



RELATIONSHIP BETWEEN ANATOMICAL PROPERTIES AND TREATABILITY OF 21-YEAR-OLD *POLYALTHIA LONGIFOLIA* (SONN) IN IBADAN, NIGERIA

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ABSTRACT: This study assessed the relationship between anatomical properties and treatability of *Polyalthia longifolia* in Ibadan, Oyo state. Samples were collected from five trees obtained from Akobo, a residential area in Ibadan Oyo state, Nigeria. Bolts of 60cm were obtained at breast height of each tree and were later converted and partitioned into inner, middle and outer wood across the radial position. Fibre characteristics investigated are fibre length, fibre diameter, lumen width and wall thickness. The mean fibre length of *Polyalthia longifolia* along the radial position is 1.18mm, fibre diameter is 9.38 μ m, lumen width is 5.92 μ m and wall thickness is 1.88 μ m. The treatability was determined using leaf extract of *Hyptis suaveolens* and used engine oil as water and oil base preservative respectively. The wood samples were treated using steeping method at: 0.05%, 0.1% and oil concentration levels for 48 hours, absorption and retention were determined. The highest percentage absorption was observed in the outer wood (67.20%) and at 0.1% concentration level. Similarly, the highest retention was observed in outer wood (1.64Kg/m³) also at higher concentration level. Analysis of variance showed a significant difference in percentage absorption among the wood zones and at different concentration level, while retention vary significantly only in the concentration levels at ($P < 0.05$) probability level. A strong positive correlation exists between fibre length, lumen width with the preservative absorption and retention whereas wall thickness correlates negatively with both absorption and retention. However, no significant correlation exists between the fibre characteristics and absorption and retention at ($P < 0.05$) probability level. The wood is also permeable given the high absorption and retention rate; this makes it amenable to treatment with water and oil base preservatives.

Key word: wood anatomy, absorption, retention, water borne preservative, oil borne preservative

1. INTRODUCTION

Wood has been described as one of the most attractive materials due its complex structure and wide range of application in the world. However, its hygroscopic nature causes it to absorb and loss moisture under different weather condition thus, putting it to disadvantage by exposing it to rapid deterioration (Devi *et al.* 2003). This effect is more significant in the tropical regions of the world where wood is exposed to adequate sun light and high humidity which support the growth and development of many agent of biodegradation. Some wood species are naturally more durable and are mostly preferred due to their physical, mechanical and aesthetically pleasing performance. As

a result of rapid increase in population, wood production and quality forest product are drastically reducing, creating an imbalance between demand and supply of forest product. The prevalence of this situation has motivated different researches into alternative lesser used species for value-added applications. One way to achieve this is to apply suitable wood preservatives needed to improve the resources in order to meet end-use requirements (Wang *et al.* 2007). However, the suitability of any chemical preservative depends on the amenability of wood to treatment with such chemical preservative. According to Lebow *et al.* (2005) the utilisation potentials of many lesser used tropical hardwood species is largely dependent on other variables such as their treatability.

Increasing the value of such underutilised species will expose forest managers to more flexible forest management and conservation.

Wood treatability simply means the response of wood to treatment with preservatives needed to increase its durability in service. Treatability can be explained further as a measure of amenability of a wood species to preservative treatment. Wood needs protection from various wood degradation agents in order to extend its life in service, particularly when it is used in exterior or semi exterior condition. Wood treatability depends on the porosity of wood which is also the function of void volume controlled by the size, arrangement and distribution of the wood structures (Schultz *et al.* 2005; Larnøy *et al.* 2008). Liquid moves in the wood by either diffusion through the walls or flowing in the cell lumen. The latter is more common during wood preservation. Preservative movement in wood samples mainly takes place through the same path way as in the living tree with the fibres and vessels responsible for longitudinal movement while rays and pits responsible for lateral movement. According to Wang and DeGroot (1996) and Antwi-Boasiako and Barnett (2009), increasing fibre lumen diameter and pore sizes creates more void spaces in the wood to accommodate air and moisture. This means the larger the pore size and the wider the lumen width the more the volume of void space which in turn creates more room for the absorption and retention of wood treatment agent.

