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GLIRICIDIA SEPIUM (JACQ.) WALP.: HARDWOOD WITH POTENTIAL FOR PULP AND PAPER-MAKING

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ABSTRACT

The anatomy of the wood of *Gliricidia sepium* has been studied for suitability as pulpwood. Dimensions of the wood fibre were measured microscopically to determine Runkel ratio and the Flexibility coefficient. The fibre morphology ratios inform preliminary decisions on the suitability of the species as pulpwood. Slides of microtome sections were made of the wood for microscopic study of the cell and tissue types and their relative proportions that constitute the wood. Low Runkel and high Flexibility ratios and a preponderance of fibres relative to other cells are desirable and would normally encourage the pulping and paper-making trials. The wood was pulped and hand-made paper sheets were tested for physical strength properties. The studies were duplicated for *Gmelina arborea*, which is already in use as pulp and paper-making hardwood, for comparison. *Gliricidia sepium* has Runkel ratio of 1.22 and coefficient of flexibility of 0.45 compared with *Gmelina*'s 0.19 and 0.88 respectively. The relative fibre volume for *Gliricidia* is 58.9% and about 41% other cells combined, while *Gmelina* has 72% fibres and 28% all other cells together. Pulp yields in *Gliricidia* and *Gmelina* are 46.5% and 49.2% respectively, while both species showed some good physical properties in the paper sheets: *Gliricidia* produced Burst property of 3.75kg cm^{-2} and Tear of 155g at pulp freeness of 51^0 SR, while *Gmelina* recorded 3.98kgcm^{-2} and Tear of 165g at freeness 36^0 SR. These values of physical strength properties combined with the reported features of the wood anatomy and the vegetative growth characteristics reported from the literature support the conclusion that *Gliricidia sepium* has great potential as a good pulpwood.

Keywords: *Gliricidia sepium*, *Gmelina arborea*, pulp, paper.

INTRODUCTION

Increased consumption of paper and paper products by society encourages the paper industry to increase production. This increased production requires a search for new suitable vegetable material, like tree species, that can be used for pulp and paper. Determining suitability of new hardwood species involves studies in the anatomical features of the wood and the natural availability of the species and its growth characteristics. For example, rapid growth rate and high pulp yield together with good fibre morphology are some of the properties a good pulpwood must have. Such studies are usually conducted in comparison with the characteristics of hardwoods already established and are in use as pulp woods. *Gliricidia sepium* is a fast growing species. Simons and Dunsdon (1992) observed that *Gliricidia* grows very quickly after germinating to about 3 m at the age of 6 – 8 months before flowering, and this rapid growth makes it an early colonizer of re-growth forest lands left to fallow. Because *Gliricidia* is such a fast growing tree species and also amenable to plantation development, the species was selected for investigation of its wood structural characteristics as to suitability for pulp and paper production.

Pulp is defined as the crude fibre produced from cellulosic raw material that can be converted, after suitable treatment, to paper and paper products. Paper, on the other hand, is defined as the matted or felted sheets of fibre formed on a wire screen from a water suspension of pulp (Kpikpi, 2005). The investigation of a hardwood species for its suitability as pulpwood is usually done in two phases: the microscopic characteristics of the wood followed by pulping trial and testing of hand-made paper sheets.

In this work, therefore, microscopic wood structure of *Gliricidia sepium* is examined and pulping characteristics are investigated using a laboratory digester and hand-made paper sheets tested for some physical properties. The investigations are conducted alongside *Gmelina arborea*, which is a hardwood already established as pulpwood (Kpikpi, 1992).

Biology of *Gliricidia sepium*

Gliricidia sepium (Jacq.) Walp. is a native of Central America, Mexico, from where it was introduced into West Africa, India and other tropical, sub-tropical regions of the world. It is a small to medium-sized leguminous tree, nitrogen-fixing, belonging to the family Fabaceae-Papilionoideae. The stem is smooth-barked, without

