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Calorific Values of Charcoal Produced from Woods of *Gmelina arborea* (Roxb), *Tectona grandis* (Linn) and *Pentaclethra macrophylla* (Bentham)

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Abstract:
This study aimed at investigating the calorific values of charcoal produced from *G. arborea*, *T. grandis* and *P. macrophylla* woods at different longitudinal and radial positions. There were significant differences ($p<0.05$) between the longitudinal and radial position. Sapwood from *G. arborea* had the lowest calorific value (6772 kCal/kg) at the middle followed by the base sapwood (6939 kCal/kg), while the highest value was obtained at the top (7124 kCal/kg). Conversely, the middle sapwood of *T. grandis* had highest calorific value, followed by base sapwood while the top sapwood had the least. The same trend was observed in *P. macrophylla*. The heartwood had lowest calorific value at the middle with 6788, 7043 and 7121 kCal/kg for *G. arborea*, *T. grandis* and *P. macrophylla,* respectively. The calorific values for the heartwood from the base were 6960, 7419 and 7591 kCal/kg for *G. arborea*, *T. grandis* and *P. macrophylla,* respectively.

Keywords: Calorific values, Charcoal, *Pentaclethra macrophylla, Gmelina arborea, Tectona grandis*, Sapwood, Heartwood

Introduction

According to Akachuku (1997), fuelwood including charcoal accounts for 80-95% of wood consumed in tropical Africa. This shows that the forests of this region are being exploited largely for fuelwood. Attempts to save African forests from fuelwood cutting by establishing village woodlots have not been successful (ARD, 1991). In developing countries charcoal is still widely used by urban and rural people as a smokeless domestic cooking and grilling fuel with high heating value. In developed countries there is an increasing demand for charcoal for barbecue. A large amount of charcoal is used in copper and zinc production as well as in the production of precious metals. Charcoal is a popular household fuel in many parts of the developing world. Countries like Kenya have a yearly consumption of about 2.4 million tons of charcoal (Adam, 2005) while Zambia uses about 1 million tons (Chidumayo, 1991). Charcoal is produced by a partial chemical reduction of wood under controlled condition. The yield of charcoal by weight is usually about 20 - 30% of the dry weight of the wood used and the yield by volume is 50% (Earl, 1975; Eimer and Ndmana, 1987; Amous, 1992). The techniques for making charcoal range from simply covering and burning wood with soil and fuel to the use of very sophisticated and automatic retorts and furnace. In countries with surplus manpower and plentiful forest resources, the use of portable steel Kiln to make charcoal offers a low cost investment opportunity. According to Earl (1975), the physical and chemical property of charcoal depends on those of the original materials from which it was made and on the carbonization process. Most users prefer charcoals that do not break easily and will continue to emit heat for a long time. The methods of charcoal production are categorized as follows: traditional charcoal production, improved traditional methods, industrial production technologies, new high-yield and low emission system.

Charcoal has energy value of 7.1 calories which is higher than that of wood which stands at 3.5 calories (Earl, 1975). This means that charcoal cooks food faster than fuel wood when used domestically by rural households. There is however the need to investigate what species and what part of the tree produces charcoal with the highest calorific value so that efforts can be made to mass produce them in efficient ways.

According to FAO (2000) the most obvious direct benefits is that obtained from home production of valuable fuel. Equally important is the effect which charcoal production may have in reducing the cost of sivilcultural operations by reducing the cost of removal of cut-down wood which therefore increases the total profitability of forest resources. Indirect benefits include employment opportunity for the rural dwellers. The intangible benefits are difficult to quantify but these include conservation of the world fossil fuel resources, reduction of environmental pollution and waste management. Wood species used in this study include *Gmelina arborea, Tectona grandis* and *Pentaclethra macrophylla.*

Gmelina arborea is a medium-sized deciduous tree up to 40 m tall and 140 cm in diameter (Jensen 1995). The tree form is fair to good, with 6-9 m branchless, often crooked trunk and a large, low- branched crown.

