FIBRE CHARACTERISTICS AND CHEMICAL COMPOSITION OF *PANICUM MAXIMUM* (GUINEA GRASS) BIOMASS FOR PACKAGING PAPER PRODUCTION

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With a rising demand for eco-friendly alternatives to wood for pulp and paper production, *Panicum maximum* (Guinea grass) shows promise due to its fast growth, high biomass yield, and climate adaptability. This study assessed the plant's morphological and chemical suitability. Fibre analysis revealed suitable average fibre length, diameter, lumen width and thickness of the cellular layer (0.85 mm, 9.723 µm, 3.258 µm and 6.465 µm) for the leaf blade, (0.95 mm, 11.978 µm, 5.159 µm, 6.819 µm) for the midrib and (1.321 mm, 14.648 µm, 5.798 µm, 8.815 µm) for the stalks. Fibre indices, such as slenderness ratio, Luce's shape factor, and solids factor, indicated good fibre elasticity and collapse potential, favorable for papermaking. Chemical analysis showed suitable composition of 37% cellulose, 25.05% hemicelluloses, and 16.56% lignin, though high caustic soda solubility and ash content suggest low pulp yield. While suitable for general paper production, the high Runkel and rigidity ratios suggest the resulting paper would be stiff, making it ideal for packaging applications.

Keywords: non-wood fibres, *Panicum maximum*, pulp, packaging, paper

INTRODUCTION

Paper is an essential daily-use commodity that contributes to sectors such as education, communication and product packaging. Despite the electronic revolution, the demand for paper and paper products is expected to rise in the years to come.[1,2] Historically, paper was made from non-wood plant fibres,[3] and today, non-wood fibres are making a comeback in paper-making, as there are increasing concerns over deforestation and other environmental issues.[4] Still, currently, the most common raw material in producing paper and paperboard is wood pulp obtained from softwoods and hardwoods, which consists primarily of cellulose, hemicelluloses and lignin.[5] Pulp is the fibrous raw material for producing paper, paperboard, corrugated boards amongst other products.[6] Pulping involves the liberation of fibres from the lignocellulosic plant material, by either mechanical, thermal, chemical processes or a combination of treatments.[6,7]

In recent years, the global production of paper and paperboard has increased by more than 40 percent led by the demand for eco-friendly packaging solutions.[8] Based on a report by Fortune Market Insights, the growing initiative for sustainable environmental development will fuel the market growth of paper from USD 360.98 billion to 391.39 billion by 2032, exhibiting a 1.0% compound annual growth rate. Therefore, many countries are looking for alternative fibres among their readily available non-wood resources to fill the deficit, owing to the scarcity and increasing prices of wood resources.[9]

The effective use of non-wood fibre resources, especially grasses, would play a major role in the optimization of papermaking raw materials.[10] The use of non-woody raw materials provides a way forward due to its abundance and scarcity of wood resources.[11] Non-wood fibre is advantageous over wood fibre because its lower lignin content makes it easier to delignify.[12] Researchers found non-wood fibre to possess good qualities that makes it suitable to be utilized for papermaking. For instance, non-wood raw material produces pulp that has higher adhesion force, which is attributed to higher hemicelluloses, short average fibre length and higher parenchyma cells.[10] Hence, the usage of non-wood fibres is expected to increase in the coming years.[11]

Panicum maximum (Guinea grass) is a clump forming perennial grass in West and Central Africa and other tropical regions.[13,14] It is a tall, erect, tufted and robust grass, which can grow to about 3 to 4 metres.[15] Given its success as a forage species, Guinea grass has undergone an extensive cultivation, but because of its invasiveness, it has escaped its target pasture and invaded recently disturbed sites, spreading along roadsides and into native grasslands, savannas, and forests.[15] The traits of *Panicum maximum* that make it highly invasive include its highly viable seeds, insect resistance, rapid seed growth, drought tolerance amongst others.[15] These traits allow it to spread rapidly, maintain high reproductive potential, and produce long lived robust adults that are highly competitive.[16,17]

The main goal of this study was therefore to characterize chemically and morphologically *Panicum maximum* (Guinea grass), by evaluating the potential of its fibres as alternative raw material for the pulp and papermaking industry. The success of *Panicum maximum* in this regard would control the ecological damage from its invasiveness as well as reduce the dependency on traditional wood.