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thorns, whitish to grey in color and dotted all over with lenticels. The leaves are pinnately compound, about 25 to 30 cm long bearing about 6 – 20 ovate to elliptic leaflets on a central rachis. The flower is a pinkish to white, clustered inflorescence of characteristic papilionaceous flowers of a roundish standard and keel for petals. The unripe fruit is greenish turning yellowish-brown on ripening. Though deciduous, the tree is hardly leafless in the dry season. It is propagated by seed and stem cuttings. In Nigeria and Ghana and other areas of the West African sub-region, it is propagated by stakes, which is considered as a major advantage in its survival, since seed production in this plant depends on a marked dry season, and stakes up to 1m long have been found to give better establishment and subsequent growth (Adejuwon, 1991). *Gliricidia sepium* is a multi-purpose tree, useful as fuel wood, animal fodder, tree for honey production by bees, green manure and therefore really always has a reason to go under plantation development.

MATERIALS AND METHODS

Wood Anatomy

The structure of the wood of *Gliricidia sepium* and *Gmelina arborea* was studied from slide preparations made from two each of the species. *Gliricidia* trees were felled from a re-growth forest and *Gmelina* from an old abandoned homestead in Ado Ekiti, Nigeria. Wood discs were cut from the butt, the breast height (1.3 m up the bole) and just below the point where the stem branches up to form the crown of the tree. Four quadrants were sketched on the wood discs and from each quadrant wood blocks were scooped and macerated in Schultze's solution (Bradbury, 1976). Temporary mounts of the materials were made in glycerin on glass slides and examined under the microscope for the cell morphology. Measurements were made, from the microscope with micrometers, of the fibre dimensions for the derived ratios of Runkel ratio and Flexibility coefficient. Wood blocks were also scooped and microtome sections were cut, stained differentially in Saffranin and Fast green and permanently mounted in Canada balsam for microscopic examination and description of the wood structure with respect to proportions of tissues making up the wood.

Wood Density

The wood density of *Gliricidia* and *Gmelina* was determined by measurements based on Archimedes principle described by Browning (1967)

Ash content

The ash content of the wood of *Gliricidia* and *Gmelina* was determined by incinerating the wood shavings in an oven at 550^{o}C. The ash, being the inorganic deposit left after the organic matter has volatilized, was weighed and reported.

Pulping/Refining/Hand paper sheets formation

Wood chips of *Gliricidia* and *Gmelina* were cooked separately in laboratory digester in the Paper Laboratory of the Nigerian Paper Mill, Jebba, Kwara State. Cooking of the two test species was done under identical cooking conditions (Table 1) adopted from Lopez *et al*. (2000). Cooked chips were defibered manually to pulp which was refined in a laboratory refiner, Valley beater. The pulp freeness, by Schopper Riegler scale (SR^o) was measured after every 10 minutes of beating and paper sheets were formed at the changing freenesses for comparison of the physical properties at the varying pulp freenesses.

Table 1. Cooking conditions for wood chips.

Parameter	Parameter value
Liquor-to-wood ratio	4:1
Total active alkali: NaOH/Na_2S (g/l)	73.53/7.35
Sulphidity (%)	18
Maximum temperature (^{o}C)	160
Maximum pressure (Kpa)	7 x 10^5
Time at maximum T^o	2 hrs

RESULTS

Wood Structure

Average fibre lengths for *Gliricidia* are 1.001 mm, ranging between 0.4 mm and 2.0 mm (Figs.1a, 1b and Table 2). The fibre diameter is narrow, ranging between 15.7 and 20.01µm with mean of 19.14 µm, all mostly libriform fibres (Fig. 1c). The cell wall is thick, with a wall thickness average of 5.3 µm, ranging between 4.5 and 6.0 µm, and an average lumen/cavity of 8.7 µm (Figs. 1d, 1e). This gives a Runkel ratio of 1.22 to the *Glricidia* fibre and coefficient of flexibility of 0.45 (Table 2). *Gmelina* has average fibre length of 1.05 mm, ranging between 0.4 and 1.8 mm, average fibre diameter of 34 µm and a very thin fibre wall, average thickness, 2.67 µm with a range of 2-3.2 µm and a lumen cavity of 28.77 µm conferring a Runkel ratio of 0.19 and flexibility coefficient of 0.88 (Figs. 1c, 1d, 1e and Table 2) as above for *Gliricidia.*

