Histology and Water Absorption Properties of Different Wood Species

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Research Article

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ABSTRACT

Increase in water or moisture content in wood causes dimensional changes resulting in cracking and checking of wood during utilization as water absorption has a negative effect on wood properties and wood quality. In view of this, the histology (anatomy) and water absorption properties of three selected species (*Terminalia catappa, Ficus exasperata*, and *Nauclea diderrichii*) were investigated. Wood samples were collected using increment borer of diameter 1.2 cm and length 28 cm to get inner and outer samples from the breast height of each wood species. Sectioning of wood samples was performed using a sliding microtome to produce sections of about 20 µm. Wood samples were soaked in water for 2 hours, 24 hours, 48 hours and 72 hours for water absorption experiment. Microscopic cells such as vessels were measured using a Ritchert light microscope. The results obtained showed that vessel diameter of wood species has significant impact on its water absorption capacity as larger vessels absorbed more water. Therefore, *Ficus exasperata* absorbed more water than either *Nauclea diderichii* or *Terminalia catappa* owing to the sizes of their vessels. Wood deposits such as gum and xyloses were also identified as the possible hindrances to water absorption in the wood species that were slow in during soaking. Care should be applied during the choice of *Ficus* species wood for outdoor end uses.

INTRODUCTION

Research on wood histology and water absorption can produce an indispensable tool for the identification of wood species and determining wood quality. Wood is a variable material and its cellular morphology experiences great variability within and between wood species in terms of strength as influenced by the anatomical structures that are also caused mainly by the environmental conditions and genetic factors.

Hence, the physical and mechanical properties of wood act as the main criteria when wood is considered for certain usage, but these are to a large extent determined by the histological (anatomical) characteristics of the wood fibrous cells and their arrangement. As regards liquid penetration, Siau observed that resin penetration was more significant in the early wood than in the latewood; this is because latewood contains smaller cells than early wood. Therefore, wood pore structure varies significantly in different parts within the same log and consequently among wood species resulting in significant differences in location and quantity of liquid penetrated. It should be noted that these attributes of wood have the tendency to influence changes in moisture content in wood, and the rate of absorption of water by wood during soaking is measurable as it affects the mechanical properties in a way that it decreases the strength of the wood and this has been subject into intensive research. Beside this, the moisture uptake by wood above the fiber saturation point is responsible for wood-decaying fungi to germinate and grow, and an increased wood's ability to absorb moisture might affect the dimensional stability of wooden materials in service. In fact, the effects of moisture content on the mechanical properties of wood have been the subject of an intense investigation worldwide, it is noteworthy that all strength properties decrease as wood absorbs moisture in the hygroscopic range. Important properties such as modulus of rupture and compressive strength parallel to grain may decrease up to 4% and 6%, respectively, for each percent increase in moisture content. The water absorption by wood frequently assumes great importance, especially in the structural uses of wood [1].

The wood species used for this study are commercial wood species in Nigeria and for various purposes. *Terminalia catappa* is a fast growing deciduous or semi-evergreen tree, usually growing to about 15 meters tall with specimens up to 40 meters. The bole can be straight or twisted; it is generally set with short woody spines, can be 100-150 cm in diameter and is often buttressed at the base with the buttresses up to 3 meters high recorded. The wood species is a multi purpose tree, providing food, medicines and a host of other commodities. The trunk is a source of gum and source for yellow and black dye. It is a good quality timber; it is used for cabinet work, furniture and for the construction of buildings, boats, bridges, floors, paneling, boxes etc [2].

