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Variation in the Percentages of the Bark of Ten Tropical Hardwood Species Growing in Nigeria

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Abstract
There is an increasing global interest in bark utilization as a substitute to fossil fuel as a result of climate change problems. Efforts are being directed at promoting sustainable utilization of wood bark in biorefineries and in tannin adhesives production. Until recently, bark is treated as a waste, thus, little research efforts are directed at studying the bark percentage of indigenous hardwoods in Nigeria. This study shows that there is high variation in the bark percentages of the wood species used. The mean bark percentage ranged from 6.08% in *A. leiocarpus* to 15.00% in *D. senegalense*. Within species variation was also observed to be high. The bark percentage ranged from 5.88 to 12.5% in *A. nilotica* and 5.88 to 12.24% in *A. Africana* respectively.
Keywords: bark, bioresources, bark percentages, hardwoods, variations.

Introduction

The petroleum crises of the early 1970's, coupled with need for climate change mitigation globally, have led to renewed interest in bioresources as industrial raw materials. Also, evidence of the unsustainability of large scale petrochemical use in the industry has become insurmountable (Hokkarien, 2012). More recently, research and development efforts are being initiated to focus on transforming bark biomass to higher value, eco-friendly industrial products with large market potentials. These bio-products can be used either as substitutes or replacement for petroleum-based products and help to mitigate climate change. In addition, innovative research in these areas has great potentials to improve forest, chemical and automotive industries operation as well as resulting in higher economic and environmental benefits (BBP, 2011).

Generally, the utilization of tannin from bark for adhesives production has been proposed by many authors (Long, 1991; Zhao et al, 1994; Lu et al, 1995; Vazquez et al, 1996; Yakazi, 1998; Ogama et al, 2000). Since the introduction of tannin as a substitute to phenol, in the production of adhesive resins, efforts have been made to improve tannin formaldehyde resin. Efforts by researchers have led to commercial production of resin of low viscosity and with reactivity that equals that of ureaformaldehyde resins. More recently, a bark biorefinery project was initiated in Canada as a partnership between forest, chemical and automotive industries and the public sector with the aim of converting green bark into green value added products (BBP, 2011). Research team from the University of Toronto and Lakehead University received funds from the Ontario Ministry of Research and Innovation and equal amounts from the private sector and institutional support that amounted to $5.26million for research on transforming bark into higher value eco friendly products with large market potentials along two industrial areas which include green adhesives and bark based foams. The project aimed at using these products as replacements to petroleum based products for mitigating climate change.

In view of the above, considerable interest have been generated on research into variations in the percentage of bark within trees of the same species and those of different species. Among the properties that will qualify the bark of a wood as a potential raw material in the developing biorefinery and tannin industries are the percentage of the bark they contain and the extent of within and between species variation in bark percentages. A survey of literature on the percentage of bark in hardwood species growing in Nigeria show that there is a dearth of information on the bark percentage of most hardwood species. This study was therefore carried out to determine the variation in bark percentages of 10 tropical hardwood species growing in the country.

2.0 Materials and Methods

2.1 Materials

The ten hardwood species utilized in the study comprised of *Acacia nilotica* wild ex linn Deivar nilotica*; Afzelia africana* Smith*; Anogeissus leiocarpus* (D. C), Guel and Perr; *Daniellia oliveri* (Rolfe) Hustch; *Detarium senegalense* J. F. Gmel; *Mitragyna inermis, Parinarium kerstingii* Engl; *Prosopis africana* Taub; *Pterocarpus erinaceus* Poir; and *Sterculia setigera*. All the samples were collected from the derived savanna forest at Oke Awon near Jebba (Latitude 9.3^{o}N, Longitute 4.46^{o}E). The weather conditions in Oke Awon are shown in Table 1. Five trees of each species selected at random were felled and wood discs about 7.5cm thick were taken at

breast height. The sample disc from each tree was immediately wrapped in plastic bag to prevent loss of moisture during transportation. The discs were stored in a cold room until required for test analysis.

2.2 Methods

Each disc was sanded with a mechanical sanding machine. The number of rings on each sanded disc was counted with the aid of a 10x magnification hand lens. The result was used to estimate the age of the trees.
After the above, the volume fractions of heartwood, sapwood and bark were completed on the entire discs of each sampled material using a 120 point circular grid. The test points were constructed by super imposing 15 concentric circles within the other on a tracing paper. The circles were divided into test points by constructing four diagonal lines that ran from one end of the circle to another. The number of points that fell on each feature of interest divided by total number of test points covered by the sample gave the volume fraction of each gross feature of interest.

3.0 Results and Discussions

Table 2 shows the results of the ranges, coefficient of variation in the ages, diameter and bark percentage of the ten hardwood species used in the study.