The structure of *Gliricidia* wood, compared with that of *Gmelina*, as shown by the results, is a good source of cellulose. The relative volume of fibre is about 59%, vessel, about 9.8%, ray and axial parenchyma are respectively 11.8% and 18.9%, with fibre to vessel (F/V) and fibre to non-fibrous tissue (F/NF) ratios respectively 6 and 1.2 (Fig. 1f and Table 1). For *Gmelina*, the relative volumes (as indicated in the same Table and Figure) are 72.2% fibres, 7.5% vessels, 4.9% parenchyma and 15.4 % rays. The fibre to vessel (F/V) and fibre to non-fibrous tissue (F/NF) ratios, respectively, are 9.6 and 2.6.

Pulping/Refining /Hand-made Paper Sheets

Pulp refining proceeded in a total beating time of 70 minutes, with the highest recorded freeness for *Gliricidia*

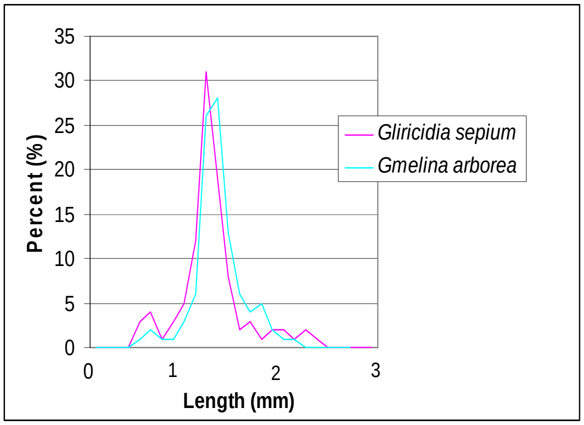

Fig. 1a. Fibre length distribution in wood of *Gliricidia sepium* and *Gmelina arborea.*

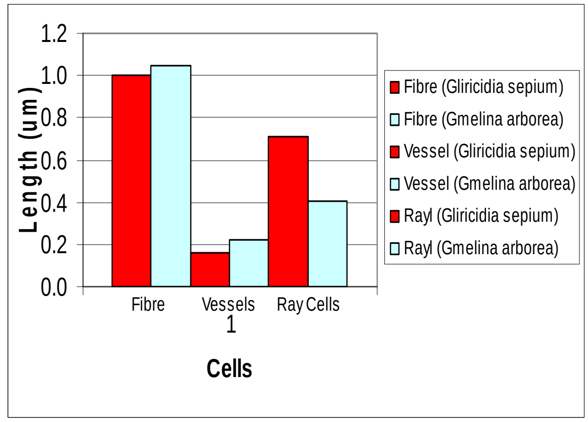

Fig. 1b. Average fibre length of *Gliricidia sepium* and *Gmelina arborea.*

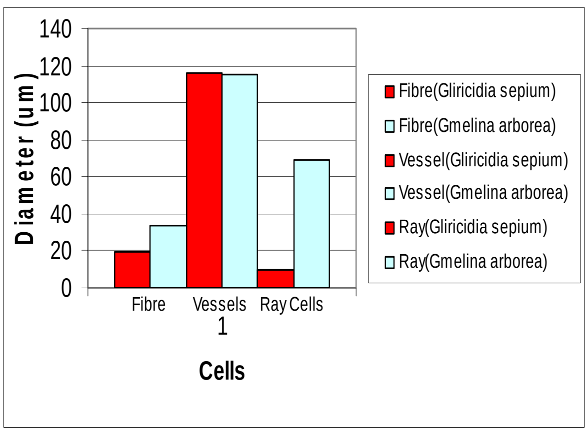

Fig.1c. Average cell diameter of *Gliricidia sepium* and *Gmelina arborea.*

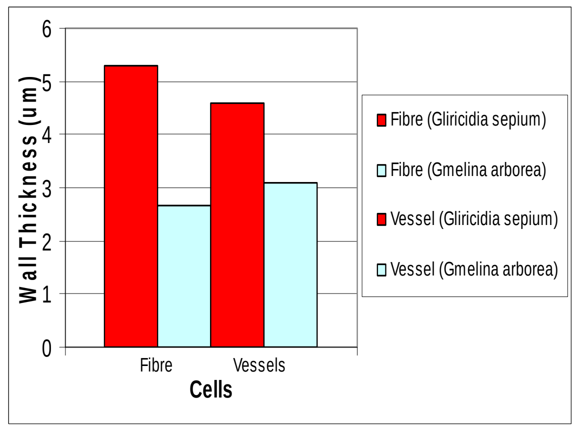

Fig.1d. Average cell wall thickness of *Gliricidia sepium* and *Gmelina arborea.*