Ficus exasperata (forest sandpaper fig) is a deciduous tree of the family Moraceae usually growing up to 21 meters tall and slightly crooked bole is up to 50 cm in diameter, it can be fluted or buttressed. The tree often begins life as an epiphyte, growing in the branch of another tree; as it grows older it sends down aerial roots and become much thicker and more vigorous. The tree is very widely used in traditional medicine in Africa; it is commonly harvested from the wild for local use and is sold in the local market. It is moderately challenging and is used for making canoes, furniture, stools, containers, drum and young branches are used for making pipes and the wood is used for fuel and charcoal. *Nauclea diderrichii* is commonly referred to as Opepe in Nigeria and UK. It has other common names such as Bilinga or Aloma in Germany, Badi and Kusia as it is known in other parts of Africa. The tree is of the genus *Nauclea* in the family Rubiaceae. *Nauclea* has its natural habitat as the subtropical and tropical moist lowland forests. The species is a huge very large evergreen tree with dense, broad, spherical crown usually growing 40 meters with a diameter at breast height of 1 m to 2 m. The tree is a source of durable construction material due to its hardness, density, and resistance to *deteriorating* agents with the heartwood being very resistant to decay and moderately resistant to termite attack. Nauclea diderrichii is used for high-quality goods such as furniture and cabinet making; outdoor purpose such as railway sleepers, for general construction wood used in dock and marine work, boat building, railroad crossties, flooring, and furniture. This study intended to investigate the influence of wood microstrucures on the water intake of *Terminalia catappa*, *Ficus exasperata*, and *Nauclea diderrichii* wood species by determining their moisture absorption properties [3].

MATERIALS AND METHODS

This study was carried out at the forestry research institute of Nigeria. The forestry research institute of Nigeria is located between Ibadan North-west and Ibadan South-West with latitude ranging from 7.397975N to 7.385619444N and longitude ranging from 3.863391667E to 3.855163889E. Samples were collected with an increment borer which was initially developed to collect samples for forest mensuration and dendrochronological investigations. Six samples per species were used for the study. Wood samples of about 1 cm x 1 cm x 1 cm were sectioned into 20 µm thin using a sliding microtome, stained in Safranin stain and dehydrated in different concentrations of ethanol. The clearing was done using a vegetable oil; sections were later mounted on a slide and covered with a coverslip. Maceration of slivers (1 cm x 2 mm x 2 mm) from samples was done in an equal ratio (1:1) of ethanoic acid and hydrogen peroxide following the work of Oluwadare and Ashimiyu. Macerated fibers were randomly selected and measured using a stage micrometer under a Zeiss light microscope at 80x in accordance following ASTM D 1030-95 and ASTM D 1413-61. Photographs illustrating the micrographs of sections were obtained using a digital camera on the zeiss light microscope. Nomenclature and cell sizes were determined following microscopic terminology for hardwood identification [4].

An experiment on water absorption was conducted at a specific temperature and the flasks were placed in the constant temperature water bath. After soaking for 2 hours, the samples were rapidly removed and superficially dried on a large filter paper to eliminate surface water before weighing. This process was repeated after 24 hours, 48 hours, 72 hours until the moisture content attained a range at which the previous weight was close or the same as with the initial weight. This was done for all the samples. Water absorption percentage was calculated using the following formula: $M(\%)=(m_t - m_o)/m_o \times 100$. Where m_o and m_t denote the oven dry weight and weight after time t, respectively [5].

The experimental design used for this research is full 3 x 2 factorial in RCBD.

Model for the experiment is given below:

The model for this experiment is

$Y_{(ij)}=\mu+T_i+P_j+TP_{ij}+£_{ij}$

Where; $Y_{(ij)}$=Individual observation; µ=General mean, T_i=Effect of wood species, P_i=Effect of position within the wood; TP=The interaction effect between T and P, $£_{ij}$=Experimental Error [6].

RESULTS

Anatomical

Anatomical features of the three wood species were stated in Table 1, while Figures 1-9 shows the wood micrographs of the wood species. Average vessel diameter of 217.32 µm, 189.54 µm and 168.42 µm were obtained for *F. exasperata*, *T. Catappa* and *N. diderichii* respectively. These variations were also shown in Figure 10. Pores in *Terminalia cattapa* were mostly solitary and diffuse with simple perforations. Rays were heterogeneous, procumbent, and commonly between 1-3 cells wide; body of procumbent rays with one row of some procumbent cells. In *Ficus exasperata*, vessels also were mostly solitary and diffuse; perforations were simple, and intravascular pits were small. Rays were homogeneous, procumbent and commonly greater than 10 seriate. Body of procumbent with one row of square cells. Vessels in *Nauclea diderrichii* were mostly solitary and diffuse with simple perforations, intravascular pits vestured. Yellow deposits inside vessels. Rays were heterogeneous, procumbent, and commonly uniseriate. Body of procumbent rays with one row of square cells. Axial parenchyma cells were diffuse, and diffuse in aggregates. Fibers were medium to thick-walled, estate, and with bordered pits. Fiber tracheid was also present [7-15].