Polyalthia longifolia is a tropical tree native to India and Sri Lanka with a moderate range of consumers' products and services. The tree has assumed a continually increasing role in landscaping system across the world. It is successfully grown in Nigeria where it is mainly used for its aesthetic value as ornamental tree. Knowledge about the tree parts medicinal values have been widely explored (Jothy *et al.* 2013; Ogunbosoye *et al.* 2015), however, its wood have never been the subject of extensive research. The wood has been reported to be tough, flexible and moderately hard but not very durable. In South India the wood is used for making drums. In China, it is used for making matches (Pande 2012). The wood of *Polyalthia longifolia* has a higher chance of being used for pole production and development of other wood products in the next few years. This is probably due to its fast growth, straight bole formation, suitable root system, and resistance to wind thrown.

Anatomical characteristics and preservative diffusion are closely linked to better treatability and longer serviceability of wood. As the wood is not very durable (Pande 2012), this study therefore evaluated the relationship between anatomical properties and the

treatability of the wood using leaf extract of *Hyptis suaveolens* and used engine oil.

2. MATERIALS AND METHOD

2.1 Study Area

Sample trees were obtained from Akobo, a residential area in Ibadan, Oyo state Nigeria. It is geographically located between latitude 7° 23'47" and 7.3°N and longitude 3° 55' 0" and 3.7°E. The city ranges in elevation from 150 m in the valley area, to 275m above sea level on the major north-south ridge which crosses the central part of the city. The city's total area is 3,080 km². Ibadan has a tropical wet and dry climate, with a lengthy wet season and relatively constant temperatures throughout the course of the year. The mean total rainfall for Ibadan is 1420.06 mm², falling in approximately 109 days and peaks in June and September. The mean maximum temperature is 26.46 °C, minimum 21.42 °C and the relative humidity is 74.55% (Wikipedia 2015).

2.2 Method of Data Collection and Preparation

2.2.1 Sample selection and preparation

Five (5) trees were selected and a bolt of 60 cm was cut at breast height with the aid of chain saw. The bolts were then transported to University of Ibadan Teaching and Researches Sawmill for further cross cutting. Selection of representative samples for the test was carried out from central planks of 6 x 60 cm obtained from the 5 bolts. Wood samples for the test were collected from the inner wood section (near the pith) and outer wood section (close to the bark) while the middle wood section was collected from midpoint between the inner and the outer wood sections of the trees.

2.2.2 Determination of fibre characteristics

Fibre maceration was done using Franklin (1945), method which involves removing a thin sliced wood (sliver) across the growth ring and placing the slivers in a beaker containing equal volume of 10% acetic acid and 30% hydrogen peroxide in a ratio of 1:1(v/v) mixture and boiling the slivers for 2 hours at 100 °C. The solution was decanted and the remaining fibrous materials were washed with water after which they were shaken vigorously to disintegrate the fibres. The fibres in suspension were mounted on a glass slide and an average 20 fibres were measured per slide using Rheichert visopan microscope for fibre length, diameter, lumen, width and cell wall thickness.

2.2.3 Determination of treatability

The test samples were cut into sizes of 20 x 20 x 60mm along the grain for treatability determination (BSI 1961). The wood blocks were conditioned and oven dried to constant weight for 18 hours at 103±2° and the weight is taken as the initial weight (W_o). The treatability of the wood was determined based on the absorption and retention of the preservatives.

2.2.4 Preparation of preservative

The wood preservative used for the treatment of the samples are extract from dried leaf of *Hyptis suaveolens* and used engine oil. The leaves were obtained from freshly harvested *H. suaveolens* plant grown within the campus of University of Ibadan. Cold extraction method was used to get the leaves extract. The fresh leaves were oven dried and ground into fine textured powder. In preparing the preservative concentration, 50 grams of the grinded leaves were dissolved in 1 litre of water to form 0.05% concentration. Similarly, 100 grams of the dried leaves was dissolved in 1 litre of water to form 0.1% concentration.

