PHYSICAL AND CHEMICAL FEATURES OF SOME AGRICULTURAL RESIDUES AND GRASSES AS ALTERNATIVE TO PULP AND PAPER PRODUCTION

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Abstract

The growing concern about the rising cost and diminishing supply of wood fibre has created a renewed interest in adopting alternative fibre sources in the manufacture of paper and paper products. This study investigated the suitability of selected agricultural residues (Sorghum bicolor, Panicum miliaceum, Abelmoschus esculentus and Hibiscus sabdariffa) and grass fibres (Oryza longistaminata and Hyparrhenia involucrata) obtained from the Federal University of Agriculture, Makurdi, Nigeria. Fibre dimensions of samples were determined by reducing samples into chips and placed into an equal volume of glacial acetic acid and Hydrogen peroxide in ratio 1:1. Macerated fibres were mounted on a slide in Reichert Visopan Microscope to determine fibre physical features. Proximate chemical analysis was done using Tappi Standard Method. Results show that Hyparrhenia involucrata had the longest fibre length of 2.23 mm while Oryza longistaminata had the least (0.24 mm). Abelmoschus esculentus had the least runkel ratio of 0.50 followed by Sorghum bicolor (0.73), Hibiscus sabdariffa and Panicum miliaceum with 0.78, respectively. While Felting rate, Elasticity coefficient, Rigidity coefficient, and F ratio ranged from 134.76 - 24.76, 66.57% - 45.88%, 27.06% - 16.71%, and 51,111.27% - 9,211.07%, respectively. Results of chemical analysis shows that ash content, Hot water solubility, Ethanol Toluene solution, Cold water solution, lignin, Hemicellulose, Alkali, and Cellulose ranged from 3.86 % - 11.00 %, 0.58 % - 7.21%, 1.11 % - 22.30%, 0.46% - 12.06%, 5.86% - 25.90%, 15.70% - 57.43%, 3.01% - 23.22%, and 14.32% - 68.21%. The outcome of the study indicated that agricultural residues and grasses are propitious fibrous raw material for the paper production.

Keywords: Fibre, agricultural residues, grasses, pulp, paper

Introduction

Paper and paper products in today's world play a very important role in everyday life. The consumption of paper per capita correlates closely with gross domestic products (Diesen, 2000), and also with the standard of welfare and education. It is said to be synonymous with development in the contemporary world. The manufacture of pulp and paper is basic to education, printing, publication and numerous packaging applications. At home, paper is used to clean, to dry things, and for so many other purposes. In short, paper is one of the most versatile and common products of modern societies (Gerboni, 2005).

World paper output increased from 0.8% to 410 million tons in 2017 (Euler, 2018). Essien, (2017) reported that as a result of the declining state of the three current paper mills in Nigeria, the country was losing over N400 billion every year because of paper products importation. About 4 billion representing 35% of the entire trees felled everywhere in the world are used in paper industries on every continent (Martin, 2011). World demand for paper has increased at an average annual rate of 4.7% over the past 40 years. Although future growth will reduce to 2 -3% because of the advent of internet and computers facilities, the existing wood resources may be inadequate to meet this growing demand for paper especially in the Asia-Pacific region and Eastern Europe (Talebizadeh and Rezayati, 2010). The total global consumption of paper was projected to increase from 316 million tons in 1999 and 351 million tons in 2005 to about 425 million tons in 2010 (García et al., 2008).

Wood is by far is the major raw material for global pulp and paper industry. It is, however, a relatively new raw material in papermaking. Historically, paper was made exclusively from nonwood plant fibres. According to Atchson and McGovern, (1993), the first made paper was from textile wastes, old rags and used fishnets, which consist of fibre of the true hemp and China grass (ramie). While nonwood was originally used for papermaking, in the seventeenth century, wood became the predominant fibre source in Europe. The seemingly inexhaustible supply and versatility of wood were the major causes of the shift. Currently, most modern pulp paper enterprises depend on wood material (Smook, 1992).
Paper industry is a forest-based industry. Depleting forest cover is a major cause of concern because of the adverse environmental implications of such activities (Vivek and Maheswari, 1998). In order to meet the increased demand for pulp and paper, researchers are looking for alternative sources of pulp supply that is both cost-effective and physically similar to traditional pulps. An added motivation to find new sources of wood pulp has risen out of environmental concern and regulations (Joey et al., 1998).

