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A COMPARATIVE STUDY OF SOME MECHANICAL PROPERTIES OF GMELINA ARBOREA, PARKIA BIGLOBOSA AND PROSOPIS AFRICANA TIMBERS FOR STRUCTURAL USE

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***Abstract*— In this paper, the mechanical properties of locally available *Gmelina arborea, Parkia biglobosa* and *Prosopis africana* timbers from forest in Idah town in North-Central part of Nigeria were investigated to compare their physical and mechanical properties as well as their suitability for structural use. Laboratory tests were carried out on the timber samples obtained from the timber types under investigation in accordance with BS 5268 [1] to determine some of the physical and mechanical properties of the timber types. The properties tested included: bending strength, tensile strength, modulus of elasticity, and shear strength. Others included compression strength, moisture content and density. The results obtained showed that the three timber types investigated are hardwood. *Prosopis Africana* had the highest mechanical and physical properties closely followed by *Parkia Biglobosa. Gmelina Arborea* ranked third in the results of these properties obtained. The results obtained show that the timber types are hardwood of higher strength classes (between strength classes D30 – D70) when compared with Table 8 of BS 5268 The F-values and p-values obtained from the ANOVA of the physical and mechanical properties tests carried out on the timber types showed that the compression strength, bending strength, modulus of elasticity, shear strength and density have no difference within the three timber types investigated except for the moisture content which revealed that there is significant difference in moisture within the group of the tested timber types. *Gmelina arborea*, *Parkia biglobosa* and *Prosopis africana* obtained from Idah (North-Central Nigeria) are therefore suitable for structural use in the construction industry.**

***Index Terms*— Timber, Strength, ANOVA, Structural, Mechanical, Physical.**

I. INTRODUCTION

Wood is the oldest material used by humans for construction after stones. Despite its complex chemical nature, wood has excellent properties that lend themselves to human use. It is readily and economically available, can easily be machined, and amenable to fabrication into an infinite variety of sizes and shapes using simple on-site building techniques. It is a natural material that is available in limited amount [2]

There are basically two types of wood namely softwoods and hardwoods; where the names are derived from the types of tree the timber comes from. While softwoods come from coniferous trees, hardwoods come from deciduous trees [3]. The hardwoods are harder and stronger than the softwoods.

Timber and timber products are utilized by a wide range of industries but the bulk of it continues to be used in the construction industry for both structural and non structural purposes. Structural uses of timber include construction of roof trusses/floor joist while non-structural uses include making of doors, window frames, external cladding, etc.

The demand for timber is unlimited as it continues to increase rapidly in Nigeria and this calls for frequent investigation for steady supplement because there is no reason to doubt that this trend will continue as demands for houses and other related structures where timber use is obvious are on the increase resulting in deforestation [4]. Hence, the need to compare the structural properties of the following timbers*:* *Gmelina arborea, Parkia biglobosa* and *Prosopis africana* has provoked this research.

Timber, like other building materials, has inherent advantages that make it especially attractive in specific applications [5]. One of the major requirements for the use of timber for structural purpose is that the strength and stiffness properties be kept within desirable limits [6].

The use of timber for structural purposes has always been affected by lack of appropriate design codes and well-established standards [7]. There are instances where the choice of a timber for a particular purpose does not depend to some extent on one or more of its mechanical or strength properties.

The timber types under investigation; *Gmelina arborea* (White teak, Melina), *Parkia biglobosa* (African locust beans) and *Prosopis africana* (African mesquite, iron wood) are found in West Africa with their common names in parentheses [8]. They are fast growing trees which almost grows very well everywhere on Nigerian soil. Furthermore, they are tropical hardwood and can be developed extensively where it has never existed before [8] and [9].

