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Areo O.S ● Omole A.O ● Adeniyi I.M ●
Oyewumi O.R



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Maiduguri, Nigeria

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VARIATION IN CHEMICAL COMPOSITIONS OF A NIGERIAN GROWN *ARTOCARPUS ALTILIS* (FOSBERG) WOOD SPECIES

AREO OS^a* • OMOLE AO^b • ADENIYI IM^b • OYEWUMI OR^a

^a Forest Products Development and Utilisation Department, Forestry Research Institute of Nigeria, Ibadan, Nigeria

^b Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan Nigeria.

* Corresponding author: areosola73@gmail.com

ABSTRACT: Wood variation is a vital factor to wood quality. Its determination provides crucial information in knowing the efficient and effective utilisation potential of wood species. This study investigated the variations in chemical compositions of *A. altilis* wood. Four trees of *A. altilis* were purposively selected and felled based on maturity (45.0±0.5 years) at Longe village, Gambari Forest Reserve, Oyo State, Nigeria. Wood dust for the chemical experimental analysis was collected during conversion of sample materials at the base, middle and top (10%, 50% and 90%) of merchantable height of each tree in accordance to the ASTM1666-87 standard procedure. Mean chemical content such as cellulose, hemicellulose, lignin and ash content were determined according to the standard procedure for determining chemical properties of wood. The results revealed the average percentage cellulose, hemicellulose, lignin and ash content of *A. altilis* along the sampling height as; 47.44%, 27.44%, 15.88% and 0.92% respectively. It was observed that cellulose, hemicellulose and ash content were highest at base (47.8±0.7, 27.8±1.2, 0.93±0.4) and least at middle (47.1±0.4, 27.1±0.7, 0.92±0.4), respectively. Percentage chemical composition varied inconsistently along the sampling height while lignin content decreased from base upward. Hence, low lignin content indicates less liquor consumption and short cooking cycle making it suitable for pulp and paper production and cellulose contents shows that the wood can be satisfactorily good for light structural construction.

Keywords: *Artocarpus altilis*, cellulose, hemicellulose, lignin, ash content

1. INTRODUCTION

Cellulose and hemicellulose account for 70-75% of the wood substance. Lignin is present in amount ranging from 25-30% and extractive which are diverse groups of low molecular weight compounds are found in variable quantities from 3-10%. The variations in the composition, volume of chemical component and the differences in cellular structure is depicted in some wood as being heavy and some stiff and flexible while some are

hard and soft Titus, *et al*, (2010). According to Panshin and Dezeuw, (1980) cellulose accounts for more than half of the total wood weight. Again, Osadare (2001) opined that cellulose is the primary cell wall component of wood fibres and it is the main structure material of wood and other plants. Dinwoodie (1989) stated that cellulose is the most important single component in the woody cell wall in terms of its volume and effect on wood properties. Udoakpan (2003) reported increase in cellulose content from pith to first 15 rings and remain

constant. Halil (2008) observed a general increase in cellulose content from pith to bark which is similar to Shupe, *et al* (1995a). Ogunsanwo (2000) in his study found out that radial variation of cellulose agrees with reported work of Halil (2008); however, there is an inconsistent variation in cellulose along the radial direction. Osadare (2001) also reported a significant cellulose increases with increasing age from pith to bark. Lignin is one of the principal components of woody plant and the second most abundant biological polymer on earth (Shupe *et al.*1995b). Lignin is found in the middle lamella of wood and also in the cell wall at 25% and 75% respectively (Dinwoodies, 1981) and constitutes between 15% and 35% of the mass of solid wood (Panshin and Dezeuw, 1980). Lignin content is higher in soft woods than in hard woods and varies from species (Osadare, 2001). Lignin is responsible for the rigidity of wood. The suitability of any species for pulp and paper making is closely related to the amount of lignin content. It is observed that lignin content increases generally from pith to bark as observed by Shupe *et al* (1995a). However, age has little effect on lignin formation across the growth increment. Halil (2008) observed that wood nearest to the pith had greater amount of lignin content than the outer wood in radiate pine. The observed trend of lignin variation along the stem axis is that of decreases from base to the top (Osadare, 2001). Extractives, often called extraneous compounds are chemical components found in association with wood (Osadare, 2001). According to Udoakpan (2003), extractive are extraneous components of wood which do not form an integral part of the cellular structure. The term extractive content refers to a large number of wood compounds, which are soluble in organic and polar solvents (TAPPI, 1998). Wood extractives vary in composition and properties due to the effect of site or geographical location (Green *et al.*, 1975). Osadare (2001) stated that extractive provides a major contribution to many of the properties of wood in spite of their usually small amount. Specific gravity has been found to be closely related and significant with extractive content of wood (Shupe *et al.*1995b). Wood extractives also contribute to many of the properties of wood such as colour, odour, light-stability, decay and insect resistance, strength, density, flammability, hygroscopicity, permeability, pulping, paintability and texture as documented from different researchers (Panshin and Dezeuw, 1980). Report on the trend of variation has been documented. Extractive content has been shown to decrease with increasing height in radiate pine and *Pinus caribea*, (Adewunmi, *et al.* 2016). Udoakpan (2003) summarized the radial variation of extractive content in three ways; decreasing from the periphery of the heartwood to the centre of the heartwood; increasing from pith to the heartwood. This pattern of variation was observed in *Pinus caribea* by Bambang, *et al.*, (2006) and Increasing from sapwood to the heartwood. The need to

