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Full Length Research Paper

Comparative study of percentage yield of pulp from various Nigerian wood species using the kraft process

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Twenty Nigerian wood species namely, Akomu (*Pycnanthus angolensis*), Ofun (*Avicennia germinans*), Akun (*Uapaca guineensis*), Oporoporo (*Pterygota macrocarpa*), Abura (*Hallea ciliata*), Masonia (*Masonia altissima*), Afara (*Terminalia superba*), Agba (*Entada gigas*), Mahogany (*Khaya ivorensis*), Obeche (*Triplochiton scleroxylon*), Itako (*Strombosia pustulata),* Odoko (*Ipomoea asarifolia*), Itara (*Sacoglottis gabonensis*), Eki-Eki (*Lophira alata*), Iroko (*Milicia exelsa*), Araba (*Ceiba pentadra*), Erimado *(Ricindendron heudelotii*), Erun (*Erythropleum suaveolens*), Opepe (*Nauclea diderrichii*) and Okilolo (*Symphona globulifera*) were subjected to kraft pulping process in order to obtain pulp. The mean percentage yield of pulp obtained from the twenty hardwood species were found to be significantly different when the data were subjected to Duncan's multiple range test at p = 0.05. Abura (*H. ciliata*), Afara (*T. superba*) and Okilolo (*S. globulifera*) gave the highest mean pulp yield of 50% each while Iroko (*M. exelsa*) gave the lowest pulp yield of 35%. The difference in pulp yields is typically attributed to lignin content and lignin type present in these wood species. The infra red analysis of the pulp obtained from the various wood species confirmed the chemical integrity of the pulps obtained from all the hard wood species surveyed.

Key words: Kraft pulp, Nigerian wood species, pulp yield, cellulose.

INTRODUCTION

Pulping is a process of converting wood or lignocellulosic nonwood materials to separated pulp fibers for paper-making and other value-added products. Pulp production represents a complex and an important economic and industrial activity (Herman, 1970). Pulp is widely used for the production of paper and paperboard, but there are also other applications like in the chemical industry (Biermann, 1993). Therefore pulp is a very necessary product for the modern society. As fibrous material, pulp is the result of some complex production processes that involve either chemical or mechanical treatment of various types of plant materials. Up to 90% of world's pulp production originates from wood pulping, the remaining 10% being the result of annual plant processing. Wood in the form of sawdust is the most widely used raw material for pulp production (Sixta, 2007).

Using wood to make paper is now a well-known process. Nigeria is the only country in West Africa producing pulp and paper, and produces only 6% of the sub-region's total paper products consumption (Nair, 2004). Almost all the other countries in the sub-region depend on imports to meet their domestic needs on printing and writing paper products, newsprint and other paperboard products (Market Pulp Association, 2007). The dominance by small to medium enterprises (SMEs), most of which operate in the informal sector, coupled with the use of obsolete equipment and low recovery rate remain the problem in the wood-processing sector in the sub-region (FAO, 2003).

The Food and Agricultural Organisation (FAO, 2002a) reported that Nigeria has about 1000 wood-processing units (sawmills and units producing panels and matches, and 3 paper factories. Low value addition of these plants resources has remained a major feature of African's wood production as majority of the wood produced in Africa is used as fuel (FAO, 2001). In 2000, Africa's share of global wood fuel was 30%. On the other hand, its global contribution of the value added biomass like sawn wood, wood-based panels, fibreboards and paper and paperboard products was only 1.8, 1.1, 0.7 and 0.9% respectively (FAO, 2002b).

