SOME PHYSICAL AND MECHANICAL PROPERTIES OF *UAPACA KIRKIANA*, A LESSER-KNOWN TIMBER SPECIES FROM TANZANIA

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ABSTRACT

This study was carried out to determine some physical and mechanical properties of *Uapaca kirkiana* a lesser known timber species growing in public land near Iyondo Catchment Forest Reserve, Kilombero District, Morogoro, Tanzania. A total of 3 trees were used in the study. Preparation of test samples and laboratory procedure to determine some physical and mechanical properties followed standard methods. Analysis of variance was used to determine the variation between and within trees and regression analysis was used to determine relationship between wood basic density and mechanical properties. The results showed that *Uapaca kirkiana* has whitish sapwood and dark brown heartwood, with a mean basic density of 518.14 kg/m^3. The properties of Uapaca kirkiana were as follows: modulus of elasticity (7185.69 N/mm^2), modulus of rupture (59.7 N/mm^2), work to maximum load (0.06 mmN/mm^3), total work to failure (0.07 mmN/mm^3), shear strength parallel to the grain (11.86 N/mm^2), compression strength parallel to the grain (34.4 N/mm^2) and cleavage strength (20.21 N/mm width). On axial direction, the modulus of elasticity, total work to failure, compression strength parallel to grain and cleavage strength were directly proportional to its basic density while modulus of rupture, work to maximum load and shear strength parallel to the grain were inversely proportional implying that *Uapaca kirkiana* is suitable for activities, which require high modulus of elasticity, total work to failure, compression strength parallel to the grain and cleavage strength. On radial direction modulus of elasticity, modulus of rupture, work to maximum load, compression parallel to the grain and cleavage strength were directly proportional to basic density while shear parallel to the grain was inversely proportional to basic density. Compared to *Khaya anthotheca*, the timber species found in the same location and market; it was found that the timber of *Uapaca kirkiana* had modulus of rupture and compression parallel to the grain far lower than those of *Khaya anthotheca,* while the work to maximum load, total work to failure, shear strength parallel to grain and modulus of elasticity were almost the same. Due to the similarity in some of their physical and mechanical properties, the wood of *Uapaca kirkiana* may berecommended to substitute *Khaya anthotheca* in wood works that require medium density wood like in decoration where colour is considered an important aspect for appearance and in cabinet, panel and furniture making though it is not adequate in high-class strength joinery.

Key words: Lesser known, timber, Uapaca kirkiana, physical and mechanical properties

INTRODUCTION

Over exploitation of some specific well known timber tree species including *Pterocarpus angolensis, Khaya anthotheca, Milicia excelsa and Afzelia quanzensis* mainly from natural forests is rampart in different parts of Tanzania (Ishengoma *et al.*, 1998). Following over exploitation, younger trees with inferior properties are now being cut to temporarily meet the market demand (Ishengoma *et al.*, 1997). It is unfortunate also that only a few well-known trees are utilized, and often for purposes for which other equally suitable but far cheaper timbers could be used

(Bryce 1967 revised by Chihongo, 1999). A similar situation exists also in other countries (Barany *et al.,* 2003). This therefore, calls for need to put in use of some of the formerly considered non-usable tree species of which majority comprised of lesser-utilized tree species. Also, a good and satisfactory technical knowledge on these lesser known and utilized timber species is important and a prerequisite towards their successful utilization.

The natural forests of Tanzania have been indicated to harbor a number of useful tree species for timber production. With 45% of its land under forest cover, Tanzania is estimated to have more than 700 tree species (Ishengoma *et al.,* 1997). However, according to Bryce (1967) revised by Chihongo (1999), a big number i.e. over 200 timber tree species are known to be marketable indicating possible diverse selection of different trees for different uses. But on contrary the most used ones are based mainly on the taste of the end users i.e. the basic knowledge and experience they have on specific timber tree species. Others include availability and costs (especially transport costs). Therefore, some tree species have become scarce leading to rapid increase in timber prices hence search for substitute now becomes more urgent than ever.

Uapaca kirkiana is one of the lesser-known tree species in Tanzania forests of which very little is known and much have not yet been documented about its physical and mechanical properties. If its properties are found to be technically suitable, then much more uses could be revealed and hence contribute in substituting some of the well known highly exploited tree species which are now running into short supply.