Table 1. Anatomical features of the wood species.

Species	Vessel	Inclusions	Fiber	Rays	Axial parenchyma
Ficus	218.98 µm mostly solitary and diffuse	Crystals in parenchyma cells	Thin walled sometimes estate	Homogeneous	In bands of about 4 cells wide
Terminalia	190.63 µm mostly solitary and diffuse	gum deposits inside the rays	Medium walled	Heterogeneous	Paratracheal, vasicentric
Nauclea	176.11 µm mostly solitary and diffuse	Gum/yellow deposits inside vessels	Medium/thick walled, and estate with bordered pits	Heterogeneous	Apotracheal, diffue and diffuse in aggregate

Figure 1. *T. catappa* transverse section.

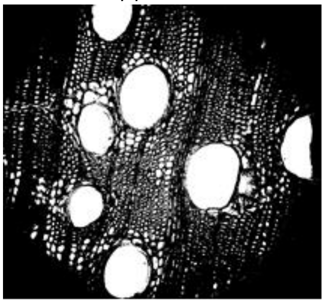


Figure 2. *T. catappa* tangential longitudinal section.

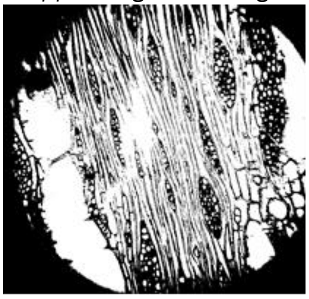


Figure 3. *T. catappa* radial longitudinal section.

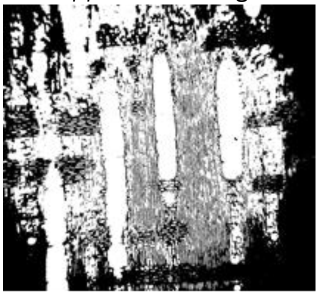


Figure 4. *F. exasperata* transverse section.

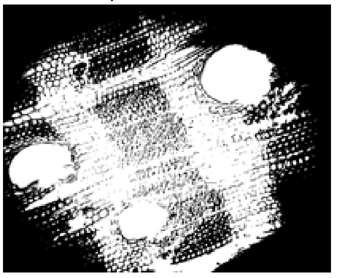


Figure 5. *F. exasperata* tangential longitudinal section.

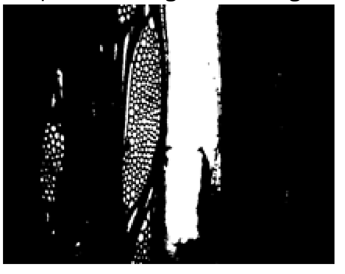


Figure 6. *F. exasperata* radial longitudinal section.

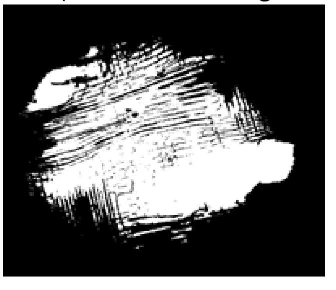


Figure 7. *N. diderrichii* transverse section.

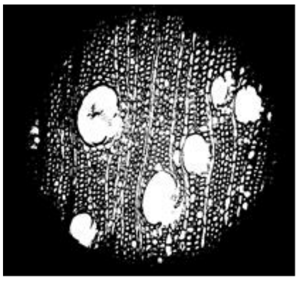


Figure 8. *N. diderrichii* tangential longitudinal section.

Figure 9. *N. diderrichii* radial longitudinal section.