EXPERIMENTAL

Materials

The grass was collected from different localities of the Oforikrom and Ejisu municipalities in the Southern part of Ghana in the month of July. The grasses were randomly selected from the areas of each municipality, washed and dried.

Fibre morphological characterization

Samples of *Panicum maximum* were cut into small pieces and kept in a test tube containing 10 mL of Franklin solution (1:1 hydrogen peroxide and acetic acid). The sample-solution mixtures were incubated at a controlled temperature of 60 °C for 24 hours. The macerates were rinsed with distilled water for preservation, after which the samples were placed in a Petri dish. Glycerol was added to the macerated fibres, which were teased to separate individual fibres. Teased samples were mounted on a glass slide and placed under a microscope for observation and measurement. A total of 30 fibres were measured for each material following the International Association of Wood Anatomist (1989) protocol. The dimensions measured included fibre length and diameter, and lumen diameter. Fibre length was measured at 10 x 10 magnification, and the fibre and lumen diameter at 10 x 40 magnification. Fibre wall thickness values were calculated by reducing the fibre diameter value with lumen diameter, then divided by two.

Fibre derived indices

The fibre indices (fibre length, fibre diameter, lumen diameter, and wall thickness) were used to calculate the pulping characteristics by the following formulas:[18]

$$Slenderness\ ratio = \frac{Fibre\ length}{Fibre\ diameter} \quad (1)$$

$$Rigidity\ cooeficient = \frac{fibre\ wall\ thickness}{fibre\ diameter} \quad (2)$$

$$Flexibility\ cooefiecient = \frac{fibre\ lumen\ diameter}{fibre\ diameter} \quad (3)$$

$$Runkel\ ratio = fibre\ wall\ thickness \times \frac{2}{fibre\ lumen\ diameter} \quad (4)$$

$$Luces\ shape\ factor = \frac{(Fibre\ diameter)^2 - (fibre\ lumen\ diameter)^2}{(fibre\ diameter)^2 + (Fibre\ lumen\ diameter)^2} \quad (5)$$

$$Solid\ factor = (fibre\ diameter^2 - lumen\ diameter^2) \times fibre\ length \quad (6)$$

Chemical composition analysis

The analysis of chemical composition involved the quantification of the holocellulose, lignin, and hemicelluloses. The lignin content was determined using the gravimetric method in compliance with the standard TAPPI T222 om-98 (Lignin), after the removal of extractives according to the standard TAPPI T204 cm-97. The content of holocellulose was determined according to the TAPPI method 249 (Cellulose in Pulp). Hemicelluloses were determined gravimetrically using NaOH.[19] The cellulose was calculated as the difference between the holocellulose and hemicelluloses. The caustic soda solubility was determined according to ASTM D1109-21, respectively. Ash was determined with a muffle furnace at a temperature of 525 °C using TAPPI T 211.

Statistical analysis

Statistical studies were performed at a 95% confidence level ($p < 0.05$) using the statistical tool Sigma Plot for Windows, version 15.0, to analyze the data using descriptive statistics. Dunn's post-hoc test at 5% confidence level was used to determine the variations between the fibre properties of the leaf, midrib and stalk.

RESULTS AND DISCUSSION

Fibre morphological characterization

Fibre morphology greatly affects the final paper properties, such as physical and strength properties, and printing quality.[20] Consequently, fibre length, fibre diameter, fibre lumen diameter and fibre wall thickness play a key role in assessing the suitability of cellulosic raw materials for pulp and paper. Table 1 presents the results of the measurements of the fibre characteristics of the leaf blade, midrib and stalk of Guinea grass. Table 2 presents fibre dimensions of some grasses and non-wood plants from literature for comparison.

