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SPATIAL VARIATION OF PULP AND PAPER QUALITIES OF *Ficus exasperata (VAHL)*

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Abstract
This study examined the qualities of pulp and paper produce from Ficus exasperatain Bunu Tai, Rivers State, Nigeria. Samples were collected along the axial direction(base, middle and top) along the sampling height. Wood samples for anatomical properties were prepared by trimming of the splinter wood into thin slices(silvers) and placing them in well labeled test tubes containing equal volume (1:1) of 10% Acetic acid and 30% Hydrogen Peroxide. The silvers in tube were later placed in oven for 4 hours at a temperature of 80°C for bleaching and softening. The chemical mixture was decanted and the fibres were washed with distilled water five times, the fibres were then separated. The experiments were in 2 factor factorial experimental in Completely Randomized Design (CRD) and the data collected were subjected to analysis of variance using the SPSS version 20.0.The results showed inconsistency wood properties sampled as fibre length (FL) at base (1.44±0.41)mm, Middle (1.14±0.21) mm and top (1.344 ± 0.514)mm while fibre lumen diameter highest at top (14.5960±4.806) µm followed by base (13.0790±4.069µm) and lowest middle with 11.0905±3.223µm similarly, fibre cell wall thickness highest attop5.699±1.405µm followed by base 5.217±1.461µm and lowest middle 4.2845±1.097µm. Runkel ratio variation decreased from the base to the middle and thereafter increased to the top: 0.8604±0.357, 0.821±0.250 and0.8320±0.242 respectively. Coefficient of flexibility of the wood was highest inmiddle 55.759±7.962 followed by top 55.5274±7.312 and lowest at base 55.210±8.117 while fibre felting power decreased from the base 64.7998±26.418, followed by middle - 62.141±22.988 and lowest at top - 51.947±16.469. The pattern of variation observed from fibre length, fibre density, fibre lumen, cell wall, Runkel ratio were inconsistent .The species can be recommended for paper production and low construction purposes.

Keywords: Ficus exasperata, Fibre length, Runkle ratio, Lumen width

Introduction

Wood is an isotropic, hydroscopic, porous and permeable with a sophisticated structure that is complicated by three major microscopic components – the vessel elements, the fibre and the parenchyma. In wood structure, each of the major planes, longitudinal (crosscutting direction), radial (quarter sawn direction) and tangential (flat sawn direction), possess distinctive features. Each plane has its own anatomical, physical and strength properties in relation to both the wood itself and to the wood machining process, which is affected by its distinct structure.

Fibres are the principal element that is responsible for the strength of the wood (Panshin & Zeeuw, 1980). Fibre characteristics of wood are very attribute that is very important to pulp and paper industry but may be easily overlooked from solid-wood product perspective (David-Sarogoro and Amakiri, 2016). Fibre characteristics are the raw materials for pulp and paper industry (Kayama, 1979).

Fibre length, cell wall, fibre diameter and lumen diameter are indices of intrinsic wood quality and their Runkel Ratio determine suitability for pulping (Ogunsanwo and Omole, 2010).

Ficus exasperata belongs the family Moraceae, with 800 species occurring in the tropics, chiefly in Indomalaya and Polynesia (Odunbaku *et al*., 2008) and in Nigeria there are over 45 different species of *Ficus* (Keay and Onochie, 1964): such as *Ficus glomosa, Ficus lecardi, Ficus goliath, Ficus capensis, Ficus ingens* and *F. elastica,* which can be found in the Savannah, rainforest, beside rivers and streams. *F. exasperata* is commonly known as sand paper tree and is widely spread in West Africa, East Africa, India, Sri Lanka and in all kinds of vegetation and particularly in secondary forest re-growth (Hyde *etal*., 2012).

Ficus exasperata is a lesser-known wood species like many tropical forest trees that have not been used due to lack of information of their strength and anatomical properties which will provide firsthand information on their utilization potential. Therefore there is need to examine the anatomical characteristics of this species in order to determine its suitability and potential for pulp and paper making. Therefore, this study was conducted with the aim of determining the spatial variation of pulp and paper qualities of *Ficus exasperata* in Bunu Tai.

Materials and Methods

The Study Area

Wood samples of *Ficus exasperata* were collected from various locations at BunuTai in Tai Local Government Area on latitude 4°46'N and longitude 7°13'E East of Port Harcourt (David-Sarogoro&Emerhi, 2016) and 18.48km away from Port Harcourt (State capital). Figure 1 is the map of River State showing Tai LGA with the Map of Nigeria showing River State.

