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*Full Length Research Paper*

# Assessment of anisotropic and drying characteristics of *alstonia boonei* (dewild) wood using solar kiln dryer and air drying shed

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**Abstract**

**Integrity of wood in service is of major concern to architects and builders when selecting materials for construction. The physical properties of *Alstonia boonei* wood investigated include moisture content, density, volumetric shrinkage, and percentage water absorption distribution carried out according to ASTM2009 standard. The anisotropic changes of the wood were also assessed with the use of the processed disc from the log to observe the shrinkages, and checks characteristics according to specified standard. Drying activities was carried out for 31 days using the solar kiln dryer and air drying shed to investigate the drying behavior of the wood. From the studies it was observed that the drying in the solar kiln was more efficient than the air drying shed which may be as a result of the higher temperature and low humidity observed in the solar kiln dryer. The percentage moisture content and density distribution recorded for *Alstonia boonei* wood is 62.5% and 379 kg/m$^3$ on average respectively, while the volumetric shrinkage of 9.7 %, specific gravity of 0.37 and void volume of 76.7% was also recorded. Circumferential shrinkage of the wood disc was 9 and 6% for tangential and radial shrinkage respectively. Checks were observed from the bark to the pith of the wood indicating the need for early conversion and drying.**

**Keywords:** Anisotropic changes, Circumferential shrinkage, Dimensional stability, Checks, Alstonia boonei

## INTRODUCTION

Wood in service has been bedeviled with the problem of dimensional stability caused by the hygroscopic nature of wood i.e. the constant exchange of moisture in wood with the environment, hence the need for drying wood in order to limit these changes occurs [1]. Worsening this problem in wood is the anisotropic nature of wood caused by orientation of the wood fibers and the manner in which a tree increases in diameter as it grows. Properties vary along three mutually perpendicular axes; longitudinal, radial and tangential [2].

The properties of wood differ in each of these three axis directions, differences between the radial and tangential axis are relatively minor when compared to differences between the radial or tangential and the longitudinal axis [3].

This constant change due to the anisotropic changes has led to a strong need to dry wood effectively. Drying is a very important step in processing wood products. The drying of wood before usage enhances its strength properties, easy impregnation with preservatives, provides appropriate conditions for chemical modification; minimizes decay, fungal infestation and insect attack. Air drying involves exposing wood to the natural environmental condition. Drying of wood using air drying media depends on the weather condition

Which makes the time taken in seasoning of wood longer [4]?. In order to dry wood with ease and to meet the appropriate moisture content requirement, kiln drying becomes one of the most important processes for the efficient drying of green wood. The kiln process involves

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the drying of wood in a chamber. The solar kiln is basically identical to the conventional kiln in its function except that the solar kiln relies on heat generated from sunlight which operates at a daily circle with its highest temperature and air speed in the kiln during the day while having a lower temperature level in the kiln at night. Solar timber drying offers several advantages to those desiring an economical means of drying small quantities of lumber. For many end uses and secondary manufacturing processes, lumber should be dried to avoid undesirable defects such as excessive shrinkage, stain and decay caused by fungal attack, and minimizes drying defects such as warping, collapse, honeycomb, splitting and checking [5].

Wood utilization has in the past focused more on durable traditional indigenous tree species. However, with increasing demand for furniture and increasing scarcity of the well-known durable species, users are resorting to other available and affordable tree species which can give usable timber in merchantable volumes. Attention has now been shifted to less durable tree species [6].

Different research has been done on the drying process of Alstonia boonei. Owoyemi et al, (2015) worked on the drying characteristics of Alstonia boonei and other tree species, Ofori and Brentuo, (2010) also worked on drying characteristics and development of kiln drying schedules of Alstonia boonei, Otoide (2017) also worked on evaluation of the woody stem of Alstonia boonei for some physical properties but less or non-work has been carried out on the anisotropic characteristics of this wood. This study provided information on the dimensional and physical characteristics of the wood [7].

## MATERIALS AND METHODS

Alstonia boonei wood was sourced from the Federal University of Technology, Akure forest area (Figure 1).