Fibre length

Studies have shown that longer fibers contribute to improved mechanical properties in paper, particularly enhancing tear resistance.[21,22] This study supports earlier reports that the fibre length of non-woody plants varies depending on the plant part from which the fibre is observed.[23,24] Fibres are grouped by length into three distinct categories: first group (under 0.9 mm, *e.g.* hardwood), second group (0.9-1.9 mm, *e.g.* coir, oil palm), and third group (over 2 mm, *e.g.* softwoods and cotton).[18,25] The observed average fibre length values of the *Panicum maximum* were found to be ranging from approximately 0.5 mm to 1.5 mm, 0.3 mm to 1.6 mm and 0.7 mm to 2.9 mm for the mid-rib, leaf and stalk, respectively (Table 1). Therefore, the assessed midrib and leaf blade shows *Panicum maximum* can be counted as having a short fibre length, and short-length fibres result in a denser, smoother, and more uniform paper sheet formation.[26] However, the stalks have fibres in the third group category, which are longer fibres. These fibres are necessary for producing strong and durable papers.[27] In comparison to other non-wood plants, fibre length of *Panicum maximum* falls within the same range as corn husk of 1.71 mm,[28] giant reeds of 1.18 mm,[29] switch grass of 1.15 mm,[30] miraculous berry of 2.68 mm[21] and hardwood fibres such as *Gmelina arborea* of 1.48 mm.[31] Based on this fibre length, *Panicum maximum* can be used for a wide variety of paper products. Fibre length differed significantly across all parts of the plant ($P<0.05$).

Fibre diameter

Fibre diameter is the diameter of fibre measured from side-to-side and it is usually measured across the fibre length.[32] In this study, the average diameter of the *Panicum maximum* fibre is 11.98 ± 2.20 µm, 9.72 ± 0.79 µm and14.65 ± 4.97 µm for the leaf, mid-rib and stalk, respectively (Table 1). This is comparable with 13.2 µm obtained for wheat straw, 14.8 µm for rice straw and 13.1 µm for *Panicum virgatum* or Switch grass.[30,33,34]

A smaller fibre diameter improves mechanical strength because it increases the effective contact area for better adhesion within the fibre matrix.[18] Non-wood fibres possess an average fibre length to width ratio of about 50:1 to 1500:1.[35] Generally, fibers with aspect ratios above 50:1 produce good paper strength. The average fibre length-to-width ratio for this study was 87:1 and 79:1 for the leaf and midrib, respectively, whilst the stalks on the other hand had fibres with length-to-width ratio of 90:1, thus *Panicum maximum* may produce paper with good tear, tensile and burst strengths and durability.[36,37] Leaf fibre diameter differed significantly from both the midrib and stalk ($p=0.067$).

Fibre lumen width

Fluids can easily access the fibre lumen through capillary action when it is wider, making the beating process more efficient. However, if the lumen is narrow, fluids cannot easily penetrate, leading to poor beating, which increases energy and power consumption.[18] Fibres with narrow lumen do not collapse easily, and papers produced from them would be poor in tensile, burst and compressive strengths.

Table 1
Mean, standard deviation and ranges of *Panicum maximum* fibre dimensions

Plant part	Fibre length (mm)	Fibre diameter (µm)	Fibre lumen diameter (µm)	Fibre wall thickness (µm)
Leaf	0.85±0.23^{a} (0.32-1.64)	9.723±0.79^{a} (7.95-11.44)	3.258±0.68^{a} (2.00-4.71)	6.47±0.74^{a} (4.98-8.64)
Midrib	0.95 ±0.24^{b} (0.48-1.53)	11.98±2.20^{b} (7.75-18.07)	5.16±1.70^{b} (0.18-9.80)	6.82±1.62^{a} (4.43-14.61)
Stalk	1.32±0.38^{c} (0.68-2.90)	14.65±4.98^{b} (6.75-27.95)	5.80±3.93^{b} (0.96-21.45)	8.82±4.16^{b} (2.72-20.97)