examine the variations in chemical properties is imperative to determine the potential utilisation of wood species. Therefore, it is important to evaluate chemical composition such as lignin, hemicelluloses etc. to determine the desirable and quality wood species for structural, non-structural and industrial uses. This study evaluated the variations in chemical components available in the sawdust of *A. altilis* wood to form knowledge base for its potentials uses.

2. MATERIAL AND METHODS

Four trees of *A. altilis* were purposively selected and felled based on maturity (45.0±0.5years) at Longe village, Gambari Forest Reserve, Oyo State, Nigeria. Sawdust from *A. altilis* was collected during the conversion into sample sizes in accordance with ASTM D1413 (2007). The mill was cleaned after each conversion to ensure that different samples did not mix. The sawdust was dried and sieved in order to give standard size, which passed through No. 60 (250µm) sieve and retained on a No.80 (180µm) sieve. Two hundred grams of the sawdust was put into the extraction thimble of the Soxhlet extractor apparatus and extracted with 500ml of ethanol-toluene and extracted for the duration of 8hrs. The extracted sawdust was air dried and then weighed. The extractive content was calculated using the formula as follow;

$$Ec = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

Where:

W_1 = Weight of saw dust before extraction, W_2 = Weight of saw dust after extraction

Ec = % extractive content

2.1. Cellulose Content Determination

Cellulose content was determined in accordance with ASTM D 1348-94 (2008) and summarized as follows: Five grams of extractive free saw dust was cooked for about 30 minutes in 1% sodium hydroxide (NaOH). This was washed thoroughly with distilled water. While in the moist condition, chlorine gas generated through action of hydrochloric acid (HCl) on potassium permanganate (KMnO₄) was applied to the cooked dust through an inverted funnel for 45 minutes. The residue was washed with distilled water to remove the HCl, 2% solution of sodium sulphide (Na₂SO₃) was added. This mixture was boiled for 5 minutes and 0.2% of sodium hydroxide (NaOH) was added. The mixture was allowed to stay on hot plate for another 5 minutes. The procedure was repeated severally until the samples become bleached. This occurs at the point where additional chlorination

will no longer affect any colour change, indicating that the lignin had been completely attacked by chlorine. The residue was placed on filter cloth and washed with hot water while 0.1% of sodium hypochlorite was added to bring the residue to complete bleaching. The bleached pulp pad was left to dry under room temperature and later oven dried for 2 hours at 100°C. The percentage cellulose content was calculated as:

$$Cc = \frac{W_p}{W_d} \times 100 \quad (2)$$

Where:

Cc = Cellulose content, W_p = weight of oven dry pulp, W_d = weight of extracted dust.

2.2. Determination of Lignin Content

Lignin is a lignocellulosic material that functions as a binding agent which holds the individual fibres together. Lignin content determination was conducted according to the TAPPI standard T222om-02 (2002). One gram of oven dried weight of extractive free sawdust was digested with 15cm³ of 72% sulphuric acid, added slowly while stirring and mixing. The reaction was allowed to proceed for 2 hours with frequent stirring in a water bath at room temperature. Thereafter, 475cm³ of distilled water was added to the solution and brought to boiling point maintaining the volume of the solution by constant addition of hot distilled water. The insoluble lignin formed was allowed to settle overnight, filtered and washed with hot distilled water until it becomes neutral. The sample collected was then oven dried at 85°C until it reaches constant weight. Percentage insoluble lignin was then calculated using the below formula;

$$\% \text{ lignin} = \frac{W_o}{W_1} \times 100 \quad (3)$$

Where;