Materials and Methods

Study Area

The study was conducted at the Federal University of Agriculture, Makurdi (FUAM), Benue State, Nigeria. The ecology of Benue State known as the Food Basket of Nigeria supports extensive arable cropping and livestock production as well as fruit, palm, grains, legumes, root and tuber production. Benue State lies within the coordinates 7°47' and 10°00' East, 6°25' and 8°08' North. Sited on the bank of River Benue, and located about 300 km South of the Federal Capital, Abuja and 800 km North of the commercial city of Lagos (Gyang, 1997). The pulp and papermaking process was done at the Department of Forest Production and Products' laboratory.

Materials

Sample materials were obtained from agricultural wastes with long/tall stalks which include: Sorghum (Sorghum bicolor L.) straw and Millet (Panicum miliaceum L.) straw. Waste from crop residues with short straws were obtained from Okra (Abelmoschus esculentus) (L.) Moench stalks and Roselle Plant (Zobo) (Hibiscus sabdariffa) L. Stalks while grass materials were selected from Oryza longistaminata A. Chev. and Roehr and Hyparrhenia involucrata Stapf. The agricultural wastes and grasses were purposively collected from Federal University of Agriculture Teaching and Research Farm and within the university land. The stalk of each sample was chopped and chipped into small size of about 50 mm for the experimental procedure.

Fibre Dimension Determination

Fibre dimensions were determined by reducing some representative chips of the raw materials into the core and placed into an equal volume of glacial acetic acid and Hydrogen peroxide in ratio 1:1 in a covered bottle. The macerated cores were disintegrated by shaking the bottle to release the fibres. The fibre for each material was mounted on a slide and the fibre length (L), fibre diameter (D), lumen width (d), and cell wall thickness would be measured under a Reichert Visopan Microscope. The following morphological indices also called important criteria in papermaking were determined using the following five equations according to Kırcı, 2006.

\[
FR = \frac{FL}{FD} \quad \text{Equation i} \\
EC = \frac{LD}{FD} \times 100 \quad \text{Equation ii} \\
RC = \frac{CWT}{FD} \times 100 \quad \text{Equation iii} \\
RI = 2 \left( \frac{CWT}{LD} \right) \quad \text{Equation iv} \\
Fr = \frac{FL}{CWT} \times 100 \quad \text{Equation v}
\]

Where:

FR - Felting rate
FL - Fibre length
FD - Fibre diameter
EC Elasticity (Flexibility) coefficient
LD - Lumen diameter
RC - Rigidity coefficient
CWT - Cell wall thickness
RI - Runkel index
Fr - F ratio

The derived values were compared with those of softwoods and hardwoods to assess the suitability of the plant raw materials for paper production. The Runkel ratio would show the pulpability of the raw
Physical and Chemical Features of Some Agricultural Residues

Material. The determination of fibre dimension was done at the Forest Research Institute of Nigeria (FRIN) Ibadan.

Proximate Chemical Analysis

The experimental samples were chopped and powdered in a Willey mill and portion was passed through 40 mesh and retained on 60 mesh. The proximate chemical analysis was carried out as per Tappi Standard Method. The raw materials were analyzed for lignin, ash content, hot and cold-water solubility, and cellulose contents using Tappi T 222 om-88, Tappi T 211 om-85, Tappi T 207 om-88, and Kurscher-Hoffer nitric acid method respectively (Tutus, et al., 2010; Kurschner-Hoffer, 1993; Sadiku et al., 2016). This experiment was carried out at the Federal Institute of Industrial Research Oshodi (FIRRO) Lagos.

Data Analysis

Data from the study were subjected to one-way analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was used to separate means of the raw materials using the appropriate statistical software.

Results

Table 1 shows fibre morphology of studied samples. The results indicate that Hyparrhenia involucrate had the highest fibre length of 2.23 mm while Oryza longistaminata had the least (0.24 mm) and are significantly different at p<0.05. Other mean values of fibre length are, Panicum miliaceum stalk (0.98 mm) Abelmuschus esculentus stalk (0.93 mm), Hibiscus sabdariffa stalk (0.90 mm), and Sorghum bicolor stalk (0.77 mm). These means are not significantly different at p<0.05.