Apart from the fact that these trees can be used as timber for both structural and non-structural purposes, they have non-timber uses as well. The roots and bark of *Gmelina Arborea* are majorly used as herbs and laxatives while the leaves serve as feeds for cattle and goats among other uses [10] and [11]. The seeds of *Prosopis Africana* and *Parkia biglobosa* are used as local food condiments (dawadawa) when cooked and fermented while the leaves equally serve as animal feed.

This research was aimed at investigating and comparing some physical and mechanical properties of *Gmelina arborea, Parkia biglobosa* and Prosopis africana grown in Nigeria to determine their suitability for structural timber use. The physical properties that were investigated were moisture content and density while the mechanical properties investigated were: compression strength, bending strength, tensile strength, modulus of elasticity, and shear strength. Moisture content, temperature, and even the size of specimen affect the values obtained for the strength of timber and in order to achieve comparable results, standard test procedures under controlled conditions and based on the use of small clear standard specimens that are free from defects were adopted throughout this research.

II. MATERIALS AND METHODS

The timber samples were obtained and converted into pieces of 50mm x 50mm x 450 mm; 50mm x 75mm x 450mm and 75mm x 75mm x 450 mm for the purpose of bending strength, tensile strength, modulus of elasticity, and shear strength tests. While sample sizes of 50mm x 50mm; 50mm x 75mm and 75mm x 75mm were used for compression test, moisture content and density tests. Three samples each were used for each of these tests as spelt out above and average values were thus computed. The values of the various physical and mechanical properties were determined from laboratory tests carried out in accordance with BS 5268: 2002 using an electronic Universal Testing Machine model EKE900 and the values were corrected for allowable working or design stresses. The results obtained were subjected to ANOVA. The results have been presented in Tables 1a – 1b and Tables 2a – 2h. Also graphs of the relationships were also plotted. The various results were compared for the timber types under investigation.

Equation 1 was used to compute the moisture content (*mc*) of each sample.

$$mc = \frac{m_2 - m_1}{m_1} x100 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where m_2 = weight of timber sample at test (kg)
m_1 = Oven-dried weight of timber sample at test (kg)

In computing the densities of the timber samples, equation 2 below was used

$$\rho = \frac{m_s}{v_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where m_s= weight of timber sample (kg)
v_s= volume of timber sample (m^3)

The formulae used to calculate the compression strength and static bending strength are as shown in equations 3 and 4.

$$\sigma = \frac{P_s}{A_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where P_s= Applied compression load *N*
A_s = Cross Sectional Area mm^2

$$f = \frac{3PL}{2bh^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where: P = Applied bending load *N*
L = Length of sample *mm*
b = breadth of sample *mm*
h = depth of sample *mm*

In computing the modulus of elasticity and the tensile strength of the timber samples, equations 5 and 6 respectively were used

$$E = \frac{PL^3}{48Iy} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where P = bending load *N*,
y= the corresponding mid-span deflection at this load *mm*,
I = the moment of inertia mm^4.
L = Length of sample *mm*

$$T = \frac{F_s}{A_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where P_s= Applied tensile load *N*
A_s = Cross Sectional Area mm^2

The formula used to calculate the shear strength of the timber samples is as shown in equations 7

$$\tau = \frac{P_s}{A_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Where P_s= Applied shear load *N*
A_s = Cross Sectional Area mm^2

III. RESULTS

Tables 1a and 1b below shows the results obtained from the laboratory research work carried out on some mechanical properties of the timbers under investigation. Similarly, the results of the ANOVA statistical test performed for the physical and mechanical properties determined have been presented in Table 2a – Table 2h. Similarly, a plot of the Group Means with 95% Confidence Intervals for each of the determined properties have been presented in Figure 2a to Figure 2h.

