COMPARATIVE STUDY OF SOME PROPERTIES OF *Pinus caribaea* (MORELET) AND *Gmelina arborea* (ROXB) GROWN IN SOUTHERN NIGERIA FOR PULP AND PAPER PRODUCTION

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ABSTRACT

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This study compared some of the physical and chemical properties of matured *Pinus caribaea* and *Gmelina arborea* (Morelet) for pulp and paper production. Parameters assessed were extractive content, moisture content, lignin content and fibre length. Ten tree samples from each of the species were randomly selected from each of the plantations and felled for the study. The wood samples were prepared from three sampling heights of 10%, 50%, and 90% according to standard procedures. Data obtained were analyzed using descriptive statistics, correlation and t-test. The result showed that the mean values obtained for moisture content (55.92%), lignin content (27.43%) and fibre length (154.23 μm) in *Pinus caribaea* where higher than 46.89%, 27.07% and 148.49 μm obtained in *Gmelina arborea* for moisture content, lignin content and fibre length respectively. The t-test analyses for these variation indicated only significant difference in moisture content between the two species at 2-tailed test. However, the extractive content (28.73%) obtained from *Gmelina arborea* was higher and significantly different at 2-tailed test from *Pinus caribaea* (13.68%). The tested parameters in the two mature species indicated that these species chemical and physical properties are still within the acceptable level for pulp and paper production.

Keywords: Pulp and paper, *Gmelina arborea* Roxb, *Pinus caribaea*, exotic species

INTRODUCTION

Fast-growing and high-yield tree species such as *Gmelina arborea* Roxb and *Pinus caribaea* are being planted in different parts of the world to supply the growing demand for pulp and paper manufacturing and solid wood products (Espinoza 2004). However, their physical and chemical properties could influence their end-use and value (Kligler et al., 1995). These properties affect many wood-products manufacturing, like pulping process, behavior in the drying process and resistance to cutting and machining (Hughes and Alburquerque-Sardinha, 1975). For the pulping industry it affects freight costs, pulp production for a given mill size, chemical and power consumption and paper quality (Zobel and Van Buijtenen, 1989; Zobel and Jett, 1995).

*Gmelina arborea* Roxb and *Pinus caribaea* Morelet represent important plantation-grown species in Nigeria. Although they are exotic hardwood and softwood species respectively, they grow very well in the country and were established to supply pulpwood to the country’s pulp and paper mills (Udoakpan, 2014). However, due to the collapse of most of the paper mills in the country, the objective of planting these species has not been satisfactorily realized. Many of these established plantations which totaled about 89,000 hectares have over-grown their rotational age for pulpwood (Badejo et al., 2000). Therefore, there is an urgent need to assess their suitability for pulp and paper making should new pulp and paper factories spring up in the nearest future with the hope of harvesting the needed raw material from the existing plantations and also realize the investments incurred for establishing these plantations. This study therefore compared some properties of these exotic species (*Gmelina arboreae* and *Pinus caribaea*) grown in southern Nigeria and their suitability for pulp and paper production.

MATERIALS AND METHODS

Study area

The *Pinus caribaea* and *Gmelina arborea* plantations are located in Okwute in Umuahia North and in Uyo in Uyo Local Government Areas of Abia and Akwa Ibom State respectively in Southern Nigeria. The *Pinus caribaea* plantation was established by the Forestry Research Institute of Nigeria (FRIN) while the *Gmelina arborea* plantation was established by the Akwa Ibom State Forestry Directorate in 1983. Abia and Akwa Ibom States are within the lowland rainforest zone of Nigeria (Keay, 1959). Umuahia is located in latitude 05° 29’ N and longitude 07° 33’ E, while Uyo is located in 5° 30’ N, 7° 31’ E. The area has a mean annual rainfall of 2238 mm distributed over eight months of rainy season period (March to October) with bimodal peak in June/July and September. The soil is Ultisol. The minimum and maximum temperature is 23 °C and 32 °C respectively, and the relative humidity of 60-80% (Ano, 2004; Ogbonna and Nzebule, 2009).

Sample collection and preparation

Each plantation was divided into five (5) partitions and from each partition two (2) trees with good bole were randomly selected for the study. The diameter at breast height (dbh), four cardinal points (height) on the tree trunk were obtained with the aid of a meter tape and a compass. Values obtained were recorded as described by TAPPI.
(1985) and Browning (1977) in all the selected trees before they were felled. Three (3) discs with a thickness of 50mm were obtained from the felled trees at 10%, 50%, and 90% of their merchantable length. The discs were individually labeled and their surfaces coated with paraffin and stored separately in polythene bags. Each of the discs was subsequently debarked carefully and a strip of 50mm wide obtained after careful marking and rip-sawing to the pith from the bark. Half of the strip was used for the wood properties investigated – moisture content, extractive content, fibre length and lignin content, while the other halves were carefully preserved and stored for further study.