3.1 Bark Percentage in the studied species

D. senegalense has the highest bark percentage among all the species . The mean bark percentage was 15%. The bark percentage within the species varied from 13.95 to 18.18% with a coefficient of variation of 10.00. This was closely followed by *S. setigera* with a mean bark percentage of 13.37% and *M. inermis* with a mean bark percentage of 12.22%. The species with the lowest bark percentage were *A. leiocarpus,* 6.08%; *P. kestingii,* 8.88% and *A. nilotica,* at 9.69%. When bark percentage are too low, its use for production of bark chemicals may not be economical (Ogunwusi, 2013; Harkin and Rowe, 1971).

3.2 Within Species variation in Bark Percentage of the plant species

Acacia nilotica trees have the highest between tree variations in bark percentages (Table 2).
The bark percentage of the species varied from 5.88 to 12.5% with a coefficient of variation of 26.59. This was closely followed by *S. setigera* which varied considerably from 10.52 to 17.39 % with a high coefficient of variation of 21.08.The coefficient of variation in the bark percentage of species such as *M. inermis* and *D. oliveri* were within single digit, indicating, that between tree variations were not high. In general, the bark percentages observed in this study was lower than those reported for some hardwoods in literature. Perez and Kanninen (2003) reported the bark percentage of *Tectona grandis* to vary from 14 to 37% of the total tree volume. Also, Young (1971) and Chamberlain and Meyer (1950) observed that on the average, barks are about 13 to 21% of a typical log by volume.

3.3 Between species variation in bark percentage

There is wide between species variation in the bark percentages of the studied species. The mean bark percentage ranged from 6.08% in *A. leiocarpus* to 15% in *M. inermis*. The age range of the wood samples of *A. leiocarpus* used in the study varied from 35 to 57 years with a coefficient of variation of 21.92%. This age range closely followed those of the samples of *D. oliveri* used in the study. The age range of the *D. oliveri* samples ranged from 28-59 years. This however does not significantly influence the bark percentage which ranged from only 10.39 to 12.90% with a mean of 8.35%.

4.0 Conclusion

The bark percentages in the studied species are lower than those reported for some hardwoods in literature. However, where bark is to be employed as an industrial raw material, most especially, in biorefinery and chemicals production, the use of bark from species with low bark percentage may not be economical as quantity of bark generated per wood and per species, would be a very important issue for economic reasons. However, if the woods are only to be sawn and used for planks production, the lower the percentage of bark in the species the better. High bark percentage reduces the volume of usable wood and adds to the transportation cost. Thus, low bark percentages in the *A. leiocarpus, P. kerstingii* and *A. nilotica* may be an advantage in sawn wood, but a disadvantage if they are to be extracted for chemicals production at industrial level.

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Table 1. Average annual climatic conditions of Oke Awon Forest Reserve

Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rainfall (mm)	2.3	15.8	36.0	148.2	181.9	213.8	448.3	511.2	263.2	118.6	6.0	0
Relative Humidity%	4.18	41.3	46.2	52.7	69.3	75.8	78	81.8	82	78.7	73.2	51.2
Temperature (°C)	24	28	32	33	32	29	27	26	28	31	29	26

Source: Momodu (1983)

Table 2. Mean, ranges and coefficient of variation of the ages, diameter and bark percentages of the ten hardwood species

Species	Statistical Parameter	Age (years)	Diameter (cm)	Bark percentage (%)
D. oliveri	Mean	39.9	19.26	11.83
	Range	28-59	16.5-22.0	10.39-12.90
	C.V.	28.38	11.27	8.35
S. setigera	Mean	39.4	17.54	13.37
	Range	38-40	15.4-20.00	10.52-17.39
	C.V.	3.8	9.8	21.08
P. Africana	Mean	23.8	19.12	12.40
	Range	18-28	14.7-22.7	10.53-14.50
	C.V.	14.9	14.90	11.77
A. *Africana*	Mean	45	27.58	10.29
	Range	34-52	24.2-29.2	5.88-12.24
	C.V.	13.6	6.7	19.70
M. inermis	Mean	23.4	13.8	12.22
	Range	20-27	11.15-17.00	10.87-13.55
	C.V.	10.23	14.40	9.00
P. erinaceous	Mean	36	18.68	10.42
	Range	27-50	17.10-21.00	9.23-11.84
	C.V.	23	7.0	10.00
P. kerstingii	Mean	35.6	18.18	8.88
	Range	31-40	13.9-21.00	8.08-10.38
	C.V.	1.89	16.16	8.8
D. senegalense	Mean	49	21.66	15.00
	Range	29-67	14.3-27.0	13.95-18.18
	C.V.	25	21.90	10.00
A. *nilotica*	Mean	32.2	15.12	9.69
	Range	22-53	13.0-20.01	5.88-12.5
	C.V.	34	23.7	26.59
A. *leiocarpus*	Mean	39.8	23	6.08
	Range	35-57	20.2-27.5	4.94-7.07
	C.V.	21.92	10.6	11.30

cv = coefficient of variation

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