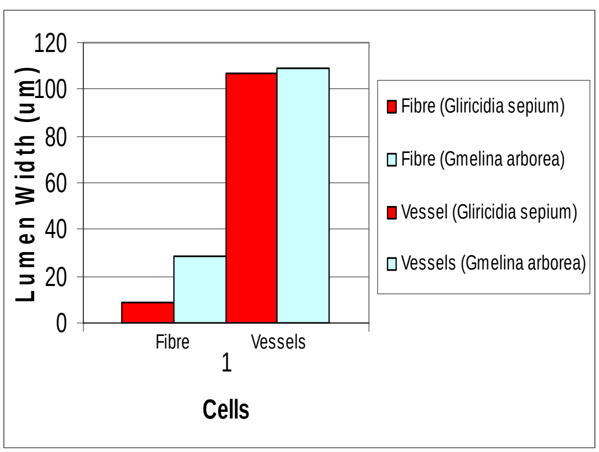

Fig. 1e. Average cell lumen *of Gliricidia sepium* and *Gmelina arborea.*

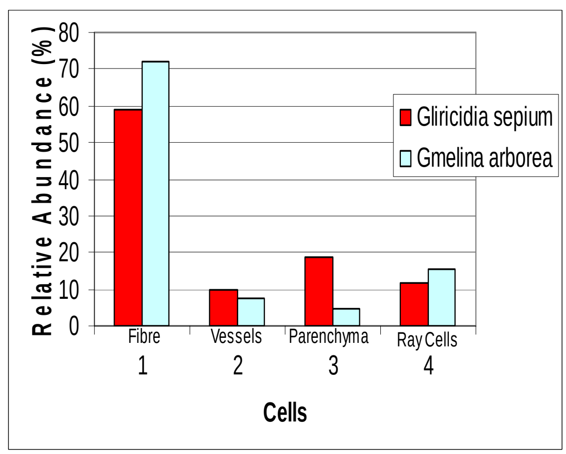

Fig.1f. Relative abundance of tissues of *Gliricidia sepium* and *Gmelina arborea.*

pulp in 70 minutes being 51° SR, while *Gmelina* pulp in the same time recorded 65° SR (Fig. 2 and Table 2). Tested Paper sheets made out manually at chosen freenesses showed enhanced physical properties with increasing refinement of pulp for both *Gliricidia* and *Gmelina* pulps, as presented in (Figs. 3a, 3b, 3c, 3d and Table 2). *Gliricidia* wood chips cooked under the adopted cooking conditions of Lopez *et al*. (2000) gave a pulp yield of 46.5% with 1.01% rejects, while *Gmelina* chips cooked under identical conditions yielded 49.2% with no rejects (Fig. 4a and Table 2).

Table 1. Summary of Characteristics of *Gliricidia sepium* and *Gmelina arborea*.

Characteristics	*Gliricidia sepium*	*Gmelina arborea*
Wood anatomy		
Mean fibre length (mm)	1.001 Range(0.4-2.0)	1.047. Range (0.4-1.8)
Runkel ratio	1.22	0.19
Flexibility coefficient	0.45	0.88
Fibre volume (%)	58.9	72.2
Vessel member (%)	9.8	7.5
Parenchyma (%)	18.9	4.9
Ray (%)	11.8	15.4
Wood density (kg m^{-3})	710	460
Pulp yield (%)	46.5	49.2
Ash content (%)	2.7	1.3
Pulp refinement time		
30 min freeness (SR^o)	23	29
40 min freeness (SR^o)	28	36
60 min freeness (SR^o)	48	59
Paper physical properties		
Burst strength (kg cm^{-2})	1.93-3.78	2.78-3.98
Tear strength (g)	126-155	145-165
Breaking weight (kg)	3.86-5.24	4.81-7.56
Breaking length (m)	1988-3820	2880-5120