**Fibre length determination**

The wood silver of 1cm x 1cm were obtained from the wood sample with the aid of knife and placed inside test tubes containing a mixture of equal volumes of acetic acid and hydrogen peroxide in a ratio of 1:1 according to Oluwadare (1998) and Oluwadare and Ashimiyu (2007). The test tubes were properly labelled according to the wood positions from where they were cut. Hydrogen peroxide was used as an oxidizing agent to bleach the wood silvers completely to white and the acetic acid served as the cooking medium that softened the fibre. The test tubes containing the various samples were oven-dried for 45 minutes hours at a temperature of 103°C±20°C to macerate. This allowed the lignin and hemicellulose to dissolve leaving only the cellulose fibre. The samples were then separated into individual fibre after washing with distill water to remove the chemicals. Slides of separated fibre were prepared for microscopic structure study. The dimensions of the fibres were determined with the use of Rheichert Visopan Microscope fitted in built micrometer with magnification of 100x. Twenty-five randomly selected tracheids and fibre lengths measured in microns and sample green volume were measured and dried in an oven at 103±2°C to constant weight. Moisture content was calculated and expressed in percentage.

**Chemical composition determination**

Wood samples were reduced to saw dust in accordance with TAPPI T264 (1985) and subsequently extracted using TAPPI T204 (1998). Acid insoluble lignin and other chemical components were determined in accordance with TAPPI T222 (1985), American Society for testing materials. ASTM D1104 (1974) and ASTM D1103 (1974) were used for total sugar determination. Wood subjected to treatment with 72% sulphuric acid (H₂SO₄) at 20 °C for 3 hours followed by 11/2 hours hydrolysis with 1M H₂SO₄ at 100 °C (Seaman Hydrolysis). These methods have been used by Jalah et al. (2001), Gomes and Celso (2004), Verversis et al. (2004) and Chittenden and Palmer (1990). In the case of organic solvents, the extraction was conducted in the Soxhlet apparatus for a period of 20 hours using for this purpose, a mixture of benzene and ethanol 1:1 ratio. These procedures have been reported by Ramilachi (1970), Browning (1977) and Jalah et al. (2001).

**Data analysis**

The data obtained were analyzed using descriptive statistics and correlation (Mc Donald, 2008; Udoakpan, 2014) while the mean differences was tested using t-test.

**RESULT AND DISCUSSION**

Results of the extractive contents and other properties investigated on the two species are indicated in Table 1 below. The result indicated a significant difference in the extractive contents of the two species. The extractive content among the various levels in *Gmelina arborea* were higher than those of *Pinus caribaea*. The extractive content in *Gmelina arborea* followed a pattern of decreasing towards the top of the tree that is the highest extractive content (29.3%) was in the 10% tree level and the least in the 90% tree level (28.0%). The extractive content in *Pinus caribaea* was highest (14.1%) at the tree top (90% tree level) and the least content (13.32) was recorded in the middle of the tree (50% tree level). Analysis also showed there existed a strong correlation (negative) between both species (r = -0.7012). The mean value for the extractive content of *Pinus caribaea* and *Gmelina arborea* was 13.7±0.21% and 28.7±0.37% respectively. The variation in the extractive content in wood of *Gmelina arborea* followed a similar pattern with the lignin content but the extractive content of *Pinus caribaea* did not follow a similar pattern with the variation in the lignin content. The linear decrease as observed in *Gmelina arborea* in this study is common to most hardwood pulp species (Ogunjobi et al., 2013).

Table 1: Variations in the extractive content of the two species

<table>
<thead>
<tr>
<th>Properties</th>
<th>10%</th>
<th>50%</th>
<th>90%</th>
<th>mean</th>
<th>Correlation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pinus</em> (%)</td>
<td>13.65</td>
<td>13.32</td>
<td>14.07</td>
<td>13.68±0.21</td>
<td>-0.7012</td>
<td>27.49**</td>
</tr>
<tr>
<td><em>Gmelina</em> (%)</td>
<td>29.30</td>
<td>28.87</td>
<td>28.03</td>
<td>28.73±0.37</td>
<td></td>
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</tr>
</tbody>
</table>

