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Assessment of the Calorific Value of Charcoal from *Gmelina Arborea (Roxb), Tectona Grandis (Linn)* and *(Bentham)*

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Abstract- This study was carried out to determine the calorific values of charcoal produced from the wood of *Gmelina arborea*, *Tectona* grandis and *Pentaclethra macrophylla* (Bentham). The purpose of this study is to find out the calorific values of charcoal from these different species at different levels and positions in the tree. The wood species were subjected to three different treatments. The results shows that there were significant differences ($p<0.05$) between the treatments and parameter measured (Top sapwood, Middle sapwood, Base sapwood, Top heartwood, middle heartwood and Base heartwood). T_3 gave the highest calorific value of charcoal produced, while middle heartwood gave the best result for all treatments. Based on this investigations T_3 (*Pentaclethra macrophylla* (Bentham) can be used for charcoal production. Forest depletion by man is one of the causes of climate change. Bearing this in mind, we need to exploit our forests in a sustainable manner. Households, especially in the rural settlements rely very much on fuel wood for cooking. This has contributed in no small measure to the depletion of our forests. Extension agencies need therefore to take advantage of the result of this study toencourage households to use charcoal, especially that derived from *Pentaclethra macrophylla.*

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I. Introduction

Resources of the tropical forest are vast and these resources vary (Etukudo, 2000). Throughout the tropics, people have depended on these (indigenous) flora and fauna for food security and a host of daily needs from medicine to fibre (Etukudo, 2000). Trees are the dominant component of tropical forest and they produce timber which is termed the major forest produce (Akande *et al,* 1998).

In 1969, the FAO panel of experts on forest Genetic resources assigned priority for improved utilization and conservation to *Gmelina arborea*. This reflected the fact that many tree planters considered *Gmelina* to be a very promising species due to ease and cheapness of establishment, rapid early growth, expectations of early returns and promising wood characteristics, including high durability and good yield and quality of pulp.

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The African oil bean *Pentaclethra macrophylla* (Bentham) is a tropical tree crop found mostly in the Southern and Middle Belts regions of Nigeria and in other Coastal parts of west and Central Africa. It belongs to the family *leguminosoe*, and sub-family *Minmosoidea* (Keay, 1989) with no varietal characterization. The tree is recognized by peasant farmers on these parts of the country for its soil improvement properties and as a component of an agro-forestry system (Asoegwu *et al, 2006*).

Oka for (1982) reported that *Pentaclethra macrophylla* is a food tree species for outlying farms. In the forest zone presently, they grow either wild or semi-wild with no organized cultivation in plantations or Orchards in Nigeria.

Tectona grandis (*Teak*) is a woody tree species from the family *verbenaceae*, has a high proportion of heart wood, which trends 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 sources of pulp for the manufacture of paper generally. Teak is generally good for any work which involved wood. Past research works have revealed that positive responses have been obtained in some of the pioneering fertilizer experiments conducted by (Nwoboshi, 1973, Kadeba 1978).

Half of the world's population uses biomass fuels for cooking. In 1992, 24 million tones of charcoal were consumed worldwide. Developing countries account for nearly all of this consumption, and Africa alone consumes about half of the world's production. Charcoal production has increased by about a third from 1981-1992, and is expected to increase with the rapidly growing population in the developing world. 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). The techniques for making charcoal range from simply covering and burning wood with soil and fuel to the use of very sophisticated 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.

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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.

A lot of economic benefits may be derived from the managed use of forest energy resources directly, indirectly and intangibly. 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 sivicultural operation by reducing the cost of removal of cut-down wood which therefore increases the total profitability of forest resources. Indirect benefits are in the areas of employment, provision of employment is a benefit not only because of the extra production obtained from more efficient use of human resources but also because of the possibility of collecting taxes for government projects which will in turn generate more employment. The intangible benefits are difficult to quantify but include such benefits as the encouragement of self reliance, conservation of the world fossil fuel resources and reduction of environmental pollution, and reduction of waste.

The 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. In spite of this superior quality over fuel wood people feel it does not produce charcoal of various calorific value. It is necessary to correct these perceptions on charcoal especially with regards to the ones that will prove to have higher and lower calorific values. Because charcoal produces more heat than wood, it needs to be investigated to find out what species, what part of the tree produces the highest so that efforts can be made to mass produce them in efficient ways.