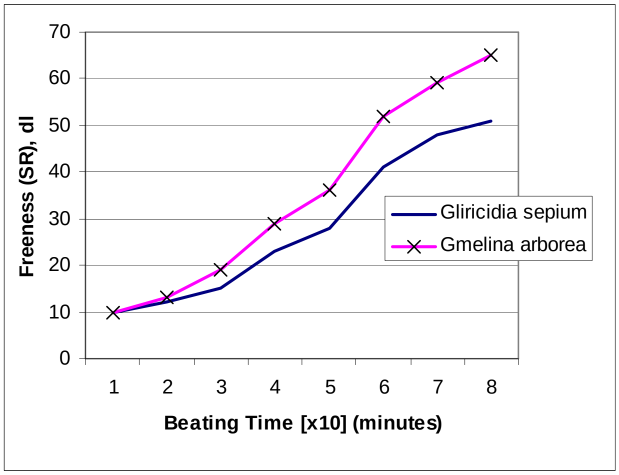

Fig. 2. Pulp Freeness as a function of Beating/Refining Time Freeness on *Schopper Riegler*, SR, Scale.

Wood Density/Ash Content

The wood density of *Gliricidia sepium* is reported as 710 kg m^{-3} compared with 460 kg m^3 for *Gmelina*. The corresponding wood ash contents were 2.7% and 1.3%, respectively (Figs. 4b, 4c and Table 2).

DISCUSSION

The average fibre lengths of both *Gliricidia* and *Gmelina* are short, about 1.0 mm, within a range of 0.4 mm and 2.0 mm. Short fibre lengths are characteristic of hardwoods, and Britt's observation (1970) that long fibres are essential for making paper of high tear and tensile strengths, properly applies to softwoods and not to hardwoods like the ones under investigation. The capacity of hardwood fibres to make strong papers depends more on the entire fibre morphology, of the relationship of the thickness of the fibre wall to its entire diameter. A fibre of a given diameter, (D), having a wide internal cavity, (I), naturally will have a thin cell wall (C), from the relationship (D-I), which collapses more easily under pressure that is generated during the pulp dehydration and paper mat formation. Fibres with collapsed cell walls have better exposed cellulose bonding surfaces in a web which bond together to form the paper sheets.

The ratio of the fibre wall thickness to its internal diameter (2C/I), known as Runkel ratio, thus controls the paper physical property in hardwoods than the fibre lengths alone. A low Runkel ratio means thin fibre walls and therefore better cell wall collapsibility; stronger inter-fibre bonding and therefore stronger paper sheets formation. Papers of various kinds like cardboards for paper boxes, newsprints or tissue papers requiring different strength properties can however be made from fibres of differing morphological characteristics. Comparing the fibre morphology of *Gliricidia* to *Gmelina*, the respective Runkel ratios of 1.22 and 0.19, shows *Gmelina* to be superior to *Gliricidia*, although both can be used to make some kind of paper.

The Runkel ratio gives almost the same information as does the Coefficient of flexibility which relates the internal cavity, (I), to the external diameter of the fibre, (I/D). The coefficient of flexibility in the *Gliricidia* fibre (0.45), gives *Gliricidia* a preponderant wall material, relative to the entire volume of the fibre which naturally

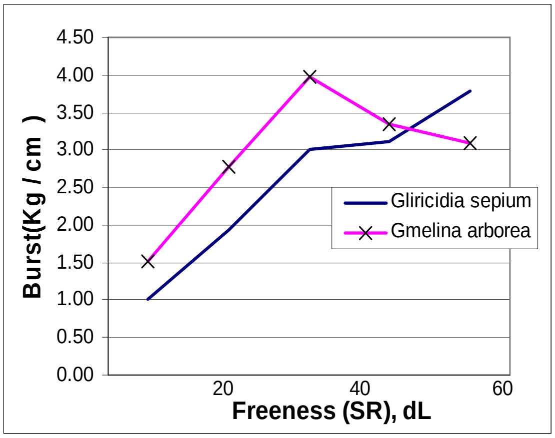

Fig. 3a. Physical property (Burst) of paper handsheet as a function of Pulp Freeness.