* ** = significant at 2-tail, ns = not significant at 2-tail*

The variation in moisture content within the trees in each species is shown in Table 2. Across all the tree levels, *Pinus caribaea* trees have higher moisture content than those of *Gmelina arborea* and are statistically significant. The highest moisture content (57.01%) in Pinus is at the 10% tree level and the 50% tree level has the least moisture content of 54.75%. In *Gmelina arborea*, the 50% tree level has the highest moisture content (48.72%), while the 10% tree level has the least moisture content (45.93%). Also, there existed a strong negative correlation (-0.9094) between both species. The mean moisture content for both species is 55.92±0.65% and 46.02±0.91% for *Pinus caribaea* and *Gmelina arborea* respectively. These levels of moisture content is too high especially if the species is intended for general carpentry work, as the moisture content is not expected to exceed 25% for interior sheeting, framing, siding and exterior trim, 9-12% is maximum according to studies by Deck (1977). It will
require quite a large energy resource to season (dry) the timber of Pinus caribaea species to the level fit for mechanical wood processing. It however becomes an advantage to the log yard operations in an integrated pulp and paper mill as the chippers will not be damaged easily and lubricating showers shall not be overstretched. The results of the study is within the acceptable limits similar to Deck (1977) on pitch Pine whose sapwood moisture content exceeded 100% and the heartwood ranged from 30% - 40% and that moisture content may also vary with height in the tree. It is likely in this study that those samples used for the analyses had more moisture contents in their sapwood content than the heartwood. These species if kept at the log yard shall require preservative treatment to avoid bio-deterioration and consumption of chemicals shall be most likely high, hence increase cost of operation.

Table 2: Variations in the moisture content of the two species

<table>
<thead>
<tr>
<th>Properties</th>
<th>10%</th>
<th>50%</th>
<th>90%</th>
<th>mean</th>
<th>Correlation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pinus</em> (%)</td>
<td>57.01</td>
<td>54.75</td>
<td>56.01</td>
<td>55.92±0.65</td>
<td>-0.9094</td>
<td>5.8877**</td>
</tr>
<tr>
<td><em>Gmelina</em> (%)</td>
<td>45.93</td>
<td>48.72</td>
<td>46.02</td>
<td>46.02±0.91</td>
<td>** = significant at 2-tail</td>
<td></td>
</tr>
</tbody>
</table>

Mean lignin content of 27.43% and 27.07% for both species was within satisfactory level (25 - 35%) for pulp and paper production (Table 3). The lignin content decreased horizontally from the 10% tree height to 90% tree height. This pattern may be as a result of extent of development and maturation of the cells. This inference is based on the premise that wood maturation is higher at the lower portion of the wood than at the crown region considering high incidence of heartwood at region close to the pith and high sapwood content towards the bark. It follows that lignifications which protects the structural integrity of the wood is more at the base of the tree than at the crown region. Malgorzata and Roman (2008) reported of values of lignin content that lay between 33.0% and 37.1%. Since the values in this study are lower for both species high pulp yield is possible. The value of lignin content indicates that milder conditions of pulping will be required to obtain a satisfactory Kappa number and bleaching will be at a faster rate and fewer chemicals will be utilized (Saikia et al., 1997).

Table 3: Variations in the lignin content of the two tree species

<table>
<thead>
<tr>
<th>Properties</th>
<th>10%</th>
<th>50%</th>
<th>90%</th>
<th>mean</th>
<th>Correlation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pinus</em> (%)</td>
<td>29.22</td>
<td>26.96</td>
<td>26.11</td>
<td>27.43±0.93</td>
<td>0.9983</td>
<td>0.3568ns</td>
</tr>
<tr>
<td><em>Gmelina</em> (%)</td>
<td>30.75</td>
<td>26.30</td>
<td>24.15</td>
<td>27.07±1.94</td>
<td>** = significant at 2-tail</td>
<td></td>
</tr>
</tbody>
</table>

Morphological characteristics of fibre like length and width are important parameter to estimate the pulp quality (Sharma et al., 2013). The result of the t-test shows that the fibre length of the two species did not differ significantly. The fibre lengths of Pinus caribaea were greater than those of Gmelina arborea across the three levels except for the 10% tree level (Table 4). The mean fibre lengths were 154.23±0.75μm and 148.49±0.82μm for Pinus caribaea and Gmelina arborea trees respectively. This result indicates uniformity in fibre length produced by the two species, which may be attributed to the fact that trees at their mature stages of growth usually produce wood features of uniform values, until senescence stage is reached when the value begins to drop (Akachuku, 1982). A regular pattern of variation was recorded in both species as the fibre length decreased linearly from base (10% tree level) to the top (90% tree level). Both species exhibited short fibre length. Their mean fibre length were lower than 1600μm classified as short while those above 1600μm are said to be long (Metcalfe and Chalk 1983). In similar observation, Kpikpi (1992) reported fibre lengths of less than 1.60mm in some Nigerian hardwood species. Oluwadare (2007) recorded 0.65 mm as fibre length for Leucaena leucocephala. Similar fibre length ranges of 1.50 to 2.9 mm and 1.46 to 2.91 mm were recorded for bamboos in Sudan and Thailand respectively (Khristova et al., 2005). However, according to Oluwadare, (1998), these values are of acceptable range for hardwoods for paper making.
CONCLUSION
The study indicates that there still exist the suitability of the use of matured trees of Pinus caribaea and Gmelina arborea for pulp and paper making especially in the deficiency of immediate alternative. This is because their physical and chemical properties are still within the accepted limit for production of quality pulp and paper.

REFERENCES
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