2.2.5 Treatment method

Steeping method according to FAO (1986) was used for treatment of the wood test blocks. The blocks were completely soaked in the preservatives for 48 hours. A total number of 180 wood samples (test blocks) of dimension 20 × 20 × 60 mm comprising of 12 replicates were treated at each concentration levels of 0.05%, 0.1% and oil. The percentage absorption of the preservatives was estimated as the ratio of the difference in the weight of wood samples before treatment (W_o) and after treatment (W_1) to the weight before treatment (W_o) using the following formula;

$$\text{Absorption (\%)} = \frac{W_1 - W_o}{W_o} \times 100 \dots\dots\dots (1)$$

Where;

W_o = weight before treatment

W_1 = weight after treatment

The preservative retentions were calculated by the formula below according to AWPA (1991) standard:

$$R = \frac{GC}{V} \times 10 \dots\dots\dots (2)$$

Where:

R = Retention (Kg/m^3)

G = net weight gain after treatment

C = concentration of treating solution (%)

V = volume of the wood sample (m^3)

2.3 Data Analysis

Data from the experiment were subjected to 3x4 factorial experiments in completely randomise design, the model for the design is given below:

$$Y_{ijk} = \mu + T_i + S_j + TS_{ij} + E_{ijk} \dots\dots\dots (3)$$

Where:

Y_{ijk} = Individual observation

μ = General mean

T_i = Effect of treatment (concentration)

S_j = Effect of sample position (wood zone)

TS_{ij} = Interaction between treatment and sample position

E_{ijk} = Experimental Error

3. RESULT AND DISCUSSION

3.1 Fibre Characteristics

In Table 1, Fibre length of *Polyalthia longifolia* studied increased consistently from inner to outer wood. The longest fibres measuring about 1.30 mm were found in the outer wood zones closer to the bark while the shortest fibres (1.07 mm) were found in the inner wood zones closer to the pith. This trend according to the authors is due to increase in length of cambial initials with diameter growth in the stem of the tree which is also in line with an early study by Zobel and Sprague (1998) who stated that there is an inherent increasing trend in latewood proportion with cambial age as related to the changing development and structure of the crown. This is because the inner wood zones are composed of earlywood cells which are principally made up of developing cells, the length increases as one moves closer to the bark where the cells in that zone are mostly matured and fully developed. Unlike fibre length, the fibre diameter showed an inconsistent increase with the increase in distance toward the bark. The average fibre diameter was high in the inner wood zones close to pith (9.64 μm), the diameter decreased in the middle wood zone (9.06 μm) and then increased in the outer wood close to the bark (9.41 μm). Radial increase in fibre diameter is a trend common to most hardwood species and can be attributed to many molecular and physiological changes that occur in the vascular cambium as well as the variation in the wood cell wall thickness during the tree ageing process (Plomion *et al.* 2001; Roger *et al.* 2007). Lumen width also increased inconsistently from the pith to bark (Table 1). The mean fibre lumen width in wood zones close to the pith is 5.52 μm , the average width of wood in the middle wood is 5.40 μm and for the for fibres found in the outer zone closer to bark the lumen width increased to 5.92 μm . Although the lumen diameter increased from pith to

bark and this increase contradicts findings from studies (such as Saravanan *et al.* 2013; Anoop *et al.* 2014), it has a direct relationship with fibre diameter. This means increase in fibre diameter is accompanied with an increase in lumen diameter across the bole (Hamid *et al.* 2011). Cell wall thickness decreased with the distance from pith to bark. The mean wall thickness ranged from 2.06 μm to 1.74 μm from the inner to outer wood zones respectively (Table 1). This however is in disagreement

with other findings such as Izekor and Fuwupe (2011), who reported a radial increase in the cell wall thickness of *Tectona grandis*. This variation might have something to do with the growing habit of the specie being a fast growing one; changes in cell size that are associated with annual and periodical growth cycles. It can also be attributed to some of the silvicultural treatment the trees received.