S/No.	Timber Name	Specimen No.	Moisture Content (%)	Density (kg/m3)	Compression parallel to grains (N/mm²)	Compression perpendicular to grains (N/mm²)	Static bending parallel to grains (N/mm²)	Tensile strength (N/mm²)	Shear strength (N/mm²)	Modulus of Elasticity (N/mm²)
1	*Prosopis Africana*	**PA1**	11.5	980	23.5	5.6	22.7	13.6	2.5	17 570
		PA2	11.6	978	23.6	5.8	22.8	13.8	2.7	18 010
		PA3	11.8	988	23.8	5.5	22.8	13.5	2.5	17 780
2	*Parkia Biglobosa*	**PB1**	11.6	785	14.8	3.8	16.0	9.8	2.3	12 850
		PB2	11.8	782	14.6	3.8	15.8	9.8	2.4	13 000
		PB3	11.5	783	14.3	4.0	15.6	9.7	2.1	13 050
3	*Gmelina Aborea*	**GA1**	11.5	688	7.6	2.4	12.6	6.5	1.3	7 950
		GA2	11.6	685	7.3	2.6	12.4	6.4	1.3	8010
		GA3	11.4	687	7.4	2.5	12.5	6.7	1.2	8020

Table 1a: Laboratory results of the mechanical properties of the timbers under investigation

S/No.	Timber Name	Mean Compression parallel to grains (N/mm²)	Mean Compression perpendicular to grains (N/mm²)	Mean Modulus of Elasticity (x10³N/mm²)	Mean Static bending parallel to grains (N/mm²)	Tensile Strenght (N/mm²)	shear Strenght (N/mm2)	Mean Moisture Content (%)	Mean Density (x10^2kg/m^3)
1	*Prosopis Africana*	23.6	5.6	17.79	22.8	13.6	2.6	11.63	9.82
2	*Parkia Biglobosa*	14.6	3.9	12.97	15.8	9.8	2.3	11.63	7.83
3	*Gmelina Aborea*	7.4	2.5	8.02	12.5	6.5	1.3	11.5	6.87

Table 1b: Mean values of mechanical and physical properties in Table 1a

Fig. 1a Graphical representation of the mechanical properties tests results for the timber types

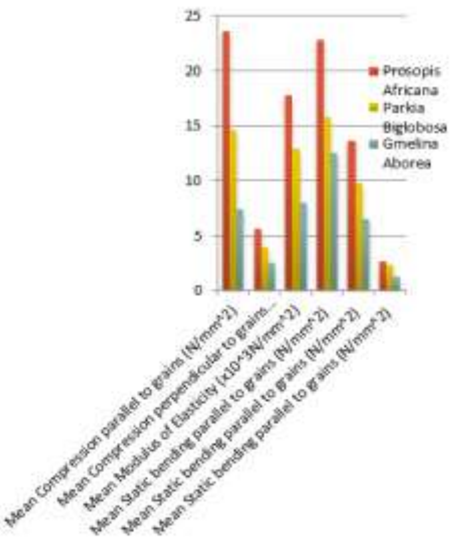


Fig. 1b Graphical representation of the physical properties tests results for the timber types

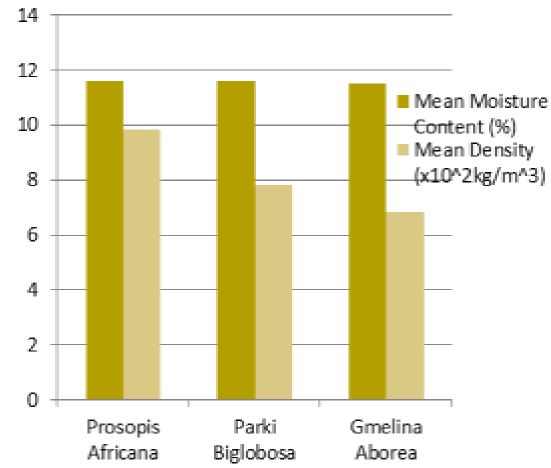


Table 2a The results of ANOVA statistical test performed on the compression strength parallel to grains data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom (D.F.)	Mean Squares (M.S)	F	P
Between Error Total	395.5 0.220 395.7	2 6 8	197.8 3.6667E-02	5394	0.0001