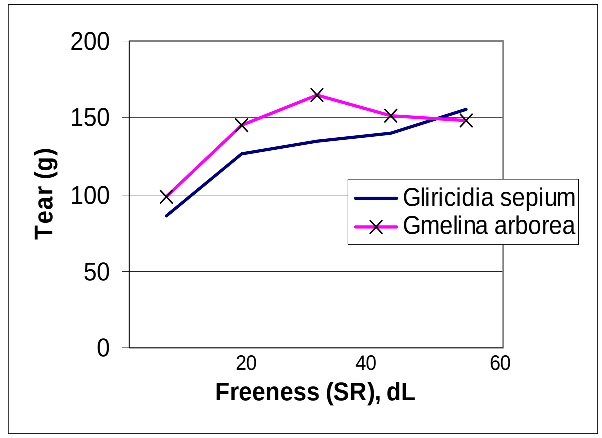

Fig. 3b. Physical property (Tear) of paper handsheet as a function of Pulp Freeness.

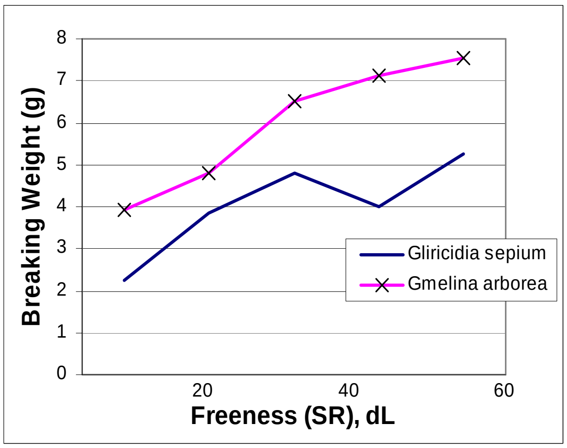

Fig. 3c. Physical property (Breaking Weight) of paper handsheet as a function of Pulp Freeness.

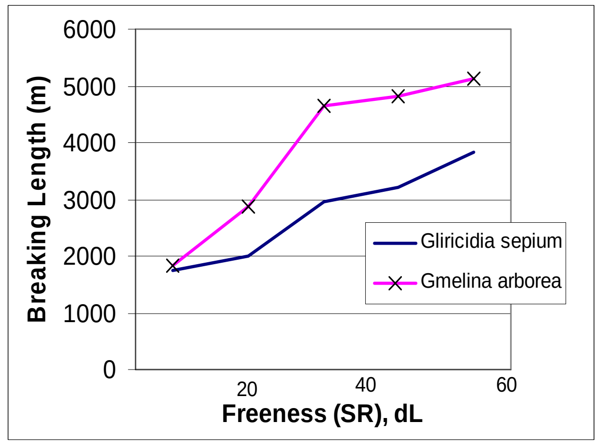

Fig. 3d. Physical property (Breaking Length) of paper handsheet as a function of Pulp Freeness.

leaves only a small internal cavity that can be filled with air compared with 0.88 of *Gmelina*'s thin walls and large cavity. The wood of *Gliricidia* is thus much higher in density (710 kg m^{-3}) than *Gmelina* (460 kg m^{-3}). The Ash content of *Gliricidia* (2.7%) is about twice as much as the ash content of the *Gmelina* wood (1.3%). The ash content of wood in pulp can lead to pitch problems in paper as the ash increases the black liquor mineral load and that of the bleach wash water, hence, its monitoring in pulpwood. Though the mineral deposit in *Gliricidia* is higher than that of *Gmelina*, the levels in both species are not excessive.