Abelmuschus esculentus stalk had the highest fibre diameter of 26.38 µm followed by Hibiscus sabdariffa stalk (19.25 µm), Hyparrhenia involucrate (17.25 µm) and Panicum miliaceum stalk (15.56 µm). The means are significantly different at p<0.05. However, the fibre diameter of Oryza longistaminata (9.94 µm) and Sorghum bicolor stalk (9.19 µm) are not significantly different p<0.05.

Mean value of fibre lumen width shows that, Abelmuschus esculentus stalk was highest (17.56 µm) followed by Hibiscus sabdariffa stalk (10.81 µm) and they are significantly different at p<0.05. Panicum miliaceum stalk had a mean value of lumen width 8.75 µm which is not significantly different from Hyparrhenia involucrate grass (8.00 µm). Sorghum bicolor stalk and Oryza longistaminata grass had the lowest mean value of 5.31 µm and 4.56 µm respectively, and are not significant.

Mean values of fibre cell wall thickness of Hyparrhenia involucrate grass, Abelmuschus esculentus stalk and Hibiscus sabdariffa stalk (4.63 µm, 4.41 µm, and 4.22 µm) respectively are not significantly different but differ significantly from mean values of Panicum miliaceum stalk (3.41 µm), Oryza longistaminata grass (2.69 µm) and Sorghum bicolor stalk (1.94 µm).

Table 1: Fibre morphology of samples

<table>
<thead>
<tr>
<th>S/No</th>
<th>Samples</th>
<th>Fibre Length (mm)</th>
<th>Fibre Diameter (µm)</th>
<th>Fibre Lumen Width (µm)</th>
<th>Fibre Cell wall Thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abelmuschus esculentus stalk</td>
<td>0.93±0.19 abcde</td>
<td>26.38±5.95 f</td>
<td>17.56±5.57 e</td>
<td>4.41±1.06 c</td>
</tr>
<tr>
<td>2</td>
<td>Hibiscus sabdariffa stalk</td>
<td>0.90±0.16 cde</td>
<td>19.25±4.61 v</td>
<td>10.81±2.16 d</td>
<td>4.22±1.61 c</td>
</tr>
<tr>
<td>3</td>
<td>Panicum miliaceum stalk</td>
<td>0.98±0.38 cde</td>
<td>15.56±4.09 i</td>
<td>8.75±2.56 c</td>
<td>3.41±1.29 d</td>
</tr>
<tr>
<td>4</td>
<td>Sorghum bicolor stalk</td>
<td>0.77±0.28 abc</td>
<td>9.19±2.82 b</td>
<td>5.31±2.18 ab</td>
<td>1.94±0.67 ab</td>
</tr>
<tr>
<td>5</td>
<td>Hyparrhenia involucrate</td>
<td>2.23±0.46 d</td>
<td>17.25±4.56 c</td>
<td>8.00±3.30 b</td>
<td>4.63±1.22 c</td>
</tr>
<tr>
<td>6</td>
<td>Oryza longistaminata</td>
<td>0.24±0.07 a</td>
<td>9.94±1.79 abc</td>
<td>4.56±1.30 abc</td>
<td>2.69±0.46 abed</td>
</tr>
</tbody>
</table>

The result of fibre morphology in Table 2 shows that Abelmuschus esculentus stalk had the least Runkel ratio of 0.50 followed by Sorghum bicolor stalk 0.73, Hibiscus sabdariffa stalk and Panicum miliaceum stalk with same mean value of 0.78 respectively. These mean values are not significantly different. However, the values are significantly different from that of Oryza longistaminata grass (1.18) and Hyparrhenia involucrate grass (1.16) which are not significant at p<0.05.

The result also reveals the mean values of felting rate (slenderness) of studied samples. The highest mean value was recorded for Hyparrhenia involucrate grass (134.76) followed by Sorghum bicolor stalk (90.66) and the means are significantly different. Nevertheless, the means differ significantly from the means of Panicum miliaceum stalk (66.70), Hibiscus sabdariffa stalk (49.53), Abelmuschus esculentus stalk (37.35) and Oryza longistaminata grass (24.76).
values of elasticity coefficient were highest in *Abelmoschus esculentus* stalk (66.57%) and it is significantly different from the means of *Sorghum bicolor* stalk (57.78%), *Panicum miliaceum* stalk (56.23%) and Hibiscus sabdariffa stalk (56.16%). The means of *Hyparrhenia involucrate* grass and *Oryza longistaminata* stalk (46.38%) and *Abelmoschus esculentus* stalk were the lowest and are not significantly different.