Table 2b The results of ANOVA statistical test performed on the compression strength perpendicular to grains data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom (D.F.)	Mean Squares (M.S)	F	P
Between Error Total	14.81 9.33E-02 14.90	2 6 8	7.403 1.556E-02	475.9	0.0001

Table 2c The results of ANOVA statistical test performed on the Modulus of Elasticity data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom	Mean Squares (M.S)	F	P
Between Error Total	1.44E+08 1.21E+05 1.44E+08	2 6 8	7.19E+07 2.02E+04	3555	0.0001

Table 2d The results of ANOVA statistical test performed on the shear strength data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom (D.F.)	Mean Squares (M.S)	F	P
Between Error Total	2.780 8.00E-02 2.860	2 6 8	1.390 1.33E-02	104.3	0.0001

Table 2e The results of ANOVA statistical test performed on the tensile strength data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom (D.F.)	Mean Squares (M.S)	F	P
Between Error Total	75.82 0.1000 75.92	2 6 8	37.91 1.6667E-02	2274	0.0001

Table 2f The results of ANOVA statistical test performed on the static bending strength

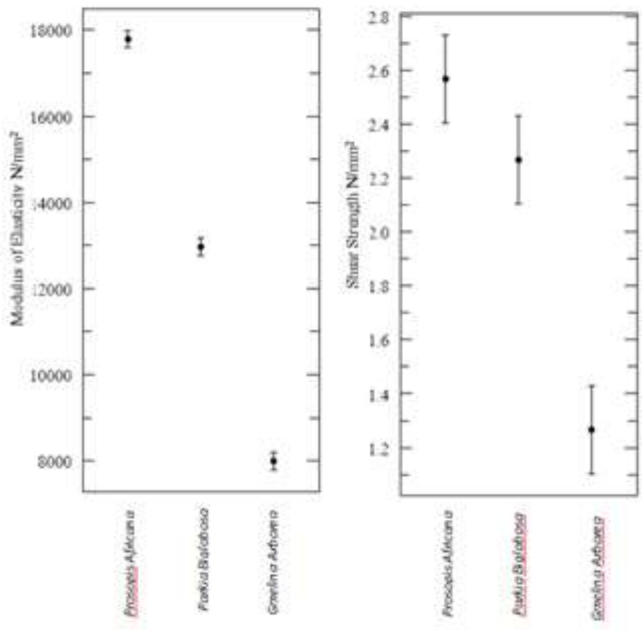
Source of Variation	Sum of Squares (S.S.)	Degree of Freedom	Mean Squares (M.S)	F	P
Between Error Total	164.8 0.1067 164.9	2 6 8	82.41 1.7778E-02	4636	0.0001

Table 2g The results of ANOVA statistical test performed on the density data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom (D.F.)	Mean Squares (M.S)	F	P
Between Error Total	1.3603E+05 65.33 1.3610E+05	2 6 8	6.8017E+04 10.89	6246	0.0001

Table 2h The results of ANOVA statistical test performed on the moisture content data

Source of Variation	Sum of Squares (S.S.)	Degree of Freedom	Mean Squares (M.S)	F	P
Between Error Total	3.5556E-02 0.1133 0.1489	2 6 8	1.7778E-02 1.8889E-02	0.9412	0.44