Means and standard deviation in the same column with the same superscripts are not significantly different

Table 2
Average fibre dimensions of some grasses and non-woody plants

Plant	Fibre length (mm)	Fibre diameter (µm)	Fibre lumen diameter (µm)	Fibre wall thickness (µm)	References
Panicum virgatum (switch grass)	1.15	13.1	5.8	4.6	Ververis *et al.*[30]
Triticum aestivum (wheat straw)	0.74	13.2	4.0	4.6	Deniz *et al.*[33]
Secale cereale (rye straw)	1.15	14.7	4.2	1.1	Eroglu[38]
Gossypium spp. (cotton stalks)	0.83	19.6	12.8	3.4	Ververis *et al.*[30]
Thaumatococcus daniellii (miraculous berry)	2.68	15.61	10.11	2.75	Oluwadare and Sotannde[21]

The lumen width range is between 4.7 µm, 9.8 µm and 5.8 µm for the *Panicum maximum* fibres with the midrib having the highest value. These values are comparable with 4.2 µm of rye straw and 5.8 µm of Switch grass, which are suitable raw materials for pulp and paper.[30,38] No statistical difference was observed between the midrib and stalk ($p<0.480$).

Cell wall thickness

An increase in cell wall thickness has a direct effect on the strength properties of fibres.[39] Thick-walled cells do not bend easily and do not collapse upon pulping, which inhibits chemical bonding. However, thin-walled cells collapse upon pulping, bond well together chemically and produce a smoother paper surface.[40]

The cell wall thickness of *Panicum maximum* fibres has an average of approximately 6.8 µm for both the midrib and the leaf and 8.9 µm for the stalks (Table 1). Compared to other non-wood plants, such as tobacco stalks (4.194–5.766 µm),[41] sugarcane bagasse (5.64 µm)[39] and *Rhizophora* spp. (8.31–8.91 µm),[42] suitable for pulp and paper production, the cell wall thickness of *Panicum maximum* is greater. Therefore, the *Panicum maximum* fibres may be suitable for stronger and bulkier packaging papers rather than smooth, high-quality printing paper.[43,44] No statistical difference was observed between midrib and leaf blade ($p=1.00$).

Pulping indices

Runkel ratio, slenderness ratio, rigidity coefficient, Luce's shape factor, solids factor and flexibility coefficient are important indices derived to determine the suitability of a material for pulp and papermaking.

Slenderness ratio

The slenderness ratio is a measure of the tearing property of pulp in the paper. To produce high-quality papers, the slenderness value should be greater than 60.[30] The fibres are classified as highly elastic fibres, elastic fibres, rigid fibres and highly rigid fibres, when the slenderness value is greater than 75, in the ranges of 50–75, 30–50 and less than 30, respectively.[45]

In this study, the mean slenderness value was 82.12, 88.23 and 99.94 for the mid-rib, leaf blade and stalk, respectively, which is greater than 75 and corresponds to highly elastic fibers (Table 3). Highly elastic fibres with high flexibility can collapse easily and flatten to produce good surface area contact, while elastic fibres collapse partially to give relative contact and fibre bonding.[45] Given this, the *Panicum maximum* fibres are perfectly suited for the pulp and papermaking industry. There was no statistical difference between leaf blade and midrib ($p=0.01$).

Flexibility coefficient

The flexibility coefficient determines the elasticity or rigidity of the fibres.[18] Fibre flexibility is correlated to the burst and tensile strength, as well as the development of the paper properties that affect printing.[45]

The flexibility coefficient (FC) can be divided into four classes: highly elastic fibres with FC over 75; elastic fibres with FC between 50 and 75; rigid fibres with FC between 30 and 50; highly rigid fibres with FC less than 30.[46] Furthermore, the values of the flexibility index ranging from 50% to 75% will produce good paper with high strength.[47] According to this classification, the average flexibility coefficient of *Panicum maximum* fibres is around 30% to 50% for the mid-rib, leaf and stalk, respectively, as shown in Table 3, thus, the fibres fall in the range of rigid fibres. Rigid fibres cannot easily flatten and have poor surface contact and fibre to fibre bonding.[45] Consequently, the papers made from *Panicum maximum* can be utilized for fibre plates and rigid cardboard for packaging.[48] The flexibility coefficient differed significantly across all parts of the plant ($p<0.05$).