Table 1: Radial variation in fibre characteristics

Radial position	Wood properties			
	Fibre length(μm)	Fibre diameter (μm)	Lumen width(μm)	Wall thickness(μm)
Inner wood	1.07 \pm 0.02a	9.64 \pm 0.33a	5.52 \pm 0.17a	2.06 \pm 0.20a
Middle wood	1.18 \pm 0.01b	9.06 \pm 0.37a	5.92 \pm 0.31a	1.82 \pm 0.17a
Outer wood	1.30 \pm 0.03c	9.41 \pm 0.41a	5.92 \pm 0.31a	1.74 \pm 0.14a
P-value	0.00*	0.57ns	0.48ns	0.45ns

\pm Standard deviation, means with the same alphabets are not significant at $\alpha = 0.05$

3.2 Treatability

3.2.1 Absorption

From Table 2, the preservative percentage absorption increased from the inner wood to outer wood. The highest absorption was observed in the wood samples from the outer wood with 66.25%, followed by 63.19% in the middle wood and the least was 51.11% for inner wood at 0.05% concentration level. The percentage absorption also increased inconsistently among the wood zones at 0.1% concentration level with 52.51% for inner wood, 56.53% for middle wood and 67.20% for outer wood. For oil, the percentage absorption was lower compared to the dried leaf extracts, but it also increased among the wood zones with the highest absorption (21.65%) observed in outer wood followed by 16.32% and 16.81% in the middle and outer wood respectively. These differences in the preservative absorption among the wood zones are strongly connected to the disproportion in sizes and arrangement of the cell structures. During preservative treatment, the treating fluids flow in an interconnected network of these cells. According to earlier study by Wang and DeGroot (1996), the size, distribution, and arrangement of the fibres and vessels are important factors affecting

the treatability of hardwoods. They also noted that treatability can also be affected by tyloses and various gummy, resinous, and chalky exudates often form in the vessel lumens within the heartwood and transition zone. Therefore, the low percentage absorption by the wood samples in the inner and middle wood zones could be as a result of these reasons (Table 2). The increase in percentage absorption in the outer wood could also be attributed to the variations in fibre lumen diameter and pore sizes. According to Wang and DeGroot (1996) and Antwi-Boasiako and Barnett (2009), increasing fibre lumen diameter and pore sizes creates more void spaces in the wood to accommodate air and moisture. The absorption of leaf extract of *H. suaveolens* was recorded to be the higher than the used engine oil, this could be because they were water base preservatives which is in agreement with ASTM (1987), which stated that absorption of water soluble preservatives is higher than that of oil base. This is because water does not only fill the cell cavity but it is also absorbed in the cell wall. Analysis of variance showed a significant difference in the percentage absorption among the wood zones and at different concentration level, while no significant difference observed in the interaction between the wood zones and the concentration (Table 3).

Table 2: Preservative absorption and retention among the wood zones

Concentration	Radial position	Absorption (%)	Retention (Kg/m^3)
0.05%	Inner wood	51.11 \pm 11.34	0.75 \pm 0.15
	Middle wood	63.19 \pm 20.40	0.80 \pm 0.60
	Outer wood	66.25 \pm 15.62	0.83 \pm 0.46
0.1%	Inner wood	52.51 \pm 8.33	1.54 \pm 0.22
	Middle wood	56.53 \pm 13.04	1.48 \pm 0.16
	Outer wood	67.20 \pm 13.81	1.64 \pm 0.05
Oil	Inner wood	16.81 \pm 9.74	0.08 \pm 0.63
	Middle wood	16.32 \pm 8.23	0.07 \pm 0.60
	Outer wood	21.65 \pm 9.67	0.08 \pm 0.65