Means of rigidity coefficient results show that *Oryza longistaminata* grass (27.06%) was highest followed by *Hyparrhenia involucrate* grass (26.84%) and are not significantly different from means of *Hibiscus sabdariffa* stalk, *Panicum miliaceum* stalk and *Sorghum bicolor* stalk.

The F ratio values of *Hyparrhenia involucrate* grass and *Sorghum bicolor* stalk were 51,111.27% and 44,583.33% respectively and are not significantly different. Nevertheless, the values are significantly different from that others samples of *Sorghum bicolor* stalk (44,583.33%), *Panicum miliaceum* stalk (32,023.06%), *Hibiscus sabdariffa* stalk (25,056.79%) and *Abelmoschus esculentus* stalk (21,919.44%). However, F ratio for *Oryza longistaminata* grass was least (9,211.07%) and is significantly different from all other samples.

Table 2: Derived indices of agricultural residues and grasses

<table>
<thead>
<tr>
<th>S/No.</th>
<th>Samples</th>
<th>Runkel ratio</th>
<th>Felting rate (Slenderness)</th>
<th>Elasticity coefficient (%)</th>
<th>Rigidity coefficient (%)</th>
<th>F ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Abelmoschus esculentus</em> stalk</td>
<td>0.50±0.22a</td>
<td>37.35±0.01ab</td>
<td>66.57±0.00d</td>
<td>16.71±0.00</td>
<td>21,919.44±5.39b</td>
</tr>
<tr>
<td>2</td>
<td><em>Hibiscus sabdariffa</em> stalk</td>
<td>0.78±0.28ab</td>
<td>45.93±0.01b</td>
<td>56.16±0.00c</td>
<td>21.92±0.00</td>
<td>25,056.79±10.71bc</td>
</tr>
<tr>
<td>3</td>
<td><em>Panicum miliaceum</em> stalk</td>
<td>0.78±0.43abc</td>
<td>66.70±0.03c</td>
<td>56.23±0.00c</td>
<td>21.85±0.00c</td>
<td>32,023.06±13.37bdc</td>
</tr>
<tr>
<td>4</td>
<td><em>Sorghum bicolor</em> stalk</td>
<td>0.73±0.32ab</td>
<td>90.66±0.04d</td>
<td>57.78±0.00c</td>
<td>21.11±0.00</td>
<td>44,583.33±21.09f</td>
</tr>
<tr>
<td>5</td>
<td><em>Hyparrhenia involucrate</em> grass</td>
<td>1.16±0.98ab</td>
<td>134.76±0.03f</td>
<td>46.38±0.00ab</td>
<td>26.84±0.00e</td>
<td>51,111.27±15.63f</td>
</tr>
<tr>
<td>6</td>
<td><em>Oryza longistaminata</em> grass</td>
<td>1.18±0.43cde</td>
<td>24.76±0.01e</td>
<td>45.88±0.00e</td>
<td>27.06±0.00d</td>
<td>9,211.07±3.70e</td>
</tr>
</tbody>
</table>

Mean value of cellulose solution was greatest (68.21%) in *Panicum miliaceum* stalk and least (14.32%) in *Abelmoschus esculentus* stalk. Other mean values are *Sorghum bicolor* (58.98%), *Hyparrhenia involucrate* grass (58.65%), *Hibiscus sabdariffa* stalk (37.82%), and *Oryza longistaminata* grass (28.77%). Means of all samples are significantly different at p<0.005.

The results of chemical characteristics of samples of Table 3 showed that *Hyparrhenia involucrate* grass had the highest (11.00%) ash content followed by *Sorghum bicolor* stalk (10.12%) while, *Panicum miliaceum* stalk and *Abelmoschus esculentus* stalk had 8.00% respectively. Other values of ash contents were *Hibiscus sabdariffa* stalk (5.25%) and *Oryza longistaminata* grass with the least of 3.86%. Mean ash contents of all samples are significantly different at p<0.005.