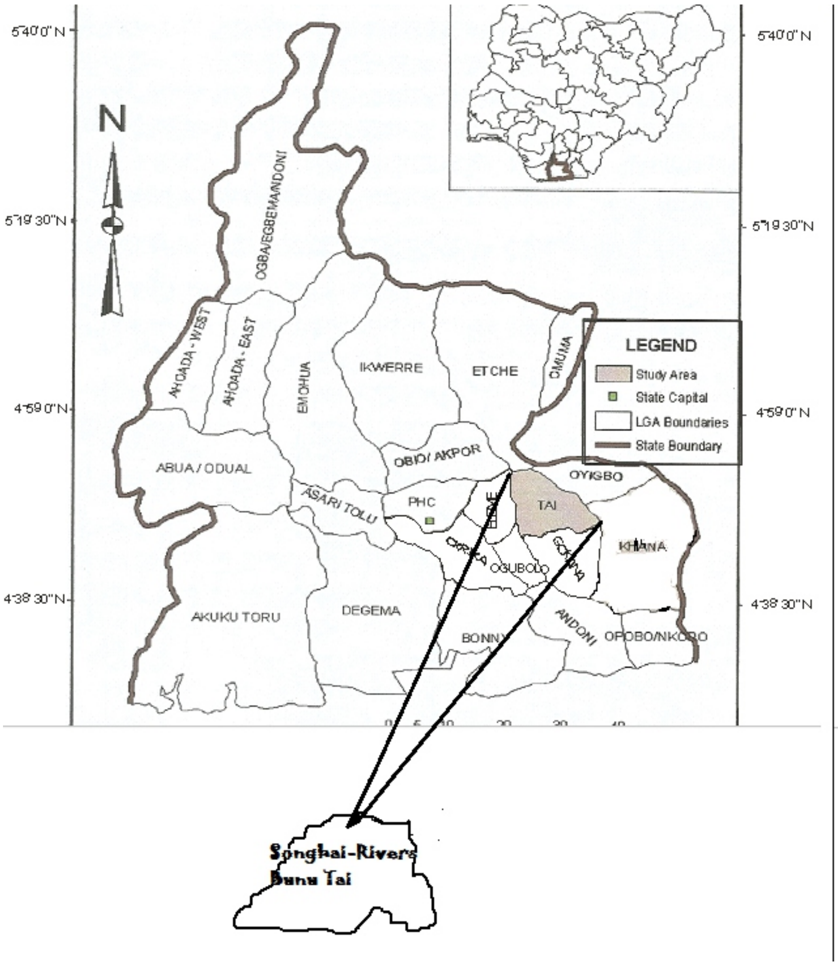

Figure1: Map of Rivers State indicating Tai LGA and map of Nigeria showing River state in inset.

Source: Rivers State Ministry of Environment

Methodology of Data Collection

Three merchantable trees of *Ficus exasperata* were randomly selected and felled and cut into boles with the use of power chain saw. Three sections were marked out at 10% (base), 50% (middle)and 90% (top) along the axial direction of the log. The bole or disc obtained from the three sections were packaged and taken to Department of Forest Products Development and Utilization (FPD&U) Wood Anatomy and Timber Quality Laboratory, Forestry Research Institute of Nigeria, Ibadan (FRIN) for wood fibre maceration and determination of fibre characteristics.

Maceration of Fibres of *Ficus exasperata*

The procedures of Franklin(1994) as reported by Oluwadare (2006) were adopted which involved trimming of the splinter wood into thin slices(silvers) and placing them in well labeled test tubes containing equal volume (1:1) of 10% Acetic acid and 30% Hydrogen peroxide. The test tubes containing the silvers were later placed into oven for 4 hours at a temperature of 80°C for bleaching and softening. The chemical mixture was decanted and the fibres were washed with distilled water five times, the fibres were then separated. The fibres were later aligned on a slide mounted microscope for viewing and measured at magnification of 8 eye place and 10 magnification of objectives lens for the measurement of fibre qualities-length, fibre diameter and lumen width, Co-efficient of flexibility, Cell wall thickness, Felting power and Runkel ratio.

Experimental Design and Data Analysis

The experiments were in 2 factor factorial experimental in Completely Randomized Design (CRD) and the data collected were subjected to analysis of variance using the SPSS version 20.0.