Rigidity coefficient

The rigidity coefficient is important for determining the tensile, bursting and tearing strength properties of paper.[49] A benchmark of 0.5 is considered appropriate for pulping process.[18] As the rigidity increases, the physical resistance properties of paper weaken.[48] The mean rigidity coefficient of *Panicum maximum* fibres is 0.57, 0.66 and 0.61 for midrib, leaf blade and stalk, respectively (Table 3). The high values mean more energy requirement in pulp beating. The *Panicum maximum* values are within the range recorded for the traditional paper-making fibres of *Eucalyptus tereticornis* (0.63) and *Eucalyptus camadulensis* (0.53).[50] The coefficient of rigidity differed significantly across all parts of the plant ($p<0.05$).

Runkel ratio

The Runkel ratio is a crucial and fundamental factor required to determine if any raw material is suitable for pulp and paper production. In contrast to fibres with a lower Runkel ratio, those with a greater ratio are less flexible, stiffer, and produce bulkier paper with low bonded regions.[30] One (1) is the benchmark for this ratio. Any Runkel ratio values greater than 1 is termed as poor and does not favour pulp strength properties.[45]

For all the three sources of variations, the average Runkel ratio for fibres derived from *Panicum maximum* is approximately 4. This is comparable to the *Bambusa dendrocalamus* spp., which has a Runkel ratio ranging from 2.8 to 4.2.[51] This high Runkel ratio (more than 1) implies the fibres are stiff and will not collapse easily, resulting in porous bulkier paper with lower flexibility and poor surface smoothness. Subsequently, the *Panicum maximum* fibres are adequate to produce kraft papers, corrugate board liners, paper sacks and bags with high tear and burst resistance and stacking strength with poor printing properties for packaging.[52,45] The Runkel ratio differed significantly across all parts of the plant ($p<0.05$).

Table 3
Mean derived pulping indices of *Panicum maximum* fibres

Part of plant	Slenderness ratio	Flexibility coefficient (%)	Rigidity coefficient	Runkel ratio	Luce's shape factor	Solid factor (μm^3)
Leaf	88.23 $\pm 24.67^a$	33 ± 6^a	0.67 $\pm 0.06^a$	4.21 $\pm 1.31^a$	0.79 $\pm 0.07^a$	72.008×10^3 $\pm 22.75\times 10^{3\ a}$
Midrib	82.12 $\pm 26.88^a$	43 ± 10^b	0.57 $\pm 0.10^b$	4.19 $\pm 14.60^b$	0.69 $\pm 0.11^b$	111.53×10^3 $\pm 44.58\times 10^{3\ b}$
Stalk	99.94 $\pm 44.04^b$	39 ± 19^c	0.61 $\pm 0.12^c$	4.88 $\pm 4.30^c$	0.71 $\pm 0.20^c$	256.43×10^3 $\pm 20.70\times 10^{3\ c}$

Means in the same column with the same superscripts are not significantly different

Luce's shape factor

Luce's shape factor exhibits a direct correlation with the density of paper sheets, emphasizing its significance in determining paper structure and properties. Luce's shape factor values less than 0.5 are considered good for high quality pulp and paper making.[18] The average Luce's shape factor was 0.68, 0.79 and 0.71, for the leaf blade, midrib and stalk, respectively (Table 3). The values are high, but comparable to the Luce's shape factor of 0.727 of *Eucalyptus tereticornis*, and 0.77 to 0.83 for seagrass used for paper production where bulk and structure are priority.[53,54] Luces's shape factor differed significantly across all parts of the plant ($p<0.05$).