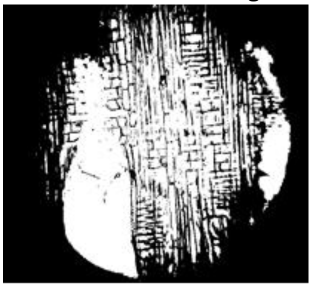
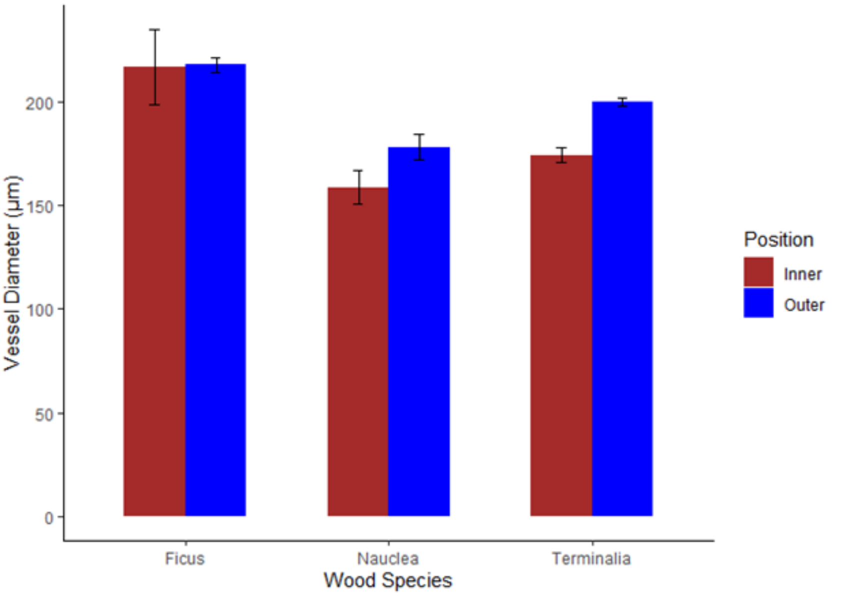


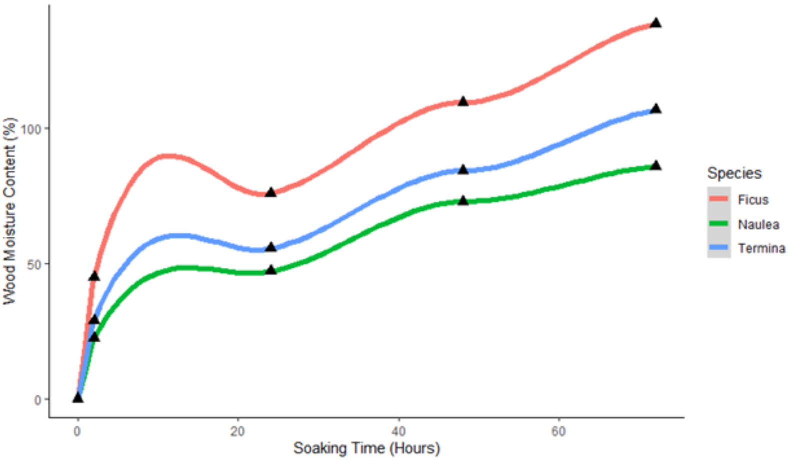
Figure 10. Sizes of vessel diameter in the three wood species.



Water absorption properties

Water absorption patterns of the three wood species are presented in Figure 11. The three wood species exhibited a high rate of moisture sorption during the first two hours, followed by slower absorption. Although *Ficus* quickly attained almost 80-90% moisture content within a few hours of soaking, the three wood species in the later stages entered the relaxation phase after 72 hours. The result of water absorption presented in Table 2 showed that *Ficus exasperata* had the highest water absorbed ranging from 41.89% (2 hours) to 146% (72 hours). The water absorbed for *Terminalia cattapa* ranged from 25.83% for 2 hours and 116.89% for 72 hours with an average of 28.92% for 2 hours and 108.23 for 72 hours. The water absorption of *Nauclea diderichii* which was the lowest with water absorption ranging from 20% for 2 hours and 107.61% for 72 hours with an average of 22.25% for 2 hours and 85.99% at the entire soaking time 72 hours respectively.