W_o = weight of lignin

W_1 = Oven dried weight of extractive free sawdust

2.3. Determination of Hemicellulose Content

Holocellulose consists of cellulose and hemicellulose. The method used by Adewunmi, *et al.* (2016) was used in the determination of holocellulose content. Two grams of extractive free sawdust of known moisture content was moistened with cold water and the excess moisture removed by suction. The sample was chlorinated for 5 minutes followed by extraction with 50ml of 95% ethanol and hot ethanol-monoethanolamine solution. At the end of each extraction, the residue was washed thoroughly with distilled water followed by another round of extraction until the residue becomes white. The washing exercise was repeated until the residue becomes neutral to litmus. The

residue obtained was oven dried to constant weight. The percentage holocellulose based on moisture free extractive free milled sample was calculated as follow;

$$\% \text{ Holocellulose} = \frac{W_0}{W_1} \times 100 \quad (4)$$

Where:

W_0 = weight of moisture free and extractive free milled sample,

W_1 = weight of dried holocellulose residue.

2.4. Percentage Ash Content Determination

Percentage ash content was determined using the TAPPI standard T211 om-02 (2002) method by heating 2g of pulverized wood samples in a muffle furnace at 600°C for 4hours and then cooled in a desiccator. The weight of the crucible plus specimen was determined and then placed in the oven at 103±2°C. It was cooled in a desiccator and weighed. This continued until a constant weight is obtained. The crucible and its content was placed in the muffle furnace and ignited until the carbon is eliminated. The content was heated slowly at the start to avoid flaming and to avoid mechanical loss of test specimen. The temperature of final ignition will be 580 – 600°C. The crucible with its content was removed from the furnace and placed in desiccator to cool and weighed accurately.

$$\text{Ash Content} = \frac{W_2}{W_1} \times 100 \quad (5)$$

Where:

W_1 = weight of crucible and ash

W_2 = weight of crucible and oven dried sample.

3. RESULTS AND DISCUSSION

3.1. Cellulose Content (%)

Cellulose has been known as a major factor responsible for strength in the wood fibre because of its high degree of polymerization and linear orientation. During tree growth, cellulose microfibrils give the cell walls tensile strength, while the lignin from the cellulose fibrils gives them rigidity (Agu, *et al.* 2012). As presented in Table 1, the results of this study along the sampling height reveal that the cellulose was highest at the base and lowest at the middle of the stem with recorded values of 47.83% and 47.13%, respectively. This was slightly higher than 42.9% obtained in *Triplochiton scleroxylon* (Ogunsanwo, 2000) and (Thomas, 1997) for Softwood (42%) and hardwood (45%). The more the cell wall is thick, the more the amount of cellulose, hemicellulose and lignin content which are the main component of the

cell wall. However, the acceptable cellulose content for pulp and paper manufacturing is above 40% because paper tensile strength is directly proportional to cellulose content (Madakadse *et al.*, 1999). This is because uniformity in specific gravity along the radial plane indicates uniformity in cellulose which is considered an important factor in structural wood utilization. The observed variation trend in axial direction in this work is similar to the report of Udoakpan, (2003) that development of S2 layers and average length of fibre, contributes to the content of cellulose amount in wood as proportion of fibre, mean wall thickness increases which is a factor that determines the wood properties of the tree. According to (Panshin and DeZeeuw, 1980), the inconsistency recorded along the axial direction might be connected with the influence of other chemical components of wood such as extractive content which can mask predicted pattern of other wood properties; hence the trend in the axial direction where the highest cellulose was recorded at the base and lowest at the middle observed in this study. This observation has a great implication on the utilisation potentials of *A. altilis* as an indigenous species suitable for light structural construction and pulp and paper production.

3.2. Hemicellulose Content (%)

Hemicellulose significantly acts as a medium for the cellulose and it increase the packing density of the wood cell wall. It was reported that high hemicellulose content is desirable because it contributes immensely to the strength of paper. As shown in Table 1, along the sampling height, hemicellulose was highest at the base and lowest at the middle with recorded values of 27.83% and 27.18% respectively. The mean of hemicellulose content in *A. altilis* wood sawdust (WSD was 27.44%). The obtained result range is similar to the report by Cao, *et al.* (2014). However, this makes it highly suitable in the production of dissolving paper as the hemicellulose removal could only take milder pre-hydrolysis conditions. In this present study, the observed hemicellulose value for *A. altilis* is better and suitable to produce a paper of good quality strength.