Result and Discussion

The table 1 shows the mean value of fibre length of *Ficus exasperata* which ranges from 0.919±0.133 to 1.839±0.337.This finding is in line with Ogunkunle and Oladele (2008)who observed that structural dimension and paper making potential of wood in some Nigeria species of *Ficus L*. (Moraceae). The pattern of variation displayed by *Ficus exasperata* is inconsistent as the fibre length (FL) decreased from base to middle and increased to the top with the base having FLof1.44±0.41 mm, Middle (1.14±0.21) mm and top (1.344 ± 0.514)mm respectively. The average fibre length (1.309±0.414) mm of this species is longer when compared with fibre length of *Gmelinaarborea* (1.2770±01828) mm and fall within the medium fibre length classification (Clark, 1992). The difference in value within the trees may be as a result of age difference, spacing arrangement and others factors such as location, hormone activities especially auxin.

Table 1: Mean Value of Fibre Length of *Ficusexasperata*according to Axial Direction and Trees

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	1.144±0.157[a]	1.726±0.400[a]	1.448±0.392[a]	1.439±0.408
Middle	1.072±0.119[b]	1.179±0.234[b]	1.1820±0.235[b]	1.144±0.206
Top	0.919±0.133[c]	1.839±0.337[c]	1.2761±0.487[c]	1.344 ± 0.514
Mean	1.044±0.165	1.5812±0.436	1.302±0.395	1.309±0.414

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

At 0.05 level of probability, the results of the one way Analysis of Variance showed that there is significant difference in fiber length along the sampling height (base, middle and top), within the trees and interaction between the sampling height and trees (Table 2).

Table 2: Analysis of Variation for Fibre Length of *Ficus exasperata*

Source of variance	degree of freedom	sum of square	mean of square	Fcal	Ftab
Height	2	2.719	1.359	14.712*	3.06
Tree	2	8.633	4.316	46.711*	3.06
Tree*Height	4	3.517	0 .879	9.515*	2.43
Error	171	15.801	0.092		
Total	179	30.670			

Table 3 below shows that the mean value of fibre diameter was (23.056±6.066), the pattern of variation exhibited along the sampling height is inconsistent (base 23.513±5.561, middle 19.659±4.399 and top 25.994±6.375). The pattern of variation observed in this work is in line with Anguruwa, (2018) who reported the average fibre diameter of *Ficus exasperata* to be 21.25±1.08µm. The difference in the value may be as a result of the location of samples and age factors. Also the pattern of variation within the trees species is inconsistent, tree1 21.013±3.8915 µm, tree2 25.727 ±7.158 µm, tree3 323.056±6.066 µm (Table 3).

Table 3: Mean Value of Fibre Diameter of *Ficus exasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	21.155±3.942[a]	25.830±5.783[a]	23.554±5.962[a]	23.513±5.561
Middle	19.1880±3.64[b]	20.725±4.924[b]	19.065±4.558[b]	19.659±4.399
Top	22.6935±3.42[c]	30.627 ±7.059[c]	24.661±5.361[c]	25.994±6.375
Mean	21.013±3.8915	25.727 ±7.158	22.427±5.775	23.056±6.066

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

At 0.05 level of probability, the analysis of variance showed that there were significant differences (P<0.05) in fiber diameter along the sampling height (base, middle and top)and within the trees. But, there is no significant difference (P>0.05) in the interaction between the sampling height and the trees as shown in Table 4.

Table 4: Analysis of variance for Fibre Diameter of *Ficus exasperata*

Source of variance	degree of freedom	sum of square	mean of square	FcalFtab	
Height	2	1222.642	611.321	23.600*	3.06
Tree	2	702.507	351.253	13.560*	3.06
Tree*Height	4	232.919	58.230	2.248 ^{ns}	2.43
Error	171	4429.469	25.903		
Total	179	6587.536			

*Significant difference (P <0.05) , ns- no significant difference (P > 0.05)

Table5 shows the fibre lumen width of *Ficus exasperata*. It is observed that the average value is 12.922±4.309 with values ranging from 10.824±3.582 µm to 17.466±5.407 µm. There is an inconsistent pattern of variation as the fibre lumen diameter decreased from the base (13.0790±4.069µm) to the middle (11.0905±3.223µm) and thereafter, it increased to the top (14.5960±4.806) µm. The value is comparable to that of Anguruwa, (2018) and Adeniyi *et al.,* (2013) who reported values of 14.050 µm and 14.10 µm respectively. The high lumen width implied that fibre will flatten to ribbon during pulp and paper making process thus giving good contact between the fibres and as a result having good characteristics which makes it a potential source of raw materials for pulp and paper production (Alonge, 2011). The lumen width of the fibres also affected the beating of pulp, in that the larger the lumen width, the better the beating of the pulp. This is because of the penetration of liquid into the empty cavities of the fibre.