Figure 11. Temporal changes of wood moisture content in different woody species.



The analysis of variance of water absorption presented in Table 3 showed that there were significant differences among the three species selected at ($p< 0.05$). Also there are no significance differences in the stem position and zone [16,17].

The means were separated using Duncan Multiple Range Test (DMRT) at 5% probably level. DMRT results show that there were significantly different between the species ranging from *F. exasperata, T. catappa* and *N. diderichii* [18].

Table 2. Mean result for water absorption at different time rate.

Species	Stem position	Zone	2 hrs	24 hrs	48 hrs
Ficus	Inner	40.54	72.46	107.49	138.07
	Outer	43.24	66.22	99.55	119.61
	Mean	41.89	69.34	103.52	128.84
Nauclea	Inner	15	39.29	56.3	68.39
	Outer	25	52.83	66.68	79.75
	Mean	20	46.06	61.49	74.07
Terminalia	Inner	27.87	54.1	79.05	111.84
	Outer	36.21	67.24	95.98	121.95
	Mean	32.04	60.67	87.52	116.89
	Outer	32.76	51.72	77.45	97.43
	Mean	28.88	54.53	80.97	102.42

Table 3. Result of ANOVA for water absorption.

Source	Type III sum of squares	Df	Mean square	F	Sig.
Species	8445.12	2	4222.56	18.4	.000*
Stem position	673.465	2	336.733	1.467	.269ns
Zone	423.386	1	423.386	1.845	.199ns
Error	2753.83	12	229.486		
Total	12295.8	17			
*Sig. diff. at probability ≤ 0.05 *not sig. diff at probability ≥ 0.05					

DISCUSSION

Our study showed that moisture uptake was relatively slower for *Nauclea* over the immersion period. This can be generally attributed to the sizes of the vessels in the wood species. Water moves freely in the large cavities, but in the small ones, trapped air bubbles influence water movement. In this study, *F. Exasperata* had the highest vessel diameter, followed by *Terminalia*, while *N. diderichii* had the lowest vessel diameter. Although fiber often constitutes the majority of woody tissue, it is not considered as necessary as vessels in primary liquid flow. For examples, petruzzello indicated that water flows relatively from vessel to vessel even through perforations and fractures. Since vessels members are the principal water conducing cells in angiosperms, it therefore follows that sizes of the vessels would influence the rate of water absorption. Hence, Ficus which had the largest vessel size in this study also had the highest absorption rate. According to the observations on water absorptivity by the wood species, *N. diderichii* ranked the least as it absorbed less water with the average of 22.25% in 2 hours and 85.99% in 72 hours than either *Terminalia* or *Ficus*, and this could be as a result of its relative smaller vessel or porous structure of wood in which of water flows. *F. Exasperata* with an average of 44.91% in 2 hours and 138.82% in 72 hours absorbed more water than any of other species. This will affect the structural and applications uses of the wood and also have negative effect on wood quality as strength properties decrease as wood absorbs moisture in the hygroscopic range for each percent increase in moisture content. Moreover, the susceptibility of wood to microorganisms attack depends on the moisture content of the wood cell wall. Therefore F. exasperata will be more susceptible to termites for exterior applications. *F. Exasperata* might have higher water conductivity than *T. catappa* and *N. diderichii* as larger vessel diameter is more efficient in water conductivity than smaller vessels. Beside the relative smaller vessels in *N. diderrichii* which seemed to have lowered its water absorption rate, the presence of xyloses and other deposits in vessels could have also contributed to water absorption resistance [19,20].

It should be noted that the trend of increasing anatomical properties from inner wood to outer wood as seen in these wood species was also observed in *Tectona grandis*.

CONCLUSION

The study provides information on histology and water absorption properties of the selected wood species. The wood species of *F. exasperata*, *T. catappa* and *N. diderichii* were influenced by their anatomical features especially the vessels and other wood deposits. The influence was witnessed on the account of the various water absorption. *F. exasperata* wood has the highest percentage of water absorption based on the size of its vessels; others were slower and absorbed less water because of the anatomical composition.

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