Study on properties of *Milletia oblata,* a lesser known and utilized tree species has found it to be comparable to *Milicia excelsa, Pterocarpus angolensis* and *Ocotea usambarensis* to the extent of recommending some of their uses to be replaced by this species (Ishengoma *et al.,* 1998). Several other tree species have also been studied and recommended, for example *Brachystegia bussei* and *Berchemia discolor* (Bangura *et al.,* 2001) and *Trichilia emetica* and *Pterocarpus stolzii* (Ishengoma *et al.,* 1997). However, further observations have shown that, understanding properties of lesser known and utilized tree species has never been an easy task. It needs more efforts and resources to be tackled (Ishengoma *et al.,* 1997; Bangura *et al.,* 2001). In many cases the limited use of the potential lesser-utilized timber species is caused by scarcity and inaccessibility of information regarding their wood properties (Barany *et al.,* 2003).

Therefore, since there is no / less technical information on physical and mechanical properties of timber of *Uapaca kirkiana* in Tanzania, then it is important to know its values compared to other highly known and over utilized timber species and see how best its uses can substitute them.

Objectives

The broad objective of this study was to determine some physical and mechanical properties of the lesser-known and utilized naturally growing *Uapaca kirkiana* timber tree species in attempting to compare it with other well known and utilized tree species and see if it can be used to substitute some of them and give out recommendations on its efficient use. Specifically the study intended to determine wood colour, wood moisture content and basic density of *Uapaca kirkiana.* Others included compression strength parallel to the grain; shear strength parallel to grain; cleavage strength and static bending i.e. its modulus of elasticity, modulus of rapture, work to maximum load and total work to failure.

In this paper, collected data were used to test the hypothesis that research on lesser-known *Uapaca kirkiana,* the timber tree species, could provide good technical knowledge leading to its utilization by majority and hence substituting the suitable fewer well known and over exploited ones.

MATERIALS AND METHODS

Study area description

Samples were collected from a public land bordering Iyondo Catchment Forest Reserve (latitude 8°00′ and 8°16′S and longitude 36°06′ and 36°22′ E) located in Kilombero District, Morogoro Region, Tanzania. The area is relatively flat with sandy soils over crystalline rocks covering part of a hilly area along the base of the Udizungwa Mountains from altitude of 300 m – 900 m (Lovert and Poc's, 1993). It borders Mngeta river to the west, West Kilombero Escarpment Forest Reserve to the north and Ruipa river to the east. It is undisturbed lowland contains good trees of valuable timber species 30 to 40 m tall canopy including *Khaya anthotheca, Milicia excelsa* and *Pterocarpus mildbraedii*. Rainfall is estimated to be around 1900 mm/yr. Temperatures are moderately high with an average of 27°C maximum in November and 22°C minimum in July (Lovert and Poc's, 1993).

Data collection

Samples were collected from three trees of *Uapaca kirkiana* randomly selected after thorough observation of their physical appearance. The trees were felled and by using caliper and a measuring tape, diameter at breast height (dbh) and total tree height were measured and recorded. Trees observed to have internal defect like rot were rejected and replaced with good ones. Three logs of 1.5 m length were cut from breast height upwards and marked from each tree felled. Using pit sawyers, the logs (billets) were sawn to cants and transported to Department of Wood Utilization of Sokoine University of Agriculture Morogoro, Tanzania for further processing. The cants were then re-sawn into 30 mm x 65 mm x 1500 mm planks from the pith left and right towards the bark. The planks were numbered and labeled sequentially to show the position of extraction and direction of sawing and stacked for drying until the moisture content reached below 15%.

Moisture content

Determination of moisture content of the samples for this study was done according to Desch (1981) using oven dry method.

Mechanical properties

The tests conducted include Compression strength parallel to grain, Cleavage strength, Shear strength parallel to grain, Basic density and Static bending i.e. Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Work to Maximum Load (Wmax) and Total work to failure (Wtotal).

The planks were first air dried then converted into scantlings of 30 mm x 30 mm x 1500 mm. The scantlings were further planed down to 20 mm x 20 mm x 1500 mm from which various dimensions of different test samples were extracted as shown in Table 1.

Table 1 Test sample for strength properties

Type of test	Test sample size (mm)	Number of test samples
Static bending	20 x 20 x 300	62
Shear parallel to grain	20 x 20 x 20	62
Cleavage	20 x 20 x 45	62
Compression parallel grain	20 x 20 x 60	62

The different mechanical properties' tests were carried out following the procedures described by BS 373 (1957 and 1976), Lavers (1969), Panshin and de Zeeuw (1970), ISO 3130 and ISO 3133 (1975).