The mean of hot water solution of samples was again maximum (7.21%) in *Hyparrhenia involucrate* grass, greater than the one of *Hibiscus sabdariffa* stalk (7.09%), *Sorghum bicolor* stalk (5.71%), *Oryza longistaminata* grass (3.23%). Also, *Abelmoschus esculentus* stalk had (1.01%) while the least was 0.58% in *Panicum miliaceum* stalk. Hot water solution of samples is significantly different at p<0.005.
Abelmoschus esculentus stalk and Hibiscus sabdariffa stalk respectively. Mean values of cold-water solution were significant at p<0.005.

Lignin content of samples was maximum (25.90 %) in Sorghum bicolor and minimum (5.86 %) in Sorghum bicolor Hyparrhenia involucrate grass. Others include Hibiscus sabdariffa stalk (23.78 %), Panicum miliaceum stalk (16.82 %), Oryza longistaminata grass (7.88 %) and Abelmoschus esculentus stalk (6.88 %). Means of esculentus lignin content of all samples are significantly different at p<0.005.

The mean value of hemicellulose was highest (57.43%) in Oryza longistaminata grass. This was followed by Sorghum bicolor stalk (41.95 %), Hibiscus sabdariffa stalk (29.16 %), Hibiscus sabdariffa stalk (25.84 %), Panicum miliaceum stalk (23.87 %), and least (15.70 %) in Abelmoschus esculentus stalk. Means of all samples are significantly different at p<0.005.

Table 3: Chemical properties of agricultural residues and grasses

<table>
<thead>
<tr>
<th>S/No</th>
<th>Samples</th>
<th>N</th>
<th>Ash content (%)</th>
<th>Hot water solution (%)</th>
<th>Ethanol Toluene solution (%)</th>
<th>Cold water solution (%)</th>
<th>Lignin (%)</th>
<th>Hemi cellulose (%)</th>
<th>Alkali (%)</th>
<th>Cellulose solution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abelmoschus esculentus</td>
<td>5</td>
<td>8.00±0.00c</td>
<td>1.01±0.02</td>
<td>1.11±0.02b</td>
<td>2.50±0.02c</td>
<td>6.88±0.13c</td>
<td>15.70±0.02</td>
<td>12.52±0.02</td>
<td>14.32±0.02</td>
</tr>
<tr>
<td>2</td>
<td>Hibiscus sabdariffa</td>
<td>5</td>
<td>5.25±0.016d</td>
<td>7.09±0.02</td>
<td>12.44±0.21i</td>
<td>0.46±0.20c</td>
<td>23.78±0.02d</td>
<td>29.16±0.02</td>
<td>9.09±0.06</td>
<td>37.82±0.02</td>
</tr>
<tr>
<td>3</td>
<td>Panicum miliaceum</td>
<td>5</td>
<td>8.00±0.00c</td>
<td>0.58±0.02</td>
<td>1.75±0.02c</td>
<td>10.03±0.02c</td>
<td>16.82±0.02c</td>
<td>23.87±0.02</td>
<td>3.01±0.02</td>
<td>68.21±0.02</td>
</tr>
<tr>
<td>4</td>
<td>Sorghum bicolor</td>
<td>5</td>
<td>10.12±0.011f</td>
<td>5.71±0.02</td>
<td>15.06±0.21f</td>
<td>7.40±0.02f</td>
<td>25.90±0.02f</td>
<td>41.95±0.02</td>
<td>11.10±0.02</td>
<td>58.98±0.00</td>
</tr>
<tr>
<td>5</td>
<td>Hyparrhenia involucrate</td>
<td>5</td>
<td>11.00±0.00e</td>
<td>7.21±0.02</td>
<td>22.30±0.02e</td>
<td>12.06±0.02e</td>
<td>5.86±0.02e</td>
<td>25.84±0.02</td>
<td>23.22±0.02</td>
<td>58.65±0.02</td>
</tr>
<tr>
<td>6</td>
<td>Oryza longistaminata</td>
<td>5</td>
<td>3.86±0.02e</td>
<td>3.23±0.02</td>
<td>11.80±0.02</td>
<td>7.55±0.02e</td>
<td>7.88±0.02e</td>
<td>57.43±0.02</td>
<td>2.84±0.02</td>
<td>28.77±0.02</td>
</tr>
</tbody>
</table>