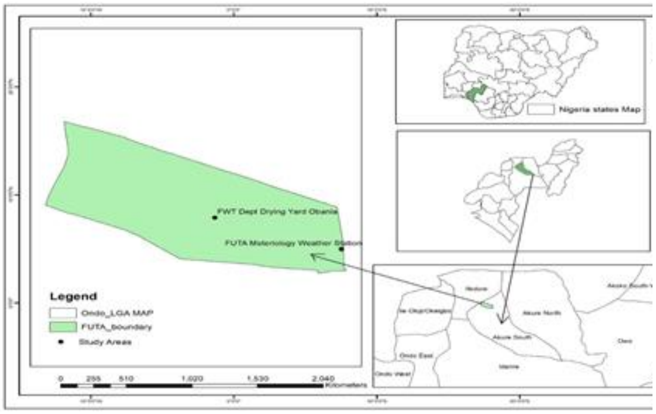

**Figure 1**. Map of Nigeria, showing Ondo State and the study area.

*Alstonia boonei* tree was felled at Federal University of Technology Akure ongoing construction site. Material preparations and testing was done according to American Society for Testing Materials (ASTM, 2009). The wood samples were processed into 20 x 20 x 60 mm for laboratory work and dried in the oven at 103 ± 20C for 24 hours to attain a constant weight [8].

The percentage moisture content distribution of the wood was determined using the following formula:

Moisture content (%) = $\frac{Wg-Wo}{Wo} X\ 100$… Equation 1

Where: Wg is the weight of green samples (gm) and Wo is the weight of dried samples (gm)

The density distribution of *Alstonia boonei* wood was determined using:

Density (kg/m^3) = $\frac{mass\ of\ oven\ dried\ sample}{volume}$ **…** Equation 2

The Volumetric Shrinkage of the wood was determined using:

Volumetric shrinkage (%) = $\frac{VI-Vo}{Vo} X\ 100$…Equation 3

Where; Vo is the wet volume of the samples and Vi is dry volume of the samples

The volumetric swelling of the samples was estimated using;

$\boldsymbol{S}\ (\%) = \frac{\boldsymbol{V3-V2}}{\boldsymbol{V2}} \boldsymbol{x\ 100}$ …….Equation 4

Where: V2 is the initial volume of wood and V3 is the final volume of wood

Anisotropic changes were determined using:

Circumferential Shrinkage (CS) (%) = $\frac{DI-Do}{Do} X\ 100$…. Equation 5

Where;
Do is the wet weight, Di is dry weight

The attainable moisture content of the wood was determined after drying samples to a constant weight in the solar kiln dryer for 31 days using;

$MC(\%) = 100\{\frac{Ti-Tf}{Tf}\}$….. Equation 6

Where: MC is the Moisture Content, T1 is the weight of the timber at constant reading and Tf is the oven dried weight of the wood after constant reading

Assessment of conditions of drying media. The drying of *Alstonia boonei* was carried out at the drying yard of the Department of Forestry and Wood Technology using the solar kiln dryer and the air drying shed. Monitoring of the ambient weather conditions was done using hygrometer, weather station and solar meter (Plates) while readings were taken for temperature, relative humidity and solar radiation [9].

## RESULTS

Moisture content variation in *Alstonia boonei* wood the mean values of the moisture content distribution of *Alstonia boonei* wood in Figure 1 showed that moisture content was higher at the top and lowest at the base. The values ranges from 62.54% to 47.73% from the top to the bottom, this minimum and maximum moisture content is in consonance with Simpson (1991) who stated that the moisture content of some species may be as low as 30% and as high as 200% due to variations in site and the seasons of felling. This also agrees with the works of that moisture content accumulates at the top portion of a tree (Figure 2) [10].