Table 5: Mean Value of Fibre Lumen of *Ficusexasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	11.869±2.91 ^{a}	14.330±4.44 ^{a}	13.0380±4.468 ^{a}	13.079±4.069
Middle	11.254±2.74 ^{b}	11.1930±3.43 ^{b}	10.824±3.582 ^{b}	11.091±3.223
Top	12.423±2.703 ^{c}	17.466±5.40 ^{c}	13.899±4.586 ^{c}	14.596±4.806
Mean	11.849±2.782	14.329±5.123	12.587±4.364	12.922±4.309

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

The results of the one-way Analysis of Variance showed that there were significant differences in fiber lumen width along the three sampling heights (base, middle and top), within the three different trees and there was no significant difference in the interaction between the sampling heights and trees as shown in Table 6.

Table 6: Analysis of Variance for Fibre Lumen of *Ficusexasperata*

Source of variance	degree of freedom	sum of square	mean of square	FcalFtab	
Height	2	370.879	185.440	12.097*	3.06
Tree	2	194.677	97.338	6.350*	3.06
Tree*Height	4	136.951	34.238	2.233 ^{ns}	2.43
Error	171	2621.326	15.329		
Total	179	3323.833			

*Significant difference (P <0.05) , ns- no significant difference (P > 0.05)

Table 7 shows the results of fibre cell wall thickness. The average value for fibre wall thickness is 5.067±1.448 µm. The pattern of variation for fibre cell wall thickness along the sampling heights is inconsistent, (base 5.217±1.461µm, middle 4.2845±1.097 µm, and top5.699±1.405µm). The value obtained is higher than that of Anguruwa, (2018)and Ogunkule and Oladele(2008) with values of 1.94±-4.99 µm and 2.94±0.38 µm respectively for the same species. The cell wall thickness of the fibre of this species revealed that it has a large lumen and thin walls. Fibre with large thin wall is expected to have positive effect that tends to form non-porous tightly bond paper sheet that easily collapse and is flexible (Syed *et al.*, 2016).

Table 7: Mean Value of Fibre Cell Wall Thickness of *Ficus exasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	4.643±1.171 ^{a}	5.750±1.85 ^{a}	5.258±1.083 ^{a}	5.217±1.461
Middle	3.966±0.902 ^{b}	4.766±1.30 ^{b}	4.120±0.916 ^{b}	4.2845±1.097
Top	5.135±0.898 ^{c}	6.581±1.774 ^{c}	5.3813±0.954 ^{c}	5.699±1.405
Mean	4.581±1.094	5.699±1.797	4.920±1.126	5.067±1.448

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

The ANOVA results showed that there were significant differences in fiber cell wall thickness along the sampling heights (base, middle and top), within the trees and while there was no significant difference in the interaction between the sampling height and trees at 5% level of probability as shown in Table 8.

Table 8: Analysis of Variance for Fibre Cell Wall Thickness of *Ficus exasperata*

Source of variance	degree of freedom	sum of square	mean of square	Fcal	Ftab
Height	2	62.058	31.029	19.652*	3.06
Tree	2	39.390	19.695	12.474*	3 .06
Tree*Height	4	4.030	1.008	0.638^{ns}	2.43
Error	171	269.996	1.579		
Total	179	375.474			

*Significant difference (P <0.05) , ns- no significant difference (P > 0.05)

Table 9 showed the Runkel ratio and the average value was 0.8378. Runkel ratio is one of the most important and primary criteria for determining the suitability of the any material for pulp and paper production. The Runkel ratio for this study fell within the recommended value of below 1 for pulp and paper making as reported by Yusuf (2007). The pattern of variation for this species decreased from the base to the middle and thereafter increased to the top (base - 0.8604±0.357, middle - 0.821±0.250 and top - 0.8320±0.242).

Table 9: MeanValue of Fibre Runkel Ratio of *Ficus exasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	0.841±0.434^{a}	0.879±0.38^{a}	0.8608±0.241^{a}	0.8604±0.357
Middle	0.727±0.11^{b}	0.904±0.258^{b}	0.8304±0.280^{a}	0.821±0.250
Top	0.860±0.217^{c}	0.804±0.271^{c}	0.8315±0.244^{b}	0.8320±0.242
Mean	0.809±0.299	0.862±.307	0.8409±0.251	0.8378±0.286

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

The ANOVA results revealed that there was no significant difference in Runkel ratio along the sampling heights (base, middle and top), within the trees and interaction between the sampling height and trees (Table 10).

