).

After inoculation, there was a slight reduction in fibre proportion in the two fungi species at some concentration levels (Table 11). The fibres were infiltrated by hyphae of both fungi at 25%, 50% and 75% concentration levels (Plates 2, 3, and 4) though more blockage were noticed in the wood blocks exposed to the brown rot fungi (*Trichoderma viride)* just as other anatomical features were affected. Fungi type, concentration levels, sampling heights and radial position had significant effect on the fibre proportion at 5% probability level (Table 12). Post mortem analysis by DMRT revealed that 100% and 50% concentration levels are not different from one another while 0% and 75% are not different from one another while the control is quite different from the 25%. Axially, the middle and top are not different, but, different from the base. Across the bole, the innerwood and outerwood are not different but different from the middlewood (Table 13).

Ray Proportion

The mean ray proportion before inoculation was 23.74% (Table 14). It ranged from 23.23% to 24.35%. It decreased gently from the innerwood outwardly while little or no variation was observed axially. Rahaman et al., (2005) reported that ray proportion remained more or less constant from pith to bark of teak from Bangladesh.

Table 10: Follow-up Test on fibre proportion of *A. robusta* before inoculation.

Tree Number	Sampling Height
1 - 56.98a	Top - 58.07a
5 - 57.80ab	Base - 58.65a
4 - 59.59bc	Middle - 60.40b
3 - 59.74bc	
2 - 61.10c	

Means with the same letter are not significantly different

Table 11: Mean values of fibre Proportion per concentration level after inoculation.

CLFT (%)	*Lentinus sajor-caju* (White) F (%)	*Trichoderma viride* (Brown) F (%)
0	61.22	59.63
25	59.83	58.73
50	54.13	59.47
75	61.38	59.98
100	56.74	56.45
Control	60.60	54.59

Legend: CL=Concentration level, FT=Fungi Type

Table 12: Analysis of variance for wood fibre of *Aningeria robusta* after inoculation.

Sources of variation	df	Sum of Square	Mean Square	F-cal	F-tab
Fungi	1	116.28	116.28	21.09*	3.86
Conc. Level	5	1593.70	318.74	57.82*	2.23
SH	2	151.08	75.54	13.70*	3.02
RP	2	99.68	49.84	9.04*	3.02
Fungi * Conc.	5	1476.89	295.38	53.58*	2.23
Fungi * SH	2	7.80	3.90	0.71	3.02
Conc * SH	10	372.31	37.23	6.75*	1.85
Fungi * Conc * SH	10	206.22	20.62	3.74*	1.85
Fungi * RP	2	7.42	3.71	0.67	3.02
Conc * RP	10	222.46	22.25	4.04*	1.85
Fungi * Conc * RP	10	220.35	22.04	3.99*	1.85
SH * RP	4	21.22	5.31	0.96	2.39
Fungi * SH * RP	4	15.06	3.77	0.68	2.39
Conc * SH * RP	20	99.51	4.98	0.9	1.60
Fungi * Conc * SH * RP	20	107.24	5.36	0.97	1.60
Error	432	2381.55	5.51		
Total	**539**	**7098.76**			

Legend: Significant at α = 0.05. ns= Not Significant, SH= Sampling Height, RP= Radial Position*

Table 13: Follow-up test on fibre proportion of *A. robusta* after inoculation.

Concentration Level (%)	Mean	Sampling Height	Mean
100	56.26a	Base	57.80a
50	56.79a	Middle	58.63b
Control	57.61b	Top	59.09
25	59.30c		
0	60.42d		
75	60.65d		

Means with the same letter are not significantly different

Table 14: Mean ray values of *Aningeri arobusta* wood along and across the bole before inoculation with fungi.

Parameter	WT/SH	Base (%)	Middle (%)	Top %)	Mean (%)
Ray	Innerwood	22.86	25.00	25.20	**24.351,29**
	Middlewood	24.89	22.84	23.17	**23.631.10**
	Outerwood	24.24	23.02	22.54	**23.230.82**
	Mean	**23.961.03**	**23.621.19**	**23.641.39**	**23.740.18**

Legend: SH=Sampling Height, WT= Wood Type

Table 15: Analysis of variance for the wood ray of *Aningeria robusta* before inoculation.

Sources of variation	df	Sum of Square	Mean Square	F-cal	F-tab
Tree (Blocks)	4	25.44	6.36	2.9	2.8
SH	2	1.77	0.88	0.40ns	3.4
Major Plot Error	8	58.2	7.12		
RP	2	7.1	3.55	1.62ns	3.4
Interaction (SH*RP)	4	30.75	7.69	3.51*	2.8
Sub-Plot Error	24	52.59	2.19		
Total	**44**	**174.57**			

Legend: Significant at α = 0.05. ns: Not Significant, SH=Sampling Height, WT=Wood Type*

Table 16: Follow-up test on ray proportion of *A. robusta* before inoculation.