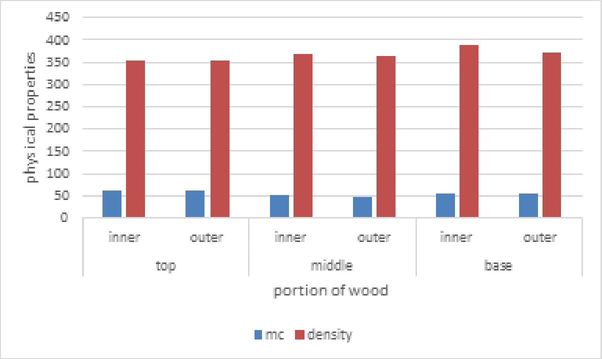

**Figure 2.** Moisture content and density of the wood samples.

### Density distribution of the wood

The result of the mean density of *Alstonia boonei* wood in Figure 1 showed that density was higher at the base with values ranging from 353.31 Kg/M$^3$ to 389.06 Kg/M$^3$ from the top to the base. This agrees with the findings of Donaldson et al, (1995) that density usually decreases with height in the stem of a tree. This is a similar trend since wood density is usually higher at the bottom due to the higher compaction of the bottom tissues exerted by overlapping cells along the bole and tree crown [11].
Variation in density of wood species has been observed to affect the drying rates and the final attainable moisture content (Aladejana et al., 2015). Wood species could be classified into three major density classes using the density values of the species to high, medium or low density as reported by. The overall mean density of Alstonia boonei was found to be 366.06 kg/m$^3$, which falls under the general classification of wood densities as low refractory wood with density less than 500 kg/m$^3$ [12].

### Volumetric shrinkage of *Alstonia boonei* wood at different directions

The shrinkage value of *Alstonia boonei* in Figure 3 showed increasing range from the bottom to top and from inner to outer wood: This agrees with the previous reports of Bekta and Guler (2001), Panshin and de Zeeuw, (1980), and Rigatto (2004). The inner wood of the study samples has less shrinkage and increases from inner wood to the outer wood. This situation may be due to the presence of greater amounts of extractives in the inner wood which tend to inhibit normal shrinkage by bulking the amorphous regions in the cell wall substance. From this study, the volumetric shrinkage of *A.boonei* was between 8 and 10%, this implies that the higher value of shrinkage makes the wood to be dimensionally unstable and highly susceptible to defects and other attacks. Therefore, the wood should not be used for operations that requires high load carrying and water prone environment (Figure 3) [13].

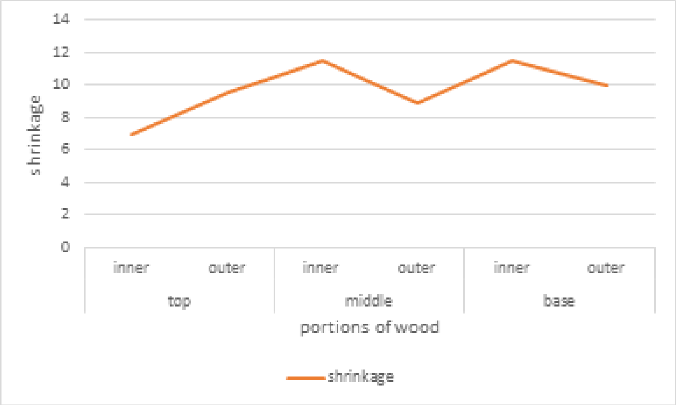

**Figure 3.** Shrinkage of the wood.

Percentage water absorption of *Alstonia boonei* wood at different directions from Figure 4, the water absorption properties increases from 24 hours to 72 hours and decreases after then. The mean percentage water absorption in *Alstonia boonei* wood presented in Figure 4 shows 33.97%, 43.15%, and 34.9% for top, middle and bottom longitudinally respectively while 35.75% and 38.93% for outer and inner respectively transversely. This situation may be due to the bulking the amorphous regions in the cell wall substance. The water absorption properties are affected by several wood factors, such as the heartwood to sapwood ratio and the fibrillar angle on the S2 layer. The rate at which *Alstonia boonei* absorbs water after 96hours decreases due to the fact that wood tends to stop absorbing water when it attains fibre saturation point (Figures 4-6) [14].