Discussion
Physical Properties of Agricultural Residues and Grasses

Fibre Length
The quality of paper and paper products influence among other qualities the fibre length. The fibre length of Hibiscus sabdariffa stalk, Abelmoschus esculentus stalk, Panicum miliaceum stalk, and Hyparrhenia involucrate which ranged between 0.90 mm - 2.23 mm, falls within fibres (0.7-1.6 mm) of hardwoods and far from 2.7-4.6 mm in softwoods as reported by Ates et al., (2008). This implies that these nonwood materials can produce a smoother paper of lower strength property compared to softwood fibres according to Biermann, (1996). However, the fibre length of Hyparrhenia involucrate was longest (2.23 mm) and is within the mean fibre length of 2.30 mm in Bambooreported by Deniz and Ates, (2002), 2.60 mm in Kenaf stalks as obtained by Atchison,(1993) and is higher than 1.52 mm and 1.59 mm reported by Eroglu et al., (1992); Samariah and Khakifirooz, (2011) for Cotton and Bagasse respectively.

Fibre Diameter
Fibre diameter in this study ranged from 9.19 µm - 26.38 µm with Abelmoschus esculentus being highest (26.38 µm). The mean fibre width of rice residues was reported by Kiaei and Veylaki (2011) to be 10.30 µm which is lower than 20.96 µm reported for Bagasse by Samariah and Khakifirooz, (2011). Enayati et al., (2009) reported 23.02 µm for Canola while Eroglu et al., (1992) recorded 26.8 µm for Tobacco as Deniz and
Ates (2002) obtained 15.1 μm for Bamboo. However, the fibre diameter in this study is lower than 32-43 μm for softwood fibres and fall within hardwood fibres (20-40 μm) as reported by Atchison (1987). Dutt and Tyagi, (2011) noted that the diameter and wall thickness of fibre influence fibre flexibility which affects the beating of pulp, bursting and tensile strengths as well as folding endurance of paper.

Fibre Lumen Width
The average fibre lumen width ranged from 4.56 - 17.56 μm and maximum in Abelmoschus esculentus stalk. These values are within results obtained by Kiaei and Veylaki (2011) for rice residues (4.56 μm), Bamboo (6.9 μm) by Deniz and Ates (2002), Bagasse (9.72 μm) recorded by Samariha and Khakifirooz, (2011) and Canola (12.50 μm) and Tobacco (16.3 μm) reported by Eroglu et al., (1992) respectively.

Cell Wall Thickness
The average cell wall thickness obtained in this research ranged from 1.94 μm - 4.63 μm with Hyparrhenia involucrata having the highest value. These values are within results of Bagasse (5.63 μm), rice residues (2.86 μm), Canola (5.26 μm), Tobacco (5.3 μm), Sunflower (3.3 μm), Cotton (3.6 μm), Bamboo (4.17 μm) and Corn (2 μm) as reported by Samariha and Khakifirooz (2011); Kiaei and Veylaki (2011); Enayati et al., (2009); Eroglu et al., (1992); Deniz and Ates (2002) respectively. Kiaei and Veylaki (2011) hassignificant consequence of physical resistance of paper.

Derived Properties of Test Samples

Runkel Ratio
The suitability of any fibrous material for pulp and paper production is determined using the Runkel ratio values reported for agricultural waste and grasses in this study ranged from 0.50 in Abelmoschus esculentus stalk to 1.18 Oryza longistaminatagras. The mean values of Hibiscus sabdariffa stalk, Panicum miliaceum stalk, and Sorghum bicolor stalk indicate that will be very good for paper production with Abelmoschus esculentus being the best. Sharma et al., (2013) reported 0.25 for Solanum torvum and Sida cordifolia respectively. Kiaei and Veylaki (2011) reported Runkel ratio of 1.38 for rice residues as Garay et al., (2009) documented 0.47 and 0.90 for wheat and corn respectively. However, Deniz and Ates (2002) reported 1.20 for Bamboo while Bagasses (1.15) was noted by Samariha and Khakifirooz (2011). Runkel ratio value of 0.65, 0.42, and 0.31 was reported correspondingly for Tobacco, Sunflower, and Cotton by Eroglu et al. (1992). Runkel ratio as a derived value from the inverse of wall thickness of fibre to lumen width of fibre is regarded as one of the utmost significant and primary parameters required to finding the suitability of cellulose material for pulp and paper making (Ogunjobi et al., 2014). Cellulose fibre materials having Runkel ratio < 1 are reported good for papermaking since fibres collapse easily, are better flexible, and produce paper with huge bonded area as, fibres with Runkel ratio > 1 are rigid, hard to collapse and produce heavier paper with reduced bonded area (Sharma et al., 2013).