II. Objectives of the Study

The major objective of this study is to determine the calorific values of charcoal produced from the wood of *Gmelina arborea, pentaclethra macrophylla (bentham) and Tectona grandis*. Specifically, this study aims at determining:

i. The calorific value of charcoal from the axial direction
ii. The calorific value of charcoal from the horizontal direction.
iii. The calorific value within species variation.
iv. The calorific value among species variation.

III. Materials and Methods

a) *Study area*

The study was carried out in Delta State University, Asaba campus and Sapele, both in Delta State. The study area is in the rainforest zone. The climate is the equatorial type with two seasons in a year, the wet and dry seasons.

The mean annual rainfall is 1250mm 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 study area in Delta State lies between latitude 06°05'N of the equator and longitude 08°02'E and 06°07'E of Greenwich meridian.

b) *Experimental Layout*

Experiment I was arranged in 3*x*3*x*2 factorial in a completely randomized design (CRD). With three factors experiment (three species; *Gmelina arborea, Tectona grandis, Pentaclethra macrophylla*), three positions (base, middle relative to the top of the tree),quality of the wood (sapwood or heartwood).

Experiment II was arranged in a one-way analysis of variance

c) *Source of wood collection*

Samples were purposely selected from the plantation of the Delta State University Asaba Campus for the study.

d) *Materials used*

1. Motor saw
2. 50m distance measuring tape.
3. Haga altimeter
4. Diameter girth tape
5. Ballistics bomb calorimeter

e) *Parameters measured*

The parameters collected in this experiment include:

i. Total height of the tree
ii. Length of the felled tree
iii. Diameter at breast height of the tree

f) *Procedures for the experiment*

The height measurements of each of the three trees species were taken with the aid of the Haga altimeter. Felled trees were cut into three discs i.e. at diameter at breast height (DBH), middle and top with the motor saw. Samples of wood were removed from the disc for the two experiments.

i. Axial: Two (2) specimens from the heartwood and sapwood were collected each at three (3) different positions i.e. at breast height, middle and top.
ii. Horizontal: From the diameter at breast height, five (5) different positions from the pith to the bark.

The discs were replicated three (3) times wrapped and marked separately and were taken to Sapele for charcoal production in earth kiln.

The charcoal was taken back to Asaba campus for measurement of the calorific value by using ballistic bomb calorimeter. It was re-burnt in the ballistic bomb calorimeter to determine the calorific values.

IV. Determination of Calorific Values of the Charcoal

Gross calorific values of the charcoal specimens (segments) were determined by using ballistic bomb calorimeter. Three determinants were carried out from each segment and the mean values were computed. This was done as applied by (Akachukwu, 2005) in his experiment on calorific values of various wood species.

V. Data Analysis

Data collected was been subjected to analysis of variance (ANOVA) and significant means separated using least significant difference (LSD).

VI. Results

Table 1 shows the results of calorific values of charcoal produced from the wood of *Gmelina arborea, Tectoria grandis* and *Pentaclethra macrophylla*. The parameters considered include: Top sapwood, middle sapwood, base sapwood, top heartwood, middle heartwood and base heartwood. Result on top sapwood indicated significant ($p<0.05$) difference among treatment means (Table 1).

Top sapwood in treatment 1 were lower than treatment 2 while treatment 3 were higher.

Result on middle sapwood revealed that treatment means were significantly ($p<0.05$) different. Middle sapwood for treatment T_1 were lower while T_2 and T_3 were higher numerically.

Result on Base sapwood collected were significantly ($p<0.05$) affected. The base sapwood in T_3 was significantly ($p<0.05$) higher in value than other treatments.

Table 1 : Calorific Values Of Charcoal Produced From The Wood Of *Gmelina Arborea, Tectona Grandis* And *Pentaclethra Macrophylla*

Parameter	1	2	3
Top sapwood	7124.33^c	7216.33^b	7402.00^a
Middle sapwood	6772.00^c	7351.67^b	7616.67^a
Base sapwood	6939.00^c	7323.00^b	7599.67^a
Top heartwood	7250.67^c	7496.00^b	7575.67^a
Middle heartwood	6788.33^a	7043.33^a	7121.33^a
Base heartwood	6960.00^b	7419.00^a	7591.00^a

abc, means with different superscript within same row are significantly ($p<0.05$) different.