Solids factor

Solids shape factor is inversely associated with the resistance of pulp to beating and resistance of paper to bending and breaking length of paper.[55] This factor measures the volume of fibers and its influence on the mechanical properties of the resulting paper. The solids shape factor of *Panicum maximum* fibres is $111.53\times 10^3 \mu m^3$, $72.008\times 10^3 \mu m^3$ and $256.427\times 10^3\ \mu m^3$ for the midrib, leaf blade and stalk, respectively (Table 3). Comparative analysis revealed that *Panicum maximum* exhibits a solid factor similar to structurally robust species like *Cocos nucifera* ($278 \times 10^3\ \mu m^3$) and *Eucalyptus tereticornis* ($256 \times 10^3\ \mu m^3$), while significantly exceeding values reported for *Chrysophyllum albidum* (346-474 × 10^3 μm^3).[18,53,56] Studies found a significant negative relationship between the solids factor and sheet density.[57] The relatively high solids factor observed in this study is expected to produce bulky, porous, and low-density paper with reduced tensile strength. This suggests the fibers may be suitable for tissue and packaging papers where bulk and absorbency are required.[58,59] Solid factor differed significantly across all parts of the plant ($p<0.05$).

Chemical composition analysis

The chemical composition of the sample was analyzed, with a focus on its lignin, cellulose, and hemicelluloses. The lignin content of the sample was found to be 16.56%. The holocellulose content, which represents the total carbohydrate fraction including both cellulose and hemicelluloses, was determined to be 62%. Of the total holocellulose, the hemicelluloses content was measured at 25.05%, while the cellulose content accounted for 37%. Caustic soda solubility and ash content of the sample was found to be 48.25% and 11.17%, respectively (Table 4).

Chemical properties of non-wood plants evaluate the pulping process to determine fiber quality. Key components include cellulose, hemicelluloses, and lignin (structural), while extractives and inorganic compounds are secondary (non-structural).[60]

Cellulose, as the primary component in paper production, must exhibit high quality, which is determined by the raw materials and pulping methods.[45] Plant materials with cellulose of 34% and above are characterized to be suitable for pulp and paper manufacture.[61] The cellulose content of Guinea grass was found to be 37%, which is satisfactory for pulp production (close to or above 40%). Hence, it is expected that Guinea grass will give high pulp yield.

Hemicelluloses primarily enhance fibre bonding, though excessive levels can reduce paper strength. Starch is commonly incorporated into pulp to improve strength through mechanisms analogous to hemicelluloses. Although less critical than cellulose, hemicelluloses significantly contribute to pulp quality, with their potential degradation posing concerns.[62,63] They enhance pulp beatability through hydrophilic groups that increase water accessibility and improve paper strength (tensile, tear, burst) by acting as inter-fibre binder in chemical pulps.[45] In this study, the hemicelluloses content derived from *Panicum maximum* fibre is 25.05 (Table 4). This value is comparable to the hemicelluloses content of various *Miscanthus* species, which is approximately 29%, and that of switchgrass, which is 30.5%.[64] The high amount of hemicelluloses contributes to the stiffness and strength of fibres during paper production, which is appropriate for the production of packaging papers.[65]

Low lignin content of fibres is advantageous for their use in paper pulp manufacturing, as they would require fewer chemicals and less drastic conditions during pulping and bleaching. However, not only the content, but the lignin composition also strongly affects delignification rates, chemical consumption and pulp yields.[66] Generally, lower lignin content implies greater fibre strength, higher yield of pulp, and the production of good quality paper.[67]

Table 4
Mean values of chemical constituents of *Panicum maximum*

Moisture content (%)	Lignin (%)	Holocellulose (%)	Hemicelluloses (%)	Cellulose (%)	1% NaOH solubility (%)	Ash (%)
67.50	16.56	62.00	25.05	37.00	48.25	11.17