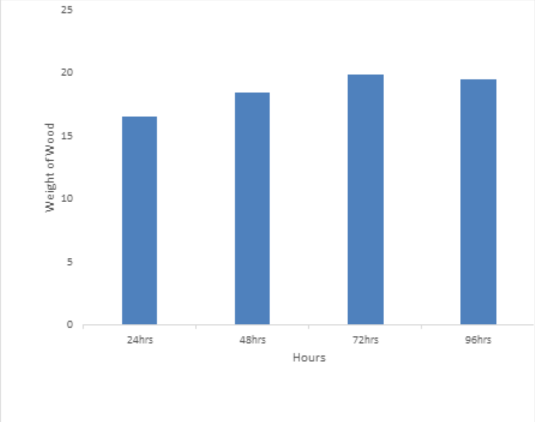

**Figure 4**. Water absorption of *Alstonia boonei* wood.

**Figure 5.** Internal and end checks developed after drying.

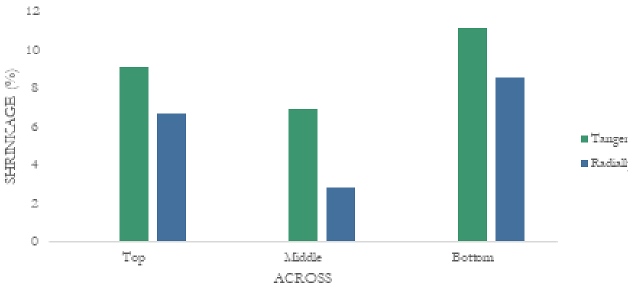

**Figure 6**. Anisotropy changes on the disc.

Figure 6 showed the circumferential shrinkage. The results revealed that the circumferential shrinkage is higher tangentially with 9% than the value recorded radially (6%) [15].

Anisotropy, the changes in different directions of wood, occurs in various planes of the wood radially, longitudinally and tangentially. From the wood, there are checks on the wood due to the effect of moisture movement on the wood. Circumferential shrinkage is higher at the top compared to the base and middle. This could be as a result of the size of the wood and the surface area to volume ratio of the wood.

Juvenile wood has less wood compared to mature wood. Juvenile wood, in comparison to mature wood, is characterized by having shorter tracheids, thinner cell walls, and lower density, lower transverse shrinkage, and lower strength. Also, it contains more compression wood, higher moisture content, and a larger: MFA, lumen diameter, and longitudinal shrinkage. The characteristics of juvenile wood result in lumber with decreased strength and poor dimensional stability. Shrinkage is higher radially and tangentially and lowers longitudinally, this is in consonance with previous work by Rigatto (2004).

Transverse shrinkages which are 2 to 10%. Shrinkage was found to be tangentially 9 % and radially 6% this is in consonance with the work of which found out that shrinkage is about 5-10% in the tangential direction and about 2 to 6% in the radial direction. End checks also occur at the end of the wood board; this may be due to the fact that wood dries quicker at the edge than the internal parts of the wood. This quick drying causes stress which the end of the board cannot handle therefore causing end checks. The checks are moderately reduced in *Alstonia boonei* wood. This is in consonance with the findings [16].

**Performance evaluation of solar kiln and air drying shed**

This study started at late period of drying season, on the 1st of February 2020 and was terminated on the 2nd of March 2020. The result of the daily mean temperature is shown in Figure 7. The highest temperature of 44.43$^{0}$C recorded during the drying period was obtained from the kiln dryer on day 22, while the highest temperature recorded in the air dryer was 34.14$^{0}$C obtained on day 29 of the drying period. The mean temperature at different hours of the day in Figure 8 also revealed that the lowest temperature in the kiln dryer 23$^{0}$C was obtained between the hour of 6am and 8am while the highest temperature in the kiln was 53$^{0}$C which was recorded between the hour of 12 pm and 2 pm. The mean daily lowest temperature in the air dryer 22$^{0}$C was recorded between the hours of 6am and 8am while the highest temperature 38$^{0}$C was recorded between 2 pm to 4 pm [17]. The mean daily Relative Humidity (RH) presented in Figure 9 showed that the humidity was highest in the solar kiln and air drier on day 26 and day 20 respectively while the lowest relative humidity was recorded on days 14 and day 7 in the solar kiln and air dryer respectively. Figure 10 revealed that the lowest relative humidity in the kiln dryer 41% was obtained between the hour of 12 and 2 pm while the highest relative humidity was 75% which was recorded between the hours of 6 am to 8 am. The lowest relative humidity in the air dryer 26% was recorded between the hours of 2 and 4 pm while the highest relative humidity 65% was recorded between 6 am to 8 am (Figures 7-10).