Data analysis

The obtained data were summarized and subjected to Excel Computer package for analysis. Analysis of variance (ANOVA) was carried out to determine the variation between and within trees. The mean, standard error, median, mode, and standard deviation were calculated. Regression analysis was used to determine relationship between wood basic density and mechanical properties. Descriptive statistics analysis was also done and coefficient of variation calculated to determine variation within the population.

RESULTS AND DISSCUSION

Physical properties

Wood colour

The sapwood of the *Uapaca kirkiana* was observed to be whitish in colour while the heartwood is dark brown; the colour that is comparable to that of *Khaya anthotheca* (TTMCL, 1978 in Bangura *et al.*, 2001). This implies that it can be useful for decorative works like other trees from elsewhere including *Khaya anthotheca,* Mahogany, the Black East African wood, the Red Opepe wood and the Green African Walnut (Dinwoodie, 1981).

Basic density

The results showed that *Uapaca kirkiana* has an average basic density of 518.14 kg/m^3. Comparatively, the density is closer to that of *Khaya anthotheca*, which is considered to be medium density tree specie (Bryce, 1967). For example a density of up to 545 kg/m^3 and 513 kg/m^3 of *Khaya anthotheca* have been reported in Tanzania and Uganda respectively. Therefore based on these findings *U. kirkiana* can be said to be medium density timber species as well.

Variation in basic density

Axial variation

Although not significant (P> 0.05), the basic density of *Uapaca* kirkiana was slightly higher at the bottom (525.76 kg/m^3), lower at the middle (506 kg/m^3) and again higher at the top (522.01 kg/m^3). Similar situation was observed by Ishengoma and Nagoda (1991). However, the change of basic density from bottom upwards might have been caused by ecological differences.

Radial variation

Table 2 shows radial variation of the basic density for *Uapaca kirkiana* from the pith to the bark. Although not significant (P>0.05), it is higher closer to the pith, decreasing outward, then increases to the maximum value before decreasing again close to the bark. A similar situation is reported by Hamza *et al.* (2001) on

Artocarpus heterophylus. However the lower basic density at the pith probably could have been due to the presence of juvenile wood with thin wall as compared to that of the outer wood (Zobel and van Buijtenen, 1989; Walker, 1993).

Table 2 Radial variation of basic density of *Uapaca kirkiana*

Position	Average density kg/m^3
P1	512.78
P2	508.32
P3	538.83
P4	512.64

Key: P1 – P2 = relative distance from pith outwards to the bark

Strength properties

Table 3 shows results of the strength properties for *Uapaca kirkiana*. The highest variation was observed with the total work to failure followed by work to maximum load, modulus of rapture, modulus of elasticity, cleavage, compression strength parallel to grain and shear strength parallel to grain. However, understanding a wood strength property is very important since it keeps the user in the right position to choose the right wood for specific use (Panshin and de Zeeuw, 1970).

Table 3 Strength properties of *Uapaca kirkiana*

Strength properties	Strength values	CV (%)
Modulus of rupture (N/mm^2)	59.7	23.8
Modulus of elasticity (N/mm^2)	7185.69	22.8
Total work to failure (mmN/mm^3)	0.0723	46.3
Work to maximum load (mmN/mm^3)	0.0596	34.2
Compression strength parallel to grain (N/mm^2)	34.4	15.1
Shear strength parallel to grain (N/mm^2)	11.86	8.7
Cleavage (N/mm-width)	20.214	17.7

Relationship between basic density and strength properties

Table 4 and 5 shows results of the relationship between basic density and strength properties of the timber of *Uapaca kirkiana* both in axial and radical direction respectively. A strong axial relationship between wood basic density and modulus of elasticity, total work to failure, compression strength parallel to the grain and cleavage strength was observed (Table 4). This implies that these strength properties are directly proportional to its basic density. With such strong relationship implies that *U. kirkiana* is suitable for activities, which require high modulus of elasticity, total work to failure, compression strength parallel to the grain and cleavage strength. A weak axial relationship was found between basic density and modulus of rupture, work to maximum load and shear strength parallel to the grain implying that these strength properties are inversely proportional to the axial basic density. Therefore the species is unsuitable for all activities, which need high shear, modulus of rupture and work to maximum load strengths.