\pm Standard deviation

3.2.2 Retention

It was also observed in table 1 that the preservative retention increased from the inner wood to outer wood and with the increase in the concentration level. The mean retention in the inner wood is 0.75Kg/m³, 0.80 Kg/m³ for middle and 0.83 Kg/m³ for outer wood at 0.5% concentration level. Preservative retention also increased at 1.0% concentration level where the inner wood retained 1.54 Kg/m³, middle wood has 1.48 Kg/m³ and outer wood had the highest retention of 1.64Kg/m³. The preservative retention for the used engine oil was very low compared to the leaf extracts. The mean retention recorded in this study ranged from 0.07Kg/m³ to 0.08Kg/m³ from the inner wood to outer wood respectively. The low retention level of the used engine oil could be as a result of low absorption by the wood samples possibly due its viscosity. However, this

can be improved by thermal process which involved heating the oil born preservative to reduce its viscosity and improved its absorption and retention. The variation in retention observed could be attributed to the differences in the anatomical structures along the radial position of the species. This observation was made by Schultz *et al.* (2005) and Adeduntan and Olusola (2008) who reported that wood exhibit variability in absorption and retention of chemical preservative when treated. The variations according to them affect the life span of individual wood products in service. This implies that the amount of preservative retained in the cellulose materials varied according to anatomical structures of various wood species. Analysis of variance in Table 3 showed a significant difference in retention at different concentration level while no significant difference was observed among the wood zones and the interaction between concentration and wood zone.

Table 3: Analysis of variance for absorption and retention

Factor	Source of variation	Df	SS	MS	F-crit	Sig
Absorption	Concentration	2	68093.18	34046.59	232.37	0.00*
	Wood zone	2	4065.45	2032.72	13.87	0.00*
	Wood zone x concentration	4	1198.37	299.59	2.04	0.90ns
	Error	171	25053.98	146.51		
	Total	179	98411.00			
Retention	Concentration	2	15.39	7.69	133.52	0.000*
	Wood zone	2	0.13	0.06	1.14	0.332ns
	Concentration x wood zone	4	0.15	1.03	0.68	0.60ns
	Error	171	9.85	0.05		
	Total	179	25.53			

*: significant at $p < 0.05$, ns: Not significant at $p < 0.05$ probability level

3.3 Relationship between fibre characteristics and treatability

From table 4 the Pearson correlation analysis showed absorption strongly correlates positively with fibre length (0.83) and lumen width (0.95). Similarly, the result also showed a strong positive correlation between retention with fibre length (0.86) and lumen width (0.98). However, both absorption and retention correlates negatively with cell wall thickness with -0.64 and -0.68 for absorption and retention respectively. Increase in lumen width and pore size and absence of pit aspiration and tyloses increases the void space in wood thereby increasing the porosity and fluid holding capacity of the wood. This explained the high

absorption and retention of the preservative in the outer wood zones. It was also observed that long fibres aid in achieving efficient longitudinal penetration of preservative which in turn influence the retention capacity of wood. Thus, the longer the fibres the deeper the preservative penetrates and the higher the retention level. The negative correlation between the cell wall thickness means that the thicker the cell the narrow the lumen width and more bordered pits which will affect the lateral movement of preservative. According to Lebow *et al.* (2005) and Larnoy *et al.* (2008) the effectiveness of any preservative treatment is a function of the amount of preservative retention and how deep and distributed the preservative is within the wood.

Table 4: Correlation between fibre characteristics and treatability

Variables	Fibre length	Fibre diameter	Lumen width	Wall thickness	Absorption	Retention
Fibre length	1					
Fibre diameter	-0.37	1				
Lumen width	0.75	0.33	1			
Wall thickness	-0.95	0.63	-0.52	1		
Absorption	0.83	0.18	0.95	-0.64	1	
Retention	0.86	0.19	0.98	-0.68	0.97*	1

*correlation significant at 0.05 level (2-tailed)

4. CONCLUSION

1. The high absorption and retention in the outer wood zone showed that the wood in that zone is permeable and is amenable to treatment with water and oil base preservative.
2. The study also showed that preservative concentration and radial position where the samples are obtained in the stem significantly affects the treatability of *Polyalthia longifolia*.
3. A strong positive correlation exists between the fibre characteristics such as fibre length and lumen width while a negative correlation was observed between cell wall thickness and treatability of *Polyalthia longifolia*.

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