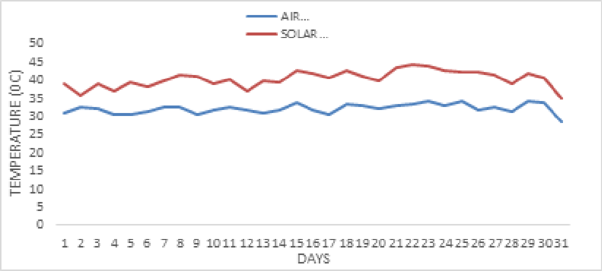

**Figure 7**. Mean daily temperature in solar kiln dryer and air-drying shed for 31 days.

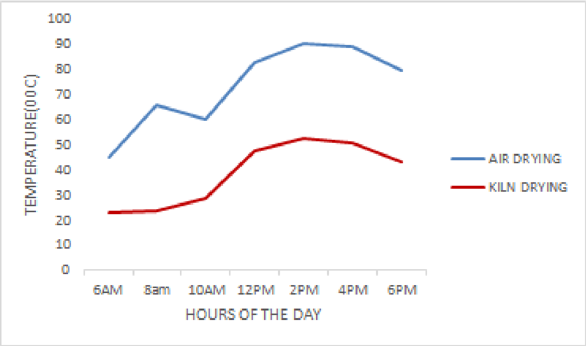

**Figure 8**. Mean temperature at different hours of the day in solar and air dryer.

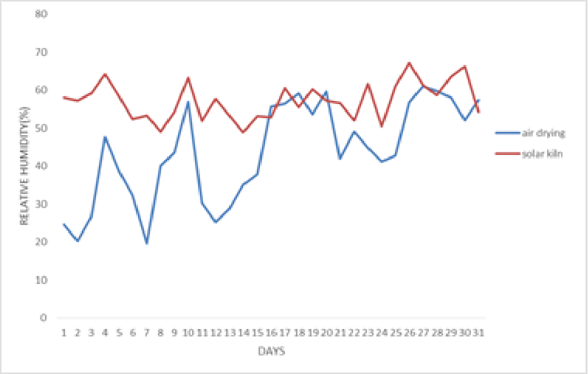

**Figure 9**. Mean relative humidity in solar kiln and air drying shed for 31days.

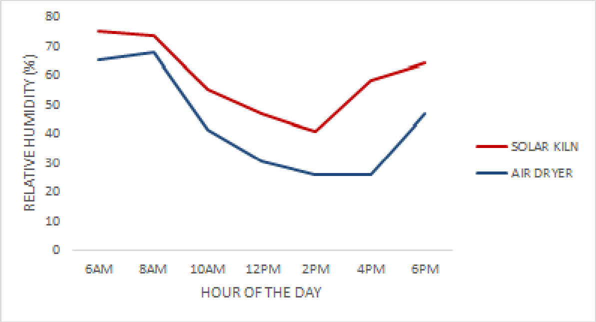

**Figure 10**. Mean relative humidity in the solar kiln and air-drying shed at different hours of the day.

The reason for wood seasoning is to improve the quality of wood, dimensional stability and also to enhance its durability in service. The study showed better drying performance of solar kiln dryer compared with the air drying shed. This is in accordance [18].