Tree Number	Menas
3	22.35a
4	23.66ab
2	23.78ab
1	23.99
5	24.66b

Means with the same letter are not significantly different

. Several authors have recorded the ray volume of hardwoods. For instance, Stokke and Manwiller (1994) reported a mean of 17.5% *in Quercus velutina*, Lei *et al.* (1996) reported an average of 14% and

13% at the diameter at breast height (DBH) and higher height respectively in *Quercus garryana.* In the work of Uetimane et al., (2009) on *Sterculia appendiculata* mean ray volume of 19% was reported. Adewusi (2012) in his work on some lesser-used hardwood species in the northern part of Nigeria reported a ray volume of 22.27%, 32.87%, 67%, 24% and 36% for *Butyrospermum paradoxum, Albizia zygia, Lanea acida, Parkia felicoida* and *Isoberlina doka* respectively. These values are in agreement with values obtained in this research. The high proportion of ray parenchyma cells that areresponsible for food storage in the plant may have some influence on the utilization potentials of the wood species. Moreover, the reservoir could result in weakness of the concerned areas within the tree and if such areas eventually become large, it could lead to susceptibility of wood in service to biodegradation opined Onilude and Audu (2002).

Number of trees used for the study and interaction between sampling heights and radial position had significant effect on wood ray before inoculation (Table 15). Post mortem analysis by DMRT showed that tree number 1, 2 and 4 are not different from one another whereas number 3 and 5 are quite different (Table 16). Plate 1 shows the multiserated ray of *A. robusta* before inoculation.

Mean ray percentage proportion after inoculation with both fungi strains ranged from 21.42% to 25.86% for woodblocks exposed *to L. sajor-caju* and from 20.01% to 23.57%for those exposed *to T. viride* (Table 17). The relatively high ray volume shows that the species is susceptible to biodegradation but the effect can be mitigated by high volume of fibre and adequate preservative treatment. Preservative effect seemed not significant on *Lentinus sajor-caju* while little significant was observed on 0% (kerosene) and 75% concentration levels of species treated with *Trichoderma viride.* Plates 2 to 4 show the multiserated ray being occupied by fungi hyphae at 25%, 50% and 75% HEG though much prevalent in the wood samples inoculated with *T. viride*.

Table 18 revealed that fungi used, concentration level, sampling height and radial position had significant effect on ray proportion after inoculation at 5% probability level. Post mortem analysis on concentration level showed that 75%, 100%, 25% and 0% are different from one another while 50% differ from the control (Table 19).

Sampling heights' post hoc analysis revealed that the wood obtained at the base is not different from the one obtained from the middle but different from the one from the top. Along the radial axis, the innerwood is not significantly different from the middlewood but differ from the outerwood while the outerwood is not significantly different from the middlewood.

Table 17: Mean Values of ray Proportion per Concentration level after Inoculation.

CLFT (%)	*Lentinus sajor-caju* (White) R (%)	*Trichoderma viride* (Brown) R (%)
0	23.31	22.92
25	23.41	23.50
50	23.00	23.41
75	21.42	20.01
100	25.86	23.57
Control	23.57	23.45

Legend: R (%) = Percentage Ray, CL=Concentration level, FT=Fungi Type

Table 18: Analysis of variance for wood ray of *Aningeria robusta* after inoculation.

Sources of variation	df	Sum of Square	Mean Square	F-cal	F-tab
Fungi	1	62.91	62.91	53.96*	3.86
Conc. Level	5	778.07	155.61	133.49*	2.23
Sampling Height (SH)	2	16.11	8.06	6.91*	3.02
Radial Position (RP)	2	7.24	3.62	3.11*	3.02
Fungi * Conc.	5	109.40	21.88	18.77*	2.23
Fungi * SH	2	5.67	2.83	2.43ns	3.02
Conc * SH	10	12.73	1.27	1.09ns	1.85
Fungi * Conc * SH	10	12.17	1.22	1.04	1.85
Fungi * RP	2	4.45	2.23	1.91	3.02
Conc * RP	10	21.00	2.10	1.8	1.85
Fungi * Conc * RP	10	14.96	1.50	1.28	1.85
SH * RP	4	14.09	3.52	3.02*	2.39
Fungi * SH * RP	4	5.07	1.27	1.09	2.39
Conc * SH * RP	20	23.98	1.20	1.03	1.6
Fungi * Conc * SH * RP	20	31.57	1.58	1.35	1.6
Error	432	503.61	1.17		
Total	**539**	**1623.02**			

*Legend:*Significant at α = 0.05. ns=Not Significant*

Table 19: Follow-up test on ray proportion of *A. robusta* after inoculation.

Concentration Level (%)	Mean	Sampling Height	Mean	Radial Position	Mean
75	20.72a	Top	20.39a	Innerwood	20.44a
0	23.15b	Middle	20.59ab	Middlewood	20.49a
50	23.26bc	Base	20,74b	Outerwood	20.79b
Control	23.50cd				
25	23.68d				
100	24.67e				

Means with the same letter are not significantly different.

CONCLUSION

Originally, the anatomical features of the wood of *A. robusta* showed the vessel to be solitary and multipores with paratracheal parenchyma, fibres thin-walled and rays multiserated in good proportion for a typical hardwood species. Exposure of the wood to fungi species resulted in hyphae infiltration into all theanatomical features. Significantly, the bio-preservative could not prevent the growth of the fungi species; it could only reduce the spread. Moreover, the type of fungi used, concentration levels adopted, sampling heights involved and radial position had significant effect on the anatomical features. It is recommended that further studies be carried out using other plant species as bio-preservative.

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