a **b**

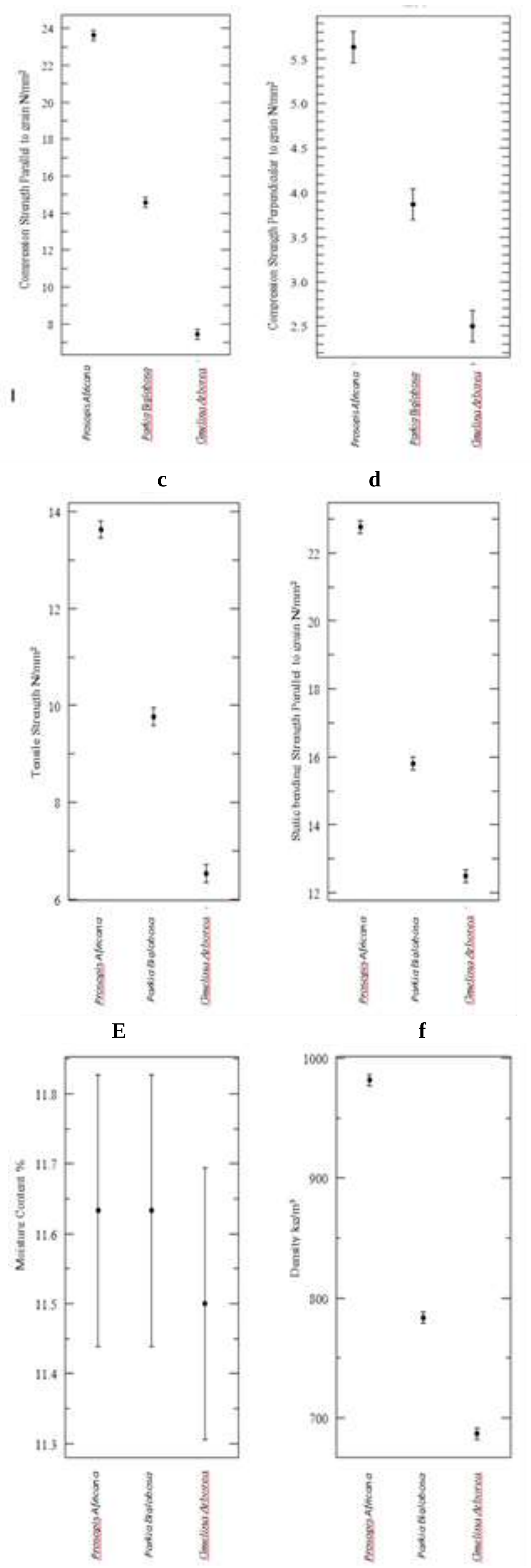


Fig 2 Plot of the Group means with 95% confidence Interval of the properties

IV. DISCUSSIONS

From the results obtained and analyzed, the three timber types have higher compression strengths when loaded parallel to the grains than when loaded perpendicular to the grains. The compression strengths parallel to the grains ranged between 7.3 N/mm^2 to 23.8 N/mm^2 while the compression strengths perpendicular to the grains ranged between 2.4 N/mm^2 to 5.8 N/mm^2

Similarly, the three types of timber performed better in tension than in shear evident in the results of tensile strengths between 6.4 N/mm^2 to 13.8 N/mm^2 and shear strengths between 1.2 N/mm^2 to 2.7 N/mm^2. The modulus of elasticity (MOE) and the static bending strengths (flexural strengths) also show that the timber types are hardwood of higher strength classes (between strength classes D30 – D70) when compared with Table 8 of BS 5268.

The densities obtained ranging from 685 to 988 kg/m^3 show that these group of timber investigated are hardwoods since the values obtained are greater than 640 kg/m^3.

The moisture content results obtained showed that the values are below saturated moisture level of 25%.

From the physical and mechanical tests carried out on the three timber types, it was observed that *Prosopis Africana* had the highest values of properties tested (Tables 1a; 1b and Figures 1a; 1b), closely followed by *Parkia Biglobosa*. *Gmelina Arborea* ranked third in values obtained from the tests.

From the ANOVA results obtained, it has been observed that the F-values are large for the tested properties ranging from 104 for shear strength test to 624 being for density test; except for the moisture content which yielded an F-value of 0.94. Also, the P-values obtained from the ANOVA of the properties tested were 0.01% with the exception of the moisture content test analysis which yielded a P-value of 44%.