Table 10: Analysis of Variance for Runkel Ratio of *Ficus exasperata*

Source of variance	degree of freedom	sum of square	mean of square	Fcal	Ftab
Height	2	0.050	0.025	0.298^{ns}	3.06
Tree	2	0.086	0.043	0.512 ^{ns}	3.06
Tree*Height	4	0.275	0. 069	0.820^{ns}	2.43
Error	171	14.314	0.084		
Total	179	14.724			

ns-no significant difference (P > 0.05)

Table 11 showed the coefficient of flexibility, which range between53.464±7.619 to 58.484±6.168. There was a slight variation in the coefficient of flexibility observed along the tree (base 55.210±8.117, middle 55.759±7.962, top 55.5274±7.312). According to Nkaa *et al*., (2007), coefficient of flexibility above 50% but less than 60% is necessary in fibres for paper making. This is because fibre having this characteristic readily collapse and produce good surface contact in addition to fibre bonding. Therefore, papers made from either species may have increased mechanical strength and thus suitable for writing and printing.

Table 11: Mean Value of Co-efficient Flexibility of *Ficus exasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	56.028±7.909^{a}	55.067±9.902^{a}	54.535±6.539^{a}	55.210±8.117
Middle	58.484±6.16^{a}	53.464±7.619^{a}	55.759±7.962^{a}	55.759±7.962
Top	55.903±7.45^{a}	54.462±6.341^{a}	55.531±7.444^{a}	55.5274±7.312
Mean	56.325±6.937	55.039±8.593	55.2754±7.234	55.546±7.600

Means in each column with the same alphabets are not significantly different (P>0.05) within individual trees using DMRT

The ANOVA results showed that there is no significant difference in the co-efficient flexibility along the sampling heights (base, middle and top), within the trees and interaction between the sampling height and trees as shown in table 12.

Table 12: Analysis of Variation for co-efficient Fexibility of *Ficus exasperata*

Source of variance	degree of freedom	sum of square	mean of square	Fcal	Ftab
Height	2	14.411	7.205	0.123 ns	3.06
Tree	2	56.167	28.084	0.480ns	3.06
Tree*Height	4	264.477	66.119	1.130 ns	2.43
Error	171	10005.180	58.510		
Total	179	10340.235			

ns-no significant difference (P > 0.05)

Felting is the measurement of ratio of fibre to diameter of the criterions that control suitability of wood materials for paper production (Akgul, 2009). It could be observed in table 13 that the pattern of variation displayed along the sampling heights is in decreasing order from the base to the top with a mean value of 56.629 (base - 64.7998±26.418, middle - 62.141±22.988, top - 51.947±16.469). According to Sharma *et al.*, (2013) andXu*et al.,* (2006), felting ratio of greater than 33 is the most suitable for pulp and paper making. However, the fibres of this species in the study exceeded the satisfactory felting ratios of 33. A high Slender Ratio in fibre will produce higher rate of tear resistance in a paper (Akpakpan *et al.,* 2012).

Table 13: Mean Value of Fibre Felting Power of *Ficus exasperata*

Sampling Height	Tree 1	Tree2	Tree3	Mean
Base	57.228±20.198a	71.209±2.193a	65.961±29.314a	64.7998±26.48
Middle	58.056±14.043b	60.731±21.56b	67.636±30.451b	62.141±22.988
Top	41.519±9.407c	61.861±12.77c	52.461±19.295c	51.947±16.469
Mean	52.267±16.800	64.600±21.927	62.019±27.243	59.629± 22.902

Means in each column with different alphabets are significantly different (P<0.05) within individual trees using DMRT

From the results of the analysis of variance as shown in table 14, there were significant differences in the felting power in the sampling heights (base, middle and top) and in the trees while there was no significant interaction between the sampling height and trees.

Table 14: Analysis of variance for Felting Power of *Ficus exasperata*

Source of variance	Degree of freedom	Sum of square	Mean of square	F cal	F tab
Height	2	5523.454	7.205	5.813*	3.06
Tree	2	5076.981	28.084	5.343*	3.06
Tree * Height	4	2041.585	66.119	1.074ns	2.43
Error	171	81243.960	58.510		
Total	179	93885.981			

*Significant difference (P <0.05) , ns- no significant difference (P > 0.05)

Conclusion and Recommendations

From this study, the fibre length falls within medium range classification and very close to that of *Gmelina*. The cell wall thickness of fibre of *Ficus exasperata* obtained from this study shows that it has a large lumen and thin wall. The Runkel ratio value observed in this study was within the recommended value for pulp and paper and could serve as alternative substitute for some already known species for pulp and paper industries or could be mixed with the already known wood species of high pulp and paper qualities. From the results of the fibre characteristics, wood density and mechanical properties this species is recommended for paper production and low construction purposes. The chemical properties should be considered to ascertain the percentage of the lignin content present in the wood.

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