Pulp/Paper Characteristics

The yield of pulp, 46.5% for *Gliricidia* and 49.2% in *Gmelina* is quite good for both species. The pulp refined well in the laboratory refiner, Valley beater. The results of refining and the tests of the physical properties of the hand-made paper sheets formed show the two hardwood pulps are quite good for making paper. For example, paper sheet of *Gliricidia*, GSM 104 at SR 51^o elicited Burst property of 3.78 kg m^{-2} and Tear strength of 155 g while *Gmelina* paper sheet of GSM 102 at SR 52^o produced a Burst property of 3.34 kg cm^{-2} and Tear of 151 g. The best physical property of Burst 3.98 kg m^{-2} however, was obtained from *Gmelina* pulp at 36^o SR^o of freeness after 40 minutes of pulp beating/refinement and the best Tear Property of 165 g at the same time of beating and the same freeness. At 40 minutes of pulp refinement, *Gliricidia* showed a pulp freeness of only 28^o SR and the Burst Property at this freeness was 1.98 kg cm^{-2} and a Tear of 126 g. These two results show that the differences in the quality of fibre morphology translates into differences in costs of fibre preparation (refinement) for paper-making, and sometimes, these differences can be very important in deciding which pulps to use for which kind of paper.

CONCLUSION

The fibre morphology and the wood structure of *Gliricidia sepium* show that the wood of *Gliricidia* compares quite favourably with that of *Gmelina arborea*. Although there is such great difference between the two

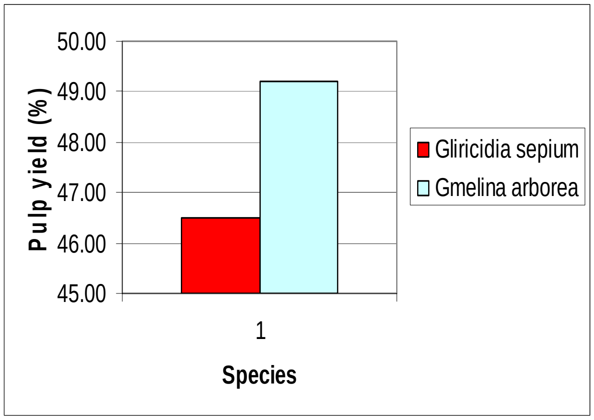

Fig. 4a. Pulp yields of *Gliricidia sepium* and *Gmelina arborea* from the laboratory digester.

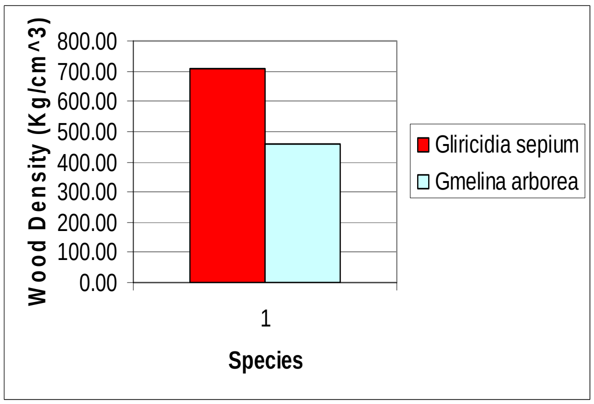

Fig. 4b. Wood density of *Gliricidia sepium* and *Gmelina arborea.*

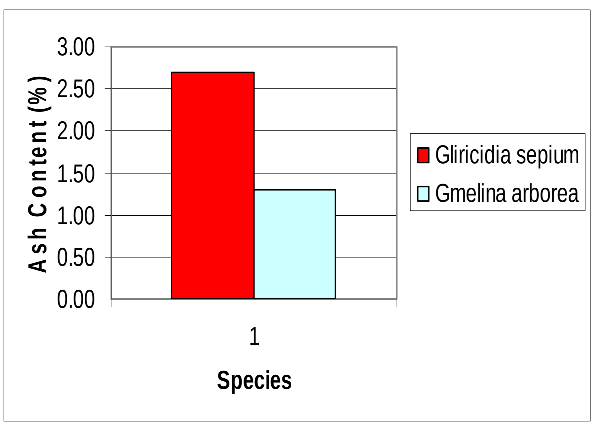

Fig. 4c. Ash content of *Gliricidia sepium* and *Gmelina arborea.*

Runkel ratios of *Gmelina* and *Gliricidia*, 0.19 and 1.22, the paper qualities produced, were comparably good. The vegetative growth habit of *Gliricidia*, illucidated from the literature, makes it such a good plantation species and this should compensate for some anatomical deficiencies. *Gliricidia sepium*, from all the test results, should be considered as a suitable hardwood species having good potentials for making pulp and paper.

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