Result on Base sapwood collected were significantly ($p<0.05$) affected. The base sapwood in T_3 was significantly ($p<0.05$) higher in value than other treatments.

Result obtained for Top heartwood shows that the treatment means were significantly ($p<0.05$) different. However, top heartwood from T_3 have higher numerical values than other treatments.

The middle heartwood shows that treatment means were not significantly ($p>0.05$) different. Middle heartwood from T_2 and T_3 were significantly higher ($p<0.05$) than those of T_1 which has a lower value of 6788.33.

Result obtained for Base heartwood shows that treatment means were significantly ($p<0.05$) different. Base heartwood from T_2 and T_3 were found to be higher than those of T_1.

Table 2 : calorific value of charcoal produced from different pith position of *Tectona grandis, Gmelina arborea, Pentaclethra macrophylla*

Pith to bark	Gmelina	Tectona	Pentaclethra
1	5852^b	6724^a	6985^a
2	5765^b	7123^a	7250^a
3	6183^c	7245^b	7433^a
4	6053^c	7400^b	7951^a
5	7231^b	7622^b	8212^a

abc, means with different superscript within same row are significantly ($P<0.05$) different

Result on pith to bark on position indicated significant ($P<0.05$) difference among treatment means. Result on pith to bark on position 2 indicated significant ($P<0.05$) difference among the treatment.

Result on pith to bark on position 3 revealed that treatment means were significantly ($P<0.05$) different, for treatment T_1 were lower while T_2 and T_3 were higher numerically.

Result on pith to bark on position 4 shows that the treatment means were significantly ($P<0.05$) different, however, T3 have higher numerical values than other treatments.

Result on pith to bark on position 5 shows that treatment means were significantly ($P<0.05$) different. T_3 was formed to be highest in term of numerical value than those of T_1 and T_2.

VII. Discussion

The better performance in the calorific values of charcoal produced from the experiment I and II, these species of woods *Gmelina arborea* (T_1), *Tectona grandis* (T_2) and *Pentaclethra macrophylla* (T_3).

Charcoal produced by *Pentaclethra macrophylla* (T_3) yield better results compared to those produced by *Gmelina arborea* (T_1) and *Tectona grandis* (T_2), T_3 has more heat locked up than T1 and T_2 and this is in agreement with FAO (2001), report that the gross calorific value of a substance is the number of heat units that are liberated when a unit weight of that substance is burnt in oxygen, carbon dioxide, sulplur dioxide, nitrogen, water and ash. And these also in line with the finds of Foley (1986) which state that, the energy efficiency of a charcoal is dependent upon many factors: with type, moisture content, wood species, wood arrangement and the skill of the producer. All these factors is what resulted to why T_3 yield more result than T_1 and T_2

VIII. Implication for Forestry Extension /Advisory Service

Forest depletion by man is one of the causes of climate change. Bearing this in mind, we need to exploit our forests in a sustainable manner. Households, especially in the rural settlements rely very much on fuel wood for cooking. This has contributed in no small measure to the depletion of our forests. It is also observed that people hardly plant trees. This has contributed to the depletion of our forests. Instead of continuing to exploit the forests indiscriminately for cheap source of fuel, charcoal is a promising alternative source of cheap fuel. These can be purchased from saw mills where they are prepared for sale at cheap rate. Charcoals are also environmental friendly unlike kerosene which is also very costly. Forestry extension agencies need therefore to take advantage of the result of this study to encourage households to use charcoal, especially the one derived from *Pentaclethra macrophylla.*

IX. Conclusion and Recommendation

The results obtained showed that there were significant ($p<0.05$) differences in treatments (T_I, T_2 and T_3 for experiment I and II) which could be related to the age of the wood.

On the other hand, there were no significant ($p>0.05$) differences in Middle heartwood among species in different treatments. Thus, it could be concluded that calorific values of charcoal produced from the wood of *Gmelina arborea, Tectona grandis* and *Pentacletura macrophylla* (*bentham*) gave the same result means that the age and species of the wood had no influence on the calorific values at T_3 (*pentaclethra macrophylla*).

Therefore, calorific values of charcoal produced from pentaclethra wood species are therefore recommended for both Experiment I and II.

Forestry extension advisory service should encourage the use of charcoal through advocacy and legislation. This will save our forests.

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