3.3. Lignin Content (%)

Lignin, a phenolic compound, not only holds the fibres together but also acts as a stiffening agent for the cellulose molecules within the fibre cell wall. All three cell wall components contribute in different degrees to the strength of wood. Together the tubular structure and the polymeric construction are responsible for most of the physical and chemical properties exhibited by wood (Abdul Khalil *et al.*, 2010). As shown in Table 1, along the sampling height, lignin was highest at the base and lowest at the middle with recorded values of 16.13% and

15.68% respectively. The mean of lignin content in *Artocarpus altilis* WSD was 15.88% as shown in Table 1. The decreasing trend of lignin content observed in this study agrees with a similar report by Ogunwusi, (1991) in *Pinus caribaea* grown in Nigeria. The decrease in lignin content from base to top of the tree may be attributed to the extent of wood development and maturation. According to Syed *et al.*, (2016) most paper manufactures preferred the low amount of lignin of about <15% because the fibres are more flexible, porous and they produce brighter colour during the bleaching process. Malik, *et al.*, (2004) observed that low lignin content is considered for pulp and paper manufacturing as hardness, bleachability and other pulp properties are closely associated with lignin content. Lignin content in the wood of *A. altilis* was 15.88%, this generally falls slightly lower within reported range values for pulp softwood species (20.8-31.3%) and hardwood pulp (18.2-30.9) by (Eroglu, 1998; Sixta *et al.*, 2006; Marques *et al.*, 2010; and Cao *et al.*, 2014), (28.0 - 24.57%) in *Gmelina* and (31.77-31.70%) in Teak by (Oluwadare, *et al.* 2016), (23.4-34.5%) in *Eucalyptus globules* (Anttonen *et al.*, 2002), (20.59%) in *Cramble tataria* (Titus *et al.*, 2010), but similar to *Gigantochloa cortechinii* (12.48-16.12%) and (18.27%) in *F. exasperata* (Anguruwa, 2018). In this study, the lignin content is low; therefore, less delignification process, low liquor consumption and short cooking cycle, pulp time, low temperature and chemical charge as with softwood and hardwood will be low to reach a required Kappa number (Cordeiro, *et al.*, 2004; Dutt, *et al.*, 2011; and Cao, *et al.*, 2014).

3.4. Ash Content (%)

Ash is considered impurity that may not burn, likewise, wood with high ash content is not suitable for pyrolysis. As presented in Table 1, along the sampling height, ash content was highest at the base and lowest at the middle with recorded values of 0.934% and 0.916% respectively. The mean ash content in *A. altilis* WSD was 0.923% as shown in table 1. The values for ash content obtained in this study for is higher than others but similar to (Mukesh, *et al.*, 2015) reported for *A. altilis* leaves (9%) and *Eulaliopsis binate* (6.0%) (Dutt *et al.*, 2011). Bambang, *et al.* (2006) suggested that higher ash content in biomass could obstruct the bio-oil yield of pyrolysis process. The high ash content and the low volatile matter of the hardwood sawdust make it unsuitable for use as feedstock for bio-oil production. In the present study, high ash content observed in *A. altilis* sawdust could come from other contaminants during handling and transportation. Increase ash content lowers the heating value and makes it unsatisfactory for fuelwood and charcoal production. This could also contribute to the

incessant dullness of the saws and blade during machining operation but suitable as forest fertilizer.

Table 1: Cellulose, hemicelluloses, lignin and ash contents of *A. altilis* WSD

Sawdust	Cellulose (%)	Hemicelluloses (%)	Lignin (%)	Ash (%)
Base	47.83±0.74 _a	27.83±1.19 _a	16.13±0.44 _a	0.934±0.41 _a
Middle	47.13±0.47 _c	27.18±0.74 _c	15.68±0.65 _c	0.916±0.46 _c
Top	47.37±0.49 _b	27.29±0.62 _b	15.83±0.49 _b	0.918±0.47 _b
Mean	47.44±0.63	27.44±0.91	15.88±0.56	0.923±0.44

Means ± standard error of mean of 5replicate samples. Values with the same alphabet in each column are not significantly different at $\alpha = 0.05$ using Duncan Multiple Range Test.

4. CONCLUSION

Based on the results of the study on the chemical composition variations in the wood of *A.altilis*, the following conclusions were drawn:

1. Cellulose, hemicellulose, lignin contents, low percentage ash and silica content showed that *A. altilis* wood for pulping characteristics requires mild process.
2. The chemical contents of *A.altilis* contains lower soluble compound and this could increase the pulp yield and contribute to lower chemical consumption during pulping and lower load of pulping effluent.
3. The finding of this study showed that cellulose, hemicellulose and lignin content is high, which implies that pulping and bleaching could need higher amount of chemical, likewise quality paper and higher pulp yield may be produced but not suitable as fuel wood because of high ash content but could serve as soil fertilizer if properly enhanced and proper decomposition of the sawdust.

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