Tectona grandis (*Teak*) is a woody tree species from the family *Verbenaceae*, it has a high proportion of heart wood, which tend to be dark and of a uniform golden brown colour. Teak is easy to tend, has fast growth rate, it is a tree that has been found to possess good quality of timber for construction, furniture work, building, and as a source of pulp for the manufacture of paper generally. This species originated from India, Burma and Malaysia Peninsula, (Keay, 1989). It belongs to the family *Verbanecease* and Tribe of *Tectoneae* from *Tekka*, the *malabor* name for *T. grandis* (White, 1991). The genus name *Tectona* is derived from the Greek world *teckton* which means carpenter's pride (Bhat, 2003). It has subsequently been introduced to many Southeast Asian countries as well as some African countries including Nigeria. Teak has been widely planted in Southern Nigeria. It was first introduced into Nigeria in 1889 with the establishment of trial plantation in *Olokemeji* forest reserve in Ogun State (Adeyoju, 1975).

Pentaclethra macrophylla is commonly known as *Ugba* in *Ibo*, *Okpagha* in *Urhobo* and *Bini*. Some parts of the plant have medicinal values. It is a leguminous tree (family *Leguminosae,* sub-family *Mimosoideae*), and recognized by peasant farmers in the southeastern portion of Nigeria for its soil improvement properties. *P. macrophylla* has been cultivated in Nigeria since 1937 (Ladipo *et al.*, 1993) and for many years in other West African countries where its seed is relished as a delicacy food. With its diverse native uses, and the present research effort on it, its utility could be further enhanced for agroforestry development in the humid tropics. The species is relatively fast growing and seedlings will achieve a height of 1-5 m in the first year on good sites. Its trunk provides timber used for structural work. The tree yields footrest products and for making wooden household utensils (Asoegwu *et al.,* 2006).

The objective of this study was to determine the calorific values of charcoal produced from the wood of *G. arborea, P. macrophylla and T. grandis* at the axial, horizontal directions and within species variation.

Materials and Methods

Wood samples collection and preparation

Tree species used for this study were selected from the plantation of the Delta State University Asaba Campus. This plantation is in the rainforest zone of Nigeria, which lies between latitude 06°05´N of the equator and longitude 08°02´E and 06°07´E of Greenwich meridian. The climate is the equatorial type with two seasons in a year, the wet and dry seasons. The mean annual rainfall is 1250 mm with a bio-modal distribution. The wet seasons starts from April and ends in October. Annual temperature ranges from an average minimum of 21.3°C to an average maximum of 31.2°C.

The height measurements of each of the three trees species were taken with the aid of the Haga altimeter. From the felled trees, discs were cut at the base (10%), middle (50%) and top ((90%) with the chain saw. Two specimens from the heartwood and sapwood were collected each at three different longitudinal positions (breast height, middle and top). Three specimens were collected at the different levels, wrapped and marked separately and were taken to Sapele for charcoal production. Charcoals were produced in an earth kiln. Calorific values of the produced charcoal were determined using ballistic bomb calorimeter. This was done following the approach adopted by Akachuku (2005).

The study was arranged as a 3×3×2 factorial experiment in a completely randomized design (CRD) with three factors of experiment. Factor A is the wood species: *G. arborea, T. grandis and P. macrophylla*, factor B is the longitudinal position: base (10%), middle (50%) and top (90%) of the merchantable height and factor C is the radial position: sapwood and heartwood.

Results

The calorific values of the three wood species investigated are presented in Table 1. Results indicated that sapwood of *G. arborea* from the middle (50%) had the lowest calorific value (6772 kCal/kg) followed by the sapwood from the base (10%) (6939 kCal/kg) while the highest value was from the top (7124 kCal/kg). The sapwood from the middle of *T. grandis* had the highest calorific value followed by sapwood from the base while sapwood from the top had the least. Similarly, the caloric values of *P. macrophylla* followed the same trend with that of *T. grandis*. Generally, *P. macrophylla* had highest calorific values while *G. arborea* had the least irrespective of the longitudinal or radial position where the samples were collected (Fig. 1). In addition, the caloric values of the wood samples collected from the middle (50%) of all the species were the lowest in the longitudinal direction.

