Comparative Study of the Morphological and Physical Properties of Juvenile and Matured *Bambusa vulgaris* Shrad. ex. JC Wendl Culms from Ghana

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Abstract: This study sought to compare the differences between the morphological and physical properties of juvenile and matured *Bambusa vulgaris* culms and the utilization potential of the culms. Two and four-year old *Bambusa vulgaris* culms were harvested and prepared to the length of twenty-one internodes. The first seven internodes were taken as bottom, the second seven internodes were taken as middle and the last seven internodes were considered as the top. Samples were taken from the bottom and top for all tests conducted for the study. The morphological properties such as the internode length, internode diameter and culm thickness were determined with the use of steel tape measure and digital caliper, whilst the physical properties including basic density and moisture content were determined in accordance with ISO 13061-2 and EN 13183-1 respectively. The study showed that, the internode length, diameter and culm thickness of juvenile were statistically different from matured culm. The moisture content increased from the bottom portion to top portion for both juvenile and matured culms. Basic density was found to be higher in the matured culm sections than in the juvenile and in some cases by 19% and 42%. Basic density decreased from bottom to top of the culm height. Generally, the mature culm possessed better morphological and physical properties than that of the juvenile culm and these could improve the utilization potential of *Bambusa vulgaris* species.

Keywords: *Bambusa vulgaris,* juvenile, matured, Morphology, physical properties

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Introduction

Bamboo is a perennial plant belonging to the Family of Gramineae (poaceae), sub-family of Bambusoideae, Order of Graminales and the tribe of Bambuseae (Chapman & Peat, 1992; Ohrnberger, 1999; Wong, 2004). There are approximately 1662 species of bamboo under 121 genera worldwide (Kaur, 2018). Bamboo grows well in Africa, Asia and Latin America (Lobovikov *et al*., 2007). About 43 species and 11 genera of bamboo are found in Africa (Lobovikov *et al*., 2007).

Bamboo is a fast-growing species that can mature within 3-4 years after cultivating (Razak *et al*., 2010; Singnar *et al*., 2017; Wahab *et al*., 2018;). Ramanuja *et al*., (1988) reported that under the right conditions, some bamboo species display fastest rates of growth which can produce culms of 40m high and 30cm diameter in just four months. Bamboo tolerates poor soils, and even without the application of fertilizer it grows fast with rich green foliage which makes it useful for planting on degraded land (Hunter, 2003; Muller & Rebelo, 2014).

Bamboo culm has been divided into two portions; the underground portion and above the ground portion. The above ground portion is the culm section which is considered as the woody material which contains nodes, internodes, branches and leaves. Its diameter tapers from the bottom to the top with the reduction in culm wall thickness (Biswas *et al*., 2011).

Bamboo as a woody plant has a long history as an exceptionally versatile and widely used resource in the world (Ramanuja *et al.*, 1988). It is estimated about 2.5 billion people use bamboo in one form or

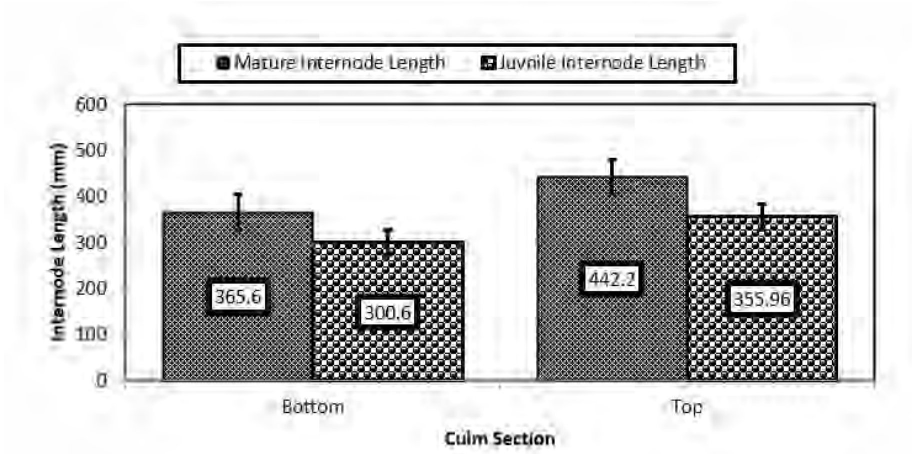

Fig 1. Internode length of *Bambusa vulgaris*; N= 10

other worldwide for their basic needs (Salleh, 1995). These many uses of bamboo include containers, chopsticks, woven mats, fishing rods, flutes, fishing traps, handicrafts, walking sticks, packing cases for teas and fruits, cages for poultry, pipes for water supply and irrigation, cradles, cart yokes, bullock carts, ladders, winnows and sieving for cleaning grains (Das, 2002).

Ghana has about 400,000 hectares of bamboo cover made up of seven (7) indigenous species and of which *Bambusa vulgaris* is the predominant species (Ebanyenle *et al*., 2005; Ebanyenle & Amoako, 2007; Tekpetey *et al*., 2008). *Bambusa vulgaris* is known as "Green Bamboo" in Ghana. It is commonly found along the river banks, botanical gardens and also distributed in the southern and middle zones of the country. *Bambusa vulgaris* forms about 95% of the total bamboo resources in Ghana (Ebanyenle & Oteng-Amoako, 2007). It is normally used especially in the rural communities for fencing houses, roofing buildings, maize and rice storages, cocoa mat support members locally known as "apa" in cocoa growing areas, handicrafts, props to support plantain and banana stems, climbing poles for yam stems and so on.

Bambusa vulgaris has become an important material for the construction industry in Ghana due to its availability, low cost and easy to be transported. The high cost of conventional building materials and the dwindling timber resource has further increased the demand for *Bambusa vulgaris*, resulting in both juvenile and matured culms being used in the construction industry. However, information on the properties for different age-group (juvenile and matured) is a major concern for many industrial players due to the significant contribution it provides for industrial utilization. For instance, matured bamboo will normally have thick culm wall and uniform sizes between the nodes and internodes and these features are usually different from juvenile bamboo as they contribute to the strength properties. Additionally, the fibre density within the matured bamboo is also an indication of the quality of matured bamboo.The matured bamboo possesses high longitudinal strength fibres of that make it the most efficient material to resist axial forces and flexural loads parallel to oriented fibres (Yu *et al*., 2014). However, the available information on the properties such as morphology, physical and mechanical properties for different age-group of bamboo is inadequate especially on *Bambusa vulgaris* species. This information is very important to assess its suitability for various end products and usage (Sattar *et al*., 1990).

Studies have shown that there are large gaps in knowledge regarding bamboo properties (Fabiani, 2015). Wang *et al*., (2014) reported that to promote the widespread application of bamboo in construction and other engineering fields, far more knowledge and understanding of its properties is required.