Felting Rate (Slenderness)
The tearing features of paper are determined by felting rate. In this study, felting rate ranged from lowest of 37.35 in Oryza longistaminata highest of 134.76 in Hyparrhenia involucrata. The low felting ratio in some of the species could be the presence of short fibres (Sharma et al., 2015). When the felting rate of
The higher the rate of rigidity coefficient distresses tear, (Akkayan, 1983). Ekhuemelo and Udo (2016) noted that as the rigidity of fibre increases there is the corresponding decrease in fibre bonding in paper sheet (Sharma et al., 2013). When the felting rate of fibrous material is more than 33, it is regarded good for pulp and paper making (Xu et al., 2006). Ates et al., (2008) reported that, when fibrous material is lower than 70 in felting rate, it is considered useful for quality pulp and papermaking. Consequently, high felting rate gives lower strength properties of paper. The strength characteristics of papers have been found to positively correlate with its felting coefficient (Ates et al., 2008).

Elasticity (Flexibility) Coefficient (%)
Flexibility coefficient governs the rate of fibre bonding in paper sheet (Sharma et al., 2013). Values obtained ranged from a minimum of 45.88 % in Oryza longistaminata a maximum 66.57 % in Abelmoschus esculentus stalk. Beketas et al. (1999) categorized cellulose fibres into four classes which include (i) Highly elastic to have flexibility coefficient >75% (ii) Elastic fibres when flexibility coefficient is 50 -70% (iii) Rigid fibres with flexibility coefficient between 30 - 50 % and, (iv) Very rigid fibres with <30% flexibility coefficient. Based on this classification, Hibiscus sabdariffa stalk, Panicum miliaceum stalk, Hyparrhenia involucrate stalk, Sorghum bicolor stalk, Hyparrhenia involucrate grass Oryza longistaminata grass fibres have rigid fibres while Abelmoschus esculentus stalk has elastic fibres. Ates et al., (2008) reported that when fibre elasticity coefficient is between 50 % and 70 %, the fibre would give a flat and good paper with high strength properties. It implies that Abelmoschus esculentus stalk will produce flat and good paper with high strength features. It is important to note that the lower the fibre diameter the lower the have flexibility coefficient (Hussin et al., 2014).

Rigidity Coefficient (%)
Rigidity coefficient regulates physical resistance characteristics of paper. The highest (27.06%) rigidity coefficient in this work was in Oryza longistaminata grass. This is in line with that of hardwoods (27.80%) reported by (Bektas et al., 1999). The least (21.11%) was noted in Sorghum bicolor stalk which is higher than 19.97 obtained in P. sylvestris, a softwood by (Akkayan, 1983). Ekhuemelo and Udo (2016) noted that the high rate of rigidity coefficient distresses tear, burst, tensile, and double fold resistance of paper undesirably. So, it implies that the lower rigidity coefficient recorded in this study indicate that the samples would be good for pulp and paper production. It noted by Akgu and Tozlugu (2009) that as the rigidity of fibre increases there is the corresponding decrease in fibre bonding.

F Ratio
F ratio mean value ranged from 9.211.07 to 51.111.27 which was highest in Hyparrhenia involucrata grass and lowest in Oryza longistaminatagrace. This result is at variance with Akgul and Tozlugu (2009) who reported 140.38 F factor for beech juvenile wood, and 240.55 in black pine juvenile wood. The F ratio result of this study also does not agree with Kar (2005) other studies, on hardwoods where F factor was reported to be 235.92 in Populusxerocana and 206.78 in Populus tremula.