The calorific value of the sapwood and heartwood of 'excellent' fuel wood is reported to be 4,908 and 5,181 kCal/kg respectively (Krishna and Ramaswamy, 1931). The calorific values of charcoal produced from *G. arborea, T.grandis* and *P. macrophylla* wood (6960, 7419 and 7591 kCal/kg, respectively) far exceed those for an excellent fuel wood. Charcoal produced from *P.macrophylla* yielded best results compared to those produced from *G. arborea* and *T. grandis*. The calorific values obtained in this study compare favourably with those of some fuelwoods already reported by various researchers: *Cratoxylum cochinchinense, Pettophorum dasylachis, Pterocarpus marcocapus, Pinus merkusii, Sindora siamensis and Ketepeleeria davidiana* with calorific values of 7222, 7269, 7727, 8246, 7607, 7068, and 7595, respectively. Heartwood had higher calorific values than sapwood in this study. Krishna and Ramaswamy (1931) attributed the higher calorific values of the heart wood to the presence of organic deposits.

The fact that the calorific values from longitudinal and radial positions as well as from base to top fall within the values of the so called excellent fuel wood, whole tree of any of the wood species considered in this study could be used for high energy generating charcoal. However, *P. macrophylla* had the highest energy value locked up compare to *G. arborea* and *T. grandis.* It should be noted that charcoal quality is dependent upon many factors such as moisture content, wood species, wood arrangement and the skill of the producer (human factor). Any or more of these factors could have resulted in *P. Macrophylla* yielding more calories than the two other species.

Conclusion

The calorific values of plantation grown *P. macrophylla, G. arborea* and *T. grandis* were investigated. The effects of the sample position (longitudinal and radial positions) were also considered. Charcoal from *P. macrophylla* had the highest calorific values compared to those of *G. arborea* and *T. grandis*. All parts of the tree considered in this study could be used for charcoal production. From sustainable forest management point of view, utilisation of any part of the trees helps in reducing the ripple effect of deforestation.

Table 1: Calorific values of charcoal (kCal/kg) produced from the wood of *Gmelina arborea, Tectona grandis* and *Pentaclethra macrophylla* at different levels and positions on the tree

Longitudinal	Radial	*Gmelina arborea*	*Tectona grandis*	*Pentaclethra macrophylla*
Top	Sapwood	7124.33^{c}	7216.33^{b}	7402.00^{a}
	Heartwood	7250.67^{c}	7496.00^{b}	7575.67^{a}
Middle	Sapwood	6772.00^{c}	7351.67^{b}	7616.67^{a}
	Heartwood	6788.33^{a}	7043.33^{a}	7121.33^{a}
Base	Sapwood	6939.00^{c}	7323.00^{b}	7599.67^{a}
	Heartwood	6960.00^{b}	7419.00^{a}	7591.00^{a}

Mean with different superscript alphabet within same row are significantly different ($p<0.05$).

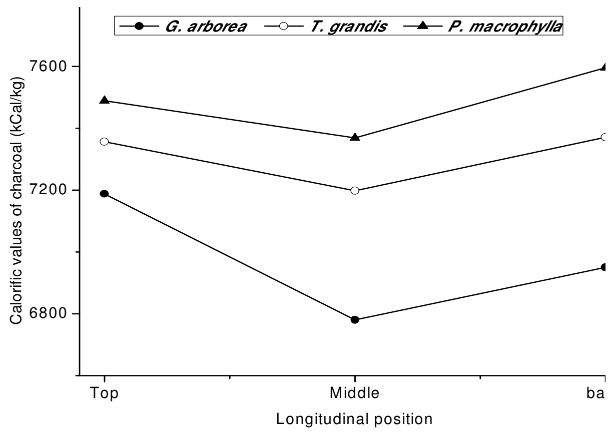

Figure 1. Calorific value of charcoal (kCal/kg) produced from *Tectona grandis, Gmelina arborea, and Pentaclethra macrophylla* at different longitudinal position.

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