The ability to dry wood to lower moisture content in the solar kiln drier may be accounted for by high temperature and low relative humidity in the kiln drier. Agrees to the fact that temperature influences the drying rate by increasing the moisture holding capacity of air as well as accelerating the rate of diffusion of moisture within the wood cells, lower relative humidity enhances higher drying rate and air flow improves the movement of water vapour from the surface of the wood. Solar wood drying has been reported to perform better than air drying, in terms of drying characteristics and resultant wood quality.

The observed mean daily temperature for solar kiln and air-drying shed showed that highest values were recorded at some periods of the day (around 2 PM) in both solar kiln and air drying shed with the solar kiln recording the highest mean temperature. Variation in the mean temperature for solar kiln and air-drying shed showed that solar kiln conserved the heat and also better heat retention compared to air-drying shed. This is in consonance with the findings of when they studied the drying characteristics of three selected Nigerian indigenous wood species using solar kiln dryer and air drying shed [19].

The result of mean Relative Humidity (RH) observed in the solar kiln and air-drying showed that throughout the drying period, air-drying shed had highest variation in % RH when compared with solar kiln. The higher variation in the mean temperature for air-drying shed showed that RH of the shed is dependent on the RH of the surrounding atmosphere which varies daily. However, the solar kiln was able to maintain fairly constant condition of daily % RH. It also revealed that RH in both solar and air-drying shed after attaining a daily minimum percentage increased gradually toward the end of the day.

It could be observed that solar kiln attained a higher temperature and higher relative humidity than the air-drying shed which enhance the rate of drying of the wood in the solar kiln dryer. This corresponds with the work of Desch and Dinwoodie, (1996) which found out that temperatures and relative humidity are important factors in the rate of wood drying [20].

**Assessment of attainable moisture content during drying period**

The result of the rate of weight decrease of the wood is shown in Figure 11. For solar kiln constant weight was obtained on day 21 while for air drying shed day 29. The overall final moisture content attained in the solar kiln and air drying shed were 3.89% and 11.30% respectively (Figure 11) [21].

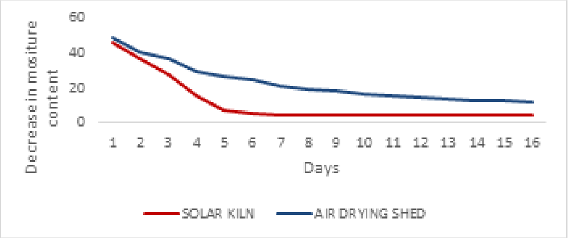

**Figure 11.** Decrease in Moisture Content for the period of drying for Solar Kiln and Air drying shed.

## DISCUSSION

Wood samples dried in the solar kiln were able to attain lower moisture content compared to the samples in the air drying shed. The rate of drying to lower moisture content in the solar kiln may be accounted for by the high temperature, low relative humidity and air flow in the solar kiln [22]. Agrees to the fact that temperature influences the drying rate by increasing the moisture holding capacity of air, as well as accelerating the rate of diffusion of moisture within the wood cells, lower relative humidity enhances higher drying rates and air flow improves the movement of water vapour from the surface of the wood. The effect of drying media is further illustrated in the attainable moisture content. Wood species in the solar kiln were able to attain a constant moisture content of 3.89 % after 21days while samples in the air drying shed attained 11.30 % moisture content after 29 days of drying. Wood dried in the solar kiln attained a lower moisture content compared to the air drying shed. This is in consonance with the findings of 2015 which examined the performance of solar kiln dryer and air drying shed when drying three selected wood species. Considering this result, solar kiln should be used during the dry season optimize its ability [23].

## CONCLUSION

The assessment of drying behavior of *Alstonia boonei* wood using the solar kiln dryer has shown that *A.boonei* would maintain stability in service if dried properly to the equilibrium moisture content of the service environment. With the average moisture content of 50% *A.boonei* should be converted and dried as quickly as possible after felling to forestall unavoidable defects which may affects its quality .Solar kiln dryer has also proved to be very suitable in drying the wood as it attains below 12 % moisture content in 16 day.

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