The large F-values corresponding with insignificant P-values obtained from the ANOVA of the results of the compression strength, bending strength, tensile strength, modulus of elasticity, shear strength and density tests have shown that there is no relative difference in the tested properties within the three timber types investigated. However, the small F-value and high P-value from the ANOVA of the results of the moisture content has revealed that there is a significant difference in the moisture content within timber types investigated.

It can also be observed from the confidence interval charts (Figs. 2a – 2h) that the means of the tested properties of the timber types investigated all fell within the sample mean which is a good correlation.

These results obtained compared favourably with other known structural timbers such as mahogany, afara, iroko, obeche, owen, idigbo, etc which are commonly known timbers in use within the tropics [1], [2] and [12].

V. CONCLUSION AND RECOMMENDATIONS

The timber types investigated *Gmelina arborea, Parkia biglobosa* and *Prosopis africana* have proved to have physical and mechanical properties that make them suitable for structural engineering use as hardwood. Structural Engineers, carpenters, etc are encouraged to explore and use *Gmelina arborea, Parkia biglobosa* and *Prosopis africana* for structural and non structural uses. However, the mechanical properties can be enhanced with adequate seasoning if these timbers are for structural purposes. More research work is needed in determining the suitability of other widely grown trees in this part of Nigeria such as neem, baobab, etc for use as structural timbers in construction. Finally, massive afforestation practices should be promoted to reduce the dearth of some notable species of trees in the forest in this study area.

REFERENCES

[1] BS 5268, "Structural use of timber". Part 2: Code of practice for permissible stress design, materials and workmanship. British Standards Institution. London, 2002

[2] USDA, "Wood handbook—Wood as an engineering material". General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 2010.

[3] Aydin, S., Yardimci, M., and Ramyar, K.. "Mechanical Properties of Four Timber Species Commonly Used in Turkey". Turkish J. Eng. Env. Sci., 2007 (31) 19 – 27.

[4] Aguwa, J.I. and Sadiku, S., "Reliability studies on the Nigerian Ekki timber as bridge beam in bending under the ultimate limit state of loading". Journal of Civil Engineering and Construction Technology, 2011 2(11), pp253-259,

[5] Afolayan, J.O., Adeyeye, A., "Failure Analysis of a Glue-Jointed Roof Truss". Journal of Engineering and Applied Sciences. 1998 17(1), pp51-63.

[6] Larsen, H.J., "Properties affecting reliability design of timber structures". COST E24 Seminar on Reliability of Timber Structures Coimbra, Portugal, 4 – 5 May 2001.

[7] Zziwa A., Ziraba, Y.N. and Mwakali J.A., "Strength Characterisation of Timbers for Building Construction in Uganda". Second International Conference on Advances in Engineering and Technology 2011 pp 450-456

[8] Orwa C., Mutua A., Kindt R., Jamnadass R, and Anthony, S., Agroforestree Database:a tree reference and selection guide version 4.0 2009 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)

[9] Teklehaimanot, Z. "Exploiting the potential of indigenous agroforestry trees: Parkia biglobosa and Vitellaria paradoxa in sub-Saharan Africa". Agroforestry Systems 2004 61-62 (1-3) pp207-220

[10] Munira B., Gururaja G.M., Deepak M., Roopashree, T.S, and Shashidhara, S., "An overview on Phytochemistry and Pharmacological properties of *Gmelina arborea".* J. Nat. Prod. Plant Resources 2013, 3 (4):62-71

[11] Gabunada, F.G., Obusa, A.P., Espinosa, E.A and Gozo, A.G. "On farm evaluation of Tree-leaf supplementation using Leucaena leucocephala and Gmelina arborea to Goats under traditional feeding management". Farm and Resource Management Institute, Leyte State University, Bay Bay, Leyte Philippines 1998.

[12] TRADA "Timbers – their properties and uses". http://www.trada.co.uk. 2002.Accessed 02/07/2012.