The lignin content of Guinea grass fibres was 16.56% and is comparable to that of poplar (17.10%), whereas lignin content of wheat straw (22.34%) and red pine (27.69%) are considerably higher.[68] The cellulose to lignin ratio obtained from Guinea grass samples studied was about 2.2:1, suggesting formation of stronger fibers that will contribute to production of papers with high tensile strength and durability.[69] Several non-wood materials, such as Kenaf, wheat straw, sorghum stalks and oat straw have also been reported to contain about 20% lignin. The lignin content of Guinea grass (16.56%) was low, indicating that this grass should be easier to pulp than wood with a lignin content of 26–30.[70]

One percent NaOH solubility dissolves extractive substances, some part of lignin, and low molecular weight hemicelluloses. It also indicates the degree of fungal decay that the non-wood can take.[71] Solubility in a 1% NaOH solution of *Panicum maximum* is 48.25% (Table 4). This is similar to 41.6% of sorghum stalks, 49.1% of rice, 47% of barley fodder, and 48.5 % of Jerusalem artichoke.[35] This indicates that *P. maximum* will undergo fungus degradation at a relatively higher rate.

The ash content of *Panicum maximum* is 11.17% (Table 4). Most non-wood tends to have a higher ash content than wood due to the presence of minerals, silica, and other inorganic materials.[72] *Panicum maximum* presents a high ash content similar to the ash content of 12.6% of rice straw.[73] The high ash content in this study might pose challenges in the liquor recovery stage in the pulping process.[74]

Despite the high 1% NaOH solubility (48.25%) and elevated ash content (11.17%), pulp production from *Panicum maximum* can still be considered a sustainable alternative. These values are consistent with other established non-wood grass species already used commercially in pulping, such as sorghum stalks (41.6% NaOH solubility), rice straw (49.1% NaOH solubility; 12.6% ash), and barley fodder (47% NaOH solubility), as noted above, and their widespread industrial use confirms that such properties do not preclude sustainable pulp production.[35,76] Furthermore, alkaline pretreatment of high-ash lignocellulosic biomass has been shown to reduce ash content by as much as 74 to 93%, effectively lowering the ash load entering the pulping system and making such feedstocks viable for industrial use.[75] The relatively low lignin content of *Panicum maximum* (16.56%) compared to wood (26 to 30%)[70] also substantially offsets these challenges. Since lignin must be removed during pulping, the lower lignin content of *Panicum maximum* means less chemical input and energy are required. Moreover, with a cellulose to lignin ratio of 2.2:1, more of the plant is converted into useful pulp, supporting a higher pulp yield and strengthening its case as a sustainable raw material.

CONCLUSION

The fibre characteristics and chemical properties were investigated of *Panicum maximum* growing in the Kumasi, Oforikrom and Ejisu Municipalities of Ghana to determine the usefulness of this grass as fibre resource for pulp and paper production. Compared to the non-wood species, most grasses and some wood species, such as *Panicum virgatum*, Kenaf, *Eucalyptus* species and *Miscanthus* species currently used for commercial pulpwood, *Panicum maximum* was considered suitable to produce pulp and paper.

There were significant variations in all the measured fibre properties and derived values from the leaf blade, midrib and stalk of the plant. The Runkel ratio was more than one (1), indicating that the pulp will yield bulky, rigid and porous papers suitable for packaging application. The slenderness ratio on the other hand indicated that the *Panicum maximum* fibres were highly elastic and will produce high quality paper. Chemical compositional analysis showed that the lignin content of Guinea grass was lower, while the cellulose and hemicelluloses contents were higher than in other non-wood papermaking resources. *Panicum maximum* exhibits high 1% NaOH solubility, indicating significant susceptibility to fungal decay, along with elevated ash content that could complicate pulping processes. These properties align with other non-woody biomass. Generally, *Panicum maximum* had appropriate fibre dimensions, derived pulping indices and cellulose content to serve as potential raw material for producing pulp and paper.

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