Chemical Properties of Test Samples

Ash Content (%)
After the whole burning of the wood material at 575±25°C, the remain is ash content (Al-Mefarrejet al., 2013). The ash content of his research ranged from 3.86 % in Oryza longistaminata 11.00 % in Hyparrhenia involucrate. These values are higher than 2.35% - 2.86% of different age and position of Bambusa vulgaris reported by Sadikuet al., (2016). Tutus et al., (2010) reported an ash content of 7.83% for Crambeorientalis and 9.3% for Crambetataria. respectively. Kristova and Karar, (1999) noted that high ash is not good for pulping because they influence usual alkali consumption and create difficulty in recovery of pulping chemicals and operational challenges in material handling, pulp washing and beating in addition to bleaching interference reported by Duttet al., (2009). Walliet al., (2009) stated that the ash content of wood provides information on the idea of inorganic portion and non-volatile of raw material. Al-Mefarrejet al., (2013) affirmed that there is a relationship between paper strength and ash content and as result, paper strength decreases as the ash content increases. So, it is expected that the strength of paper produced from Oryza longistaminata will be low.

Hot Water Solution (%)
Hot water solubility ranged from 0.58 % in Panicum miliaceum stalk to 7.21% in Hyparrhenia involucrata grass. These are higher than 4.05% - 11.96% reported by Sadikuet al., (2016) for various ages and portions of Bambusa vulgaris. Water solubility of wood signifies the low molecular weight compounds and polysaccharides (Walia et al., 2009). Generally, a wood material with lower cold and hot water soluble possess higher lignin content while the those with high values of cold and hot water soluble have more active cells Latib et al., (2014).

Ethanol Toluene Solution (%)
Ethanol Toluene solution ranged from 1.11 % for Abelmoschus esculentus stalk to 22.30 % in...
Hyparrhenia involucrata. This agrees with 14.5% for banana stem reported by (Kumar and Kumar, 2011).

Cold Water Solution (%)
Cold water solution ranged from 0.46% in Hibiscus sabdariffa stalk to 12.06% in Hyparrhenia involucrata stalk. These values agree with 1.76% - 6.63% for Bambusa vulgaris obtained by Sadiku et al., (2016). Cold and hot water soluble are significant in the assessment of water-soluble extracts like sugar, tannin,pectin, starch, and phenolic compounds within any lignocellulosic material (Jamaludin, 2006).

Lignin (%)
In this study, lignin ranged from a minimum of 5.86% in Hyparrhenia involucrata stalk to a maximum of 25.90% in Sorghum bicolor stalk. The result is consistent with 13.51% for Cupressus sempervirens a softwood and 16.31% for Populus alba, 12.15% for Eucalyptus camaldulensis, 17.56% for Acacia nilotica which are hardwood as by reported Soliman et al., (2017). Tutus et al., (2010) obtained 24.5% for Crambeorientalis. However, the values are below (29.24% - 45.90%) for Bambusa vulgaris obtained by Sadiku et al., (2016). Ogunsile and Uwajeh, (2009) reported that high lignin value requires more penetrating delignification, high chemical consumption, and long cooking cycle. Low lignin content in materials requires slight conditions of pulping like reduce cooking time and temperature. Consequently, energy requirements and cost of production would be reduced (Omotosho and Ogunsile, 2009).

Hemicellulose (%)
Hemicellulose ranged from the least of 15.70% in Abelmoschusesculentus stalk to highest value of 57.43% in Oryza longistaminatagrass. These values are within the range of 34.43 to 35.97% in Triticum aestivum reported by Al-Mefarrej et al., (2013). These are higher than 4.13% - 10.58% reported by Sadiku et al., (2016), 8.66% - 18.88% of Eucalyptus spp reported by Dutt and Tyagi, (2011) and lower than many annual plants and coniferous (68-74%) reported by Ates et al., (2008). Tyagi et al., (2004) stated that the higher the hemicellulose content; healthier the swelling behaviour of pulp, which results to a rise in mechanical strength properties, along with burst indexes, double folds tensile, and decrease in beating or refining energy.

Alkali (%)
Alkali in this research ranged from 2.01% in Panicum miliaceum stalk to 23.22% in Hyparrhenia involucrata. This agrees with an alkali-soluble of Neolamarckiacadamba which ranged from 17.50% - 18.83% reported by Latib et al. (2014). Jamaludin (2006) noted that high alkali soluble correspond to high degradation of cellulose and low polyphenol content. He further stated that in the pulping process, such property would give aid its high holocellulose content which however results in lower yield.
References


Hurter, R.W., Riccio, F.A., (1998): Why CEO's don't want to hear about nonwoods—or should they? In: TAPPI Proceedings, NA NonwoodFibre Symposium, Atlanta, GA,