Table 4 Relationship between basic density and wood properties in axial direction

Wood property	Regression equation	R^2
Modulus of elasticity	Y = -48. 661X + 327.61	0.99
Modulus of rupture	Y = 0.0424X + 40.769	0.02
Work to maximum load	Y = 0.0003X – 0.075	0.26
Total work to failure	Y = -0.0005X + 0.346	0.78
Shear strength parallel to grain	Y = -0.0121X + 18.118	0.34
Compression strength parallel to grain	Y = 0.2134X – 76.212	0.69
Cleavage strength	Y = 0.167X – 66.36	0.78

Note: Y = Wood property; X = Basic density; R^2 = Coefficient of determination

Results in table 5 indicates a strong radial relationship between the wood basic density and modulus of rupture, work to maximum load, and compression strength parallel to grain i.e. these strength properties are directly proportional to the basic density implying that all wood works which requires higher modulus of rupture, work to maximum load and compression strength parallel to grain can be substituted by timber of *Uapaca kirkiana.* A weak radial relationship was obtained between the wood basic density and modulus of elasticity, total work to failure, shear strength parallel to grain and cleavage strength i.e. these strength properties are inversely proportional to the basic density implying that the timber of *U. kirkiana* can not be used in constructional works that requires high modulus of elasticity, total work to failure, shear strength and cleavage strength.

Table 5 Relationship between basic density and wood properties in radial direction

Wood property	Regression equation	R^2
Modulus of elasticity	Y = 16.372X – 1571.7	0.37
Modulus of rupture	Y = 0.1722X – 31.644	0.73
Work to maximum load	Y = 0.0002X – 0.0577	0.70
Total work to failure	Y = 0.002X – 0.0261	0.53
Shear strength parallel to grain	Y = -0.0078X + 15.904	0.13
Compression strength parallel to grain	Y = 0.1077X – 21.435	0.74
Cleavage strength	Y = 0.0182X + 10.785	0.07

Note: Y = Wood property; X = Basic density; R^2 = Coefficient of determination

Comparison between Uapaca kirkiana and Khaya anthotheca

Results in Table 6 show that the modulus of rapture of *Uapaca kirkiana* is weaker compared to that of *Khaya anthotheca* implying that it cannot be useful in most wood works where toughness and shock resistance is required. The modulus of elasticity and total work of *Uapaca kirkiana* is closer to that of *K. anthotheca* implying that both tree species can be used in wood works, which requires certain same level of stiffness and flexibility and total work strength property. Also it was observed that work to maximum load for *U. kirkiana* was the same to that of *K. anthotheca.* The compression strength parallel to the grain for *Uapaca kirkiana* is less than that of *Khaya anthotheca* implying that its crushing strength is inferior. The shear strength parallel to the grain for the *Uapaca kirkiana* was lower than that of *Khaya anthotheca* implying that it is inferior for use especially in designing joint in construction work. The cleavage strength for *Uapaca kirkiana* is approximately twice as much of *Khaya anthotheca* and therefore can be used to substitute *Khaya anthotheca* where high nails and screws holding are needed.

Table 6 Comparison of wood properties of *Uapaca kirkiana* and *Khaya anthotheca*

Strength properties	Species	
	Uapaca kirkian	*Khaya anthotheca***
Modulus of rupture (N/mm^2)	59.7	76
Modulus of elasticity (N/mm^2)	7185.69	7800
Total work to failure (N/mm^2)	0.07	0 .109
Work to maximum load (N/mm^2)	0.06	0.066
Compression strength parallel to grain (N/mm^2)	34.4	42.4
Shear strength parallel to grain (N/mm^2)	11.86	13.8
Cleavage (N/mm-width)	20.21	11.0

** **Source:** Lavers (1969)

CONCLUSION AND RECOMMENDATIONS

From the results of the present study and preceding discussion, the following conclusions are drawn:

The wood of *Uapaca kirkiana* has similar colour and close basic density to that of *Khaya anthotheca*, and therefore could be classified as a moderate density timber species like *K. anthotheca*. Regarding radial direction, its basic density is higher closer to the pith decreasing outward and increasing before it decreases again close to the bark. In axial direction the basic density is higher at the bottom and lowest at the middle and again higher at the top.

From its mechanical properties tests, *Uapaca kirkiana* has modulus of elasticity, total work to failure, work to maximum load, and shear strength parallel to grain close to *Khaya anthotheca*. Except the cleavage strength, which was higher, its modulus of rapture and compression strength parallel to grain was significantly lower than *K. anthotheca*.

Due to the similarity in some of their physical and mechanical properties, the wood of *Uapaca kirkiana* is therefore recommended to substitute *Khaya anthotheca* in wood works especially where medium density wood is needed like in decoration where colour is considered an important aspect for appearance purposes and in cabinet, panel and furniture making except where high-class strength joinery is needed.

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