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The yield of pulp obtained from a given wood sample is influenced greatly by the type and severity of the pulping process used. Lignin removal rates are high in the Kraft pulping process (up to 90%). The chemicals used in the Kraft pulping are readily recovered and recycled within the process, making it very economical and reducing potential environmental releases. The Kraft process converts approximately 50% of wood input into pulp and thus justifies continued investigation into the use of this process in the extraction of cellulose from wood species locally sourced in Nigeria. Studies on the pulping characteristics of *Raphia hookeri* showed that lower yields were obtained for woods in the production of pulp to be used for the manufacture of viscose and other cellulose derivatives (ethanol), owing to the more severe chemical treatment in their preparation (Odeyemi, 1986a). As far as we are aware, no studies have been undertaken on the pulping characteristics of many Nigerian wood species. Yet there is increasing importance of wood pulp in the Nigerian economy. Hence, the justifications for these studies on the comparative percentage yield of pulps from different Nigerian wood species.

MATERIALS AND METHODS

Twenty Nigerian wood species were selected for the study. The wood species investigated included Akomu (*Pycnanthus angolensis*), Ofun (*Avicennia germinans*), Akun (*Uapaca guineensis*), Oporoporo (*Pterygota macrocarpa*), Abura (*Hallea ciliata*), Masonia (*Masonia altissima*), Afara (*Terminalia superba*), Agba (*Entada gigas*), Mahogany (*Khaya ivorensis*), Obeche (*Triplochiton scleroxylon*), Itako (*Strombosia pustulata),* Odoko (*Ipomoea asarifolia*), Itara (*Sacoglottis gabonensis*), Eki-Eki (*Lophira alata*), Iroko (*Milicia exelsa*), Araba (*Ceiba pentadra*), Erimado *(Ricindendron heudelotii*), Erun (*Erythropleum suaveolens*), Opepe (*Nauclea diderrichii*) and Okilolo (*Symphona globulifera*). The identification of the wood species was carried out at the Forestry Research Institute of Nigerian (FRIN).

Three samples of the trees of the same wood species were selected for the study. The trees were grown for 15 years at the Forestry Research Institute of Nigerian before felling and cutting into logs. The logs were allowed to dry for one month in the open forest after which they were transferred to the mill where 2 kg each of the wood sample was converted into sawdust.

The moisture content of each wood species was determined by heating the wood sample to 105°C until a constant weight was obtained.

Wood samples (in saw dust form) of 2.8 – 5 mm mesh were subjected to Kraft pulping process in a stainless steel rotary digester under the following conditions. The cooking liquor was made of 28.5% sulphidity, effective alkali of 21.5 and 24.5% active alkali. The digester was maintained at an operating condition of 170°C, pressure of 2 bars, with liquor to wood ratio of 4:1. Cooking period was 1 h and 45 mins in a batch process. At the end of each cooking, the contents of the digester were discharged into a bowl followed by sequential washing of the pulp with deionized water and air-dried. The weight of the pulp was taken and the percentage yield determined. The pulping was carried out on three samples of the wood species and the average weight of the pulp obtained was taken as the mean percentage yield of pulp.

The pulp obtained from each wood species was subjected to mid infrared spectroscopic analysis on a Perkin-Elmer spectrometer FT-IR 2000 model. The spectra were determined using a KBr beam splitter and a DTG detector in the region 4000 - 400 cm^{-1} and the samples were run as mulls in Nujol in KBr windows.

RESULTS AND DISCUSSION

The results showing the mean moisture content and the mean yield of pulp as well as the standard deviations obtained using ANOVA from each of the wood species investigated in this study are shown in Table 1. The result of the infra-red analysis of the pulp obtained from *T. superba* is shown in Figure 1. The OH^{-1} absorption occurred between 3150 – 3400 cm^{-1} while the C-C bonds were observed in the region of 550 – 1300 cm^{-1}. These absorptions are typical of the OH and C-C bonds found in cellulose. The infra-red spectra of the pulp obtained from the other hardwood species investigated in this study are similar to that of *T. superba* shown in Figure 1.

The yield of pulp usually indicates the content of the cellulose and the undegraded hemicellulose, which constitute the fibres. Fifteen out of the twenty hardwood species examined gave mean pulp yields between 40 - 50% under the conditions used in this study. The remaining wood samples produced pulp in the range of 35 - 39%. The highest yields of pulp were obtained from *T. superba*, *H. ciliate* and *S. globulifera*. The differences in values of yields of pulp can be attributed to lignin content and type of lignin present in these wood species. Wood samples such as *M. excelsa*, *U. guineensis*, *A. germinans and L. alata* that gave low yield of pulp will not be good raw materials for the production of pulp for the manufacture of viscose and other cellulose derivatives (ethanol), due to the more severe chemical treatments in these preparations. Moreover, lower kraft yield of wood species outside the range obtained above, under the above alkali charge may render the economic utilization of such woods for pulping activities unviable. There is a strong correlation between the yield of pulp obtained in this study and the one investigated in the comparative Kraft cooks of some tropical woods from Nigeria (Odeyemi, 1986a), where five Nigeria wood species namely; *D. oliveri*, *P. angolense*, *P. macrocarpa*, *S. oblonga* and *A. africana* gave pulp yield of 48.5, 46.5, 46, 49 and 48.7% respectively, for the wood samples. The Kraft cooking of the Nigerian raphia petiole and stem gave the highest yield of 49.7 (Odeyemi, 1986b).

The effects of different concentrations of pulping liquor on the yield of pulp from the wood species are shown in Figures 2 and 3. We found that 28.5% sulphidity, 25.4% active alkali and 21.5% effective alkali gave optimum yield of pulp from *Pycnanthus angolensis*, *Pterygota macrocarpa*, *Hallea ciliate*, *Terminalia superba*, *Entada gigas*, *Khaya ivorensis*, *Triplochiton scleroxylon*, *Strombosia pustulata* ,*Ipomoea asarifolia*, *Sacoglottis gabonensis, Ceiba pentadra, Ricindendron heudelotii, Erythropleum suaveolens*, *Nauclea diderrichii*, and *Symphonia globulifera*. Using liquor having sulphidity of 25.93, 11.75 and 13.5% for effective and active alkali respec-

Table 1. Moisture content and pulp yield of various Nigerian wood species.

S/No	Common name (Yoruba)	Botanical names	Mean moisture content(as % of oven-dried wood at 105°C)	Mean % yield of pulp (at 28.5% Sulphidity)	Mean % yield of pulp (at 25.93% Sulphidity)
1.	Akomu	*P. angolensis*	16.00 ± 0.4[d]	49.00 ± 1.0[de]	45.00 ± 2.0[b]
2.	Ofun	*A. guineensis*	12.00 ± 0.5[b]	38.00 ± 2.6[ab]	35.00 ± 1.0[a]
3.	Akun	*U. guineensis*	8.10 ± 0.1[a]	38.33 ± 2.5[ab]	35.0 ± 1.0[a]
4.	Oporoporo	*P. macrocarpa*	14.04 ± 0.05[c]	46.00 ± 3.6[cd]	42.0 ± 2.0[b]
5.	Abura	*H. ciliate*	14.05 ± 0.05[c]	50.00 ± 1.0[e]	46.0 ± 1.0[b]
6.	Masonia	*M. altissima*	14.11 ± 0.12[c]	39.00 ± 1.7[b]	35.0 ± 1.0[a]
7.	Afara	*T. superb*	12.10 ± 0.10[b]	50.00 ± 1.0[e]	46.0 ± 2.0[b]
8.	Agba	*E. gigas*	12.10 ± 0.14[b]	40.00 ± 2.6[b]	36.0 ± 2.0[a]
9.	Mahogany	*K. ivorensis*	14.03 ± 0.06[c]	40.00 ± 2.0[b]	37.0 ± 1.0[a]
10.	Obeche	*T. scleroxylon*	8.30 ± 0.58[a]	49.00 ± 2.0[de]	43.0 ± 2.6[b]
11.	Itako	*S. pustulata*	12.17 ± 0.14[b]	40.00 ± 1.0[b]	37.3 ± 1.5[a]
12.	Odoko	*I. asarifolia*	16.09 ± 0.14[d]	45.00 ± 2.0[c]	42.0 ± 1.7[b]
13.	Itara	*S. gabonensis*	12.00 ± 0.5[b]	40.00 ± 1.0[b]	37.0 ± 1.0[a]
14.	Eki-Eki	*L. alata*	14.00 ± 0.25[c]	38.00 ± 1.0[ab]	35.0 ± 1.0[a]
15.	Iroko	*M. excelsa*	12.17 ± 0.24[b]	35.00 ± 1.0[a]	36.7 ± 6.4[a]
16.	Some	*C. pentadra*	16.00 ± 0.75[d]	49.00 ± 2.0[de]	45.0 ± 2.0[b]
17.	Erimade	*R. heudelitii*	12.07 ± 0.12[b]	46.00 ± 1.0[cd]	42.0 ± 1.0[b]
18.	Erun obo	*E. suaveolens*	8.10 ± 0.10[a]	47.00 ± 3.0[cd]	45.0 ± 1.0[b]
19.	Opepe	*N. diderrichii*	14.05 ± 0.05[c]	48.00 ± 2.0[cd]	44.0 ± 1.0[b]
20.	Okilolo	*S. globulifera*	12.07 ± 0.07[b]	50.00 ± 2.0[e]	46.0 ± 1.0[b]

Means with the same letter in a column are not significantly different according to Duncan's Multiple range test at p = 0.05.

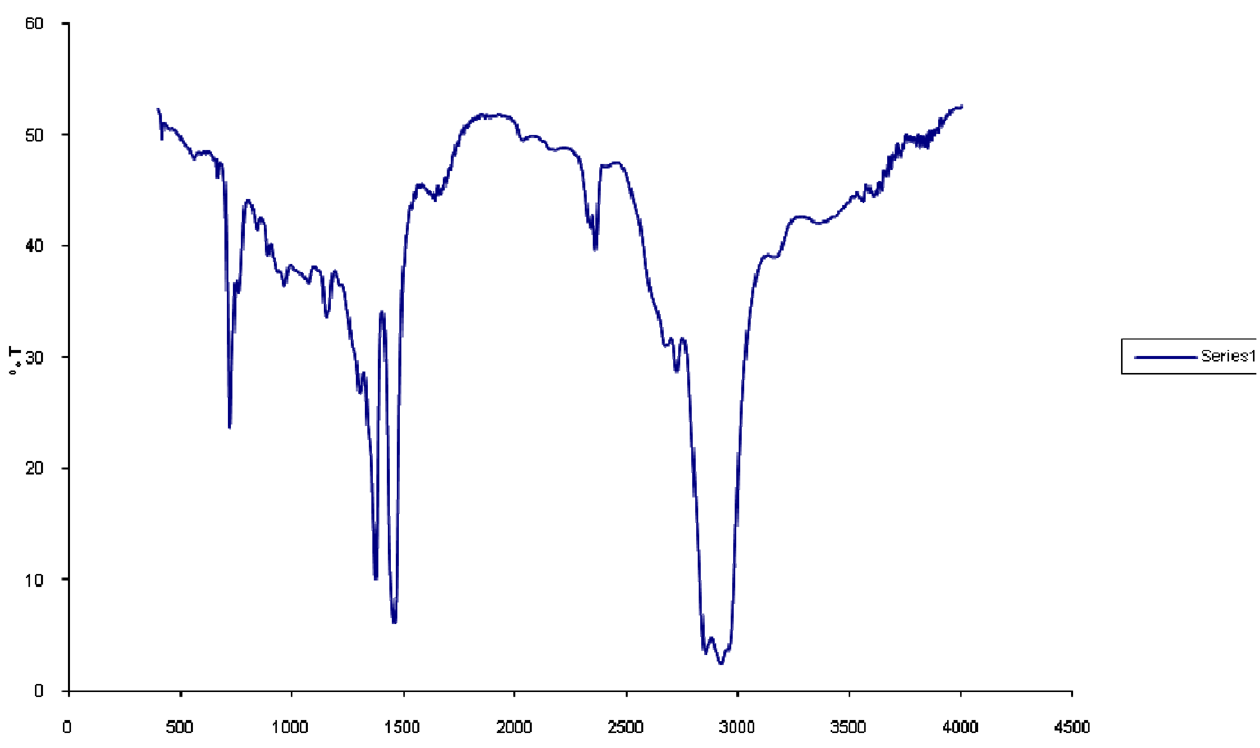

Figure 1. The i.r. spectra of pulp obtained from *T. superba*

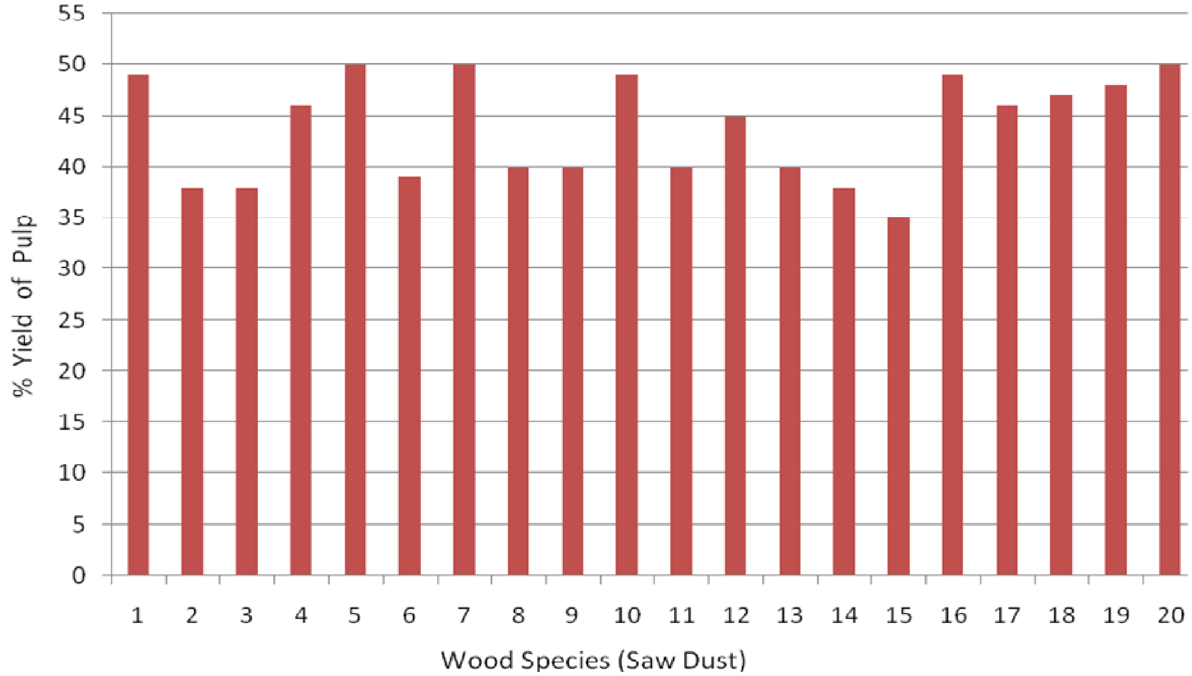

Figure 2. Percentage yield of pulp from various wood species at 28.5.0% sulphidity, 21.5 % effective alkali and 24.5% active alkali.1. *Pycnanthus angolensis*, 2. *Avicennia germinans.* , 3. *Uapaca guineensis*, 4.*Pterygota macrocarpa,* 5. *Hallea ciliate*, 6. *Masonia altissima*, 7. *Terminalia superb,* 8. *Entada gigas,* 9. *Khaya ivorensis,* 10. *Triplochiton scleroxylon,* 11. *Strombosia pustulata,* 12. *Ipomoea asarifolia,* 13. *Sacoglottis gabonensis,* 14. *Lophira alata,* 15. *Milicia excels* , 16. *Ceiba pentadra,* 17. *Ricindendron heudelotii,* 18. *Erythropleum suaveolens,* 19. *Nauclea diderrichii,* 20. *Symphonia globulifera.*

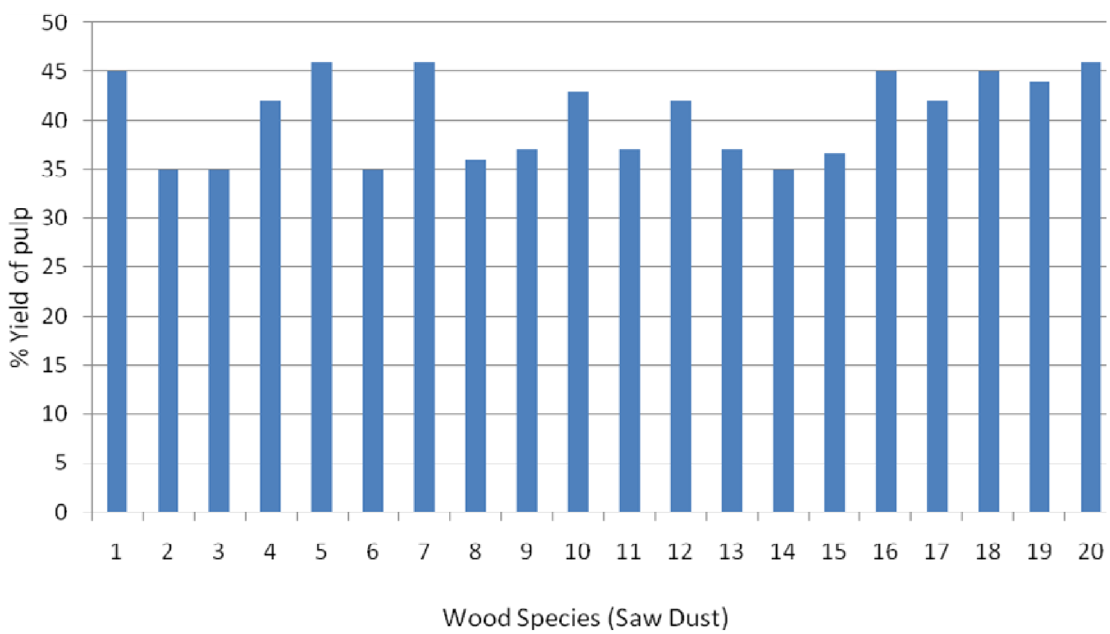

Figure 3. Percentage yield of pulp from various wood species at 25.93% sulphidity, 11.75% effective alkali and 13.5% active alkali. 1. *Pycnanthus angolensis*, 2. *Avicennia germinans.,* 3. *Uapaca guineensis*, 4.*Pterygota macrocarpa,* 5. *Hallea ciliate*, 6. *Masonia altissima*, 7. *Terminalia superb,* 8. *Entada gigas,* 9. *Khaya ivorensis,* 10. *Triplochiton scleroxylon,* 11. *Strombosia pustulata,* 12. *Ipomoea asarifolia,* 13. *Sacoglottis gabonensis,* 14. *Lophira alata,* 15. *Milicia excels* , 16. *Ceiba pentadra,*17. *Ricindendron heudelotii,* 18. *Erythropleum suaveolens,* 19. *Nauclea diderrichii,* 20. *Symphonia globulifera.*

respectively resulted in lower pulp yields at 170°C.

Conclusions

The yield of pulp in any wood or lignocellulosic non-wood material is greatly influenced by the amount of cellulose and the undegraded hemicelluloses that constitute the fibres. From the investigations carried out in this study, fifteen out of the twenty hardwood species examined gave mean pulp yields between 40 - 50% and the remaining five wood samples gave yields of 35 - 39% at optimum pulping liquor concentrations of 28.5% sulphidity, 25.4% active alkali and 21.5% effective alkali. There is a strong correlation in the results obtained in this work and the yields of pulp obtained by Odeyemi from the comparative Kraft cooks of five Tropical Woods (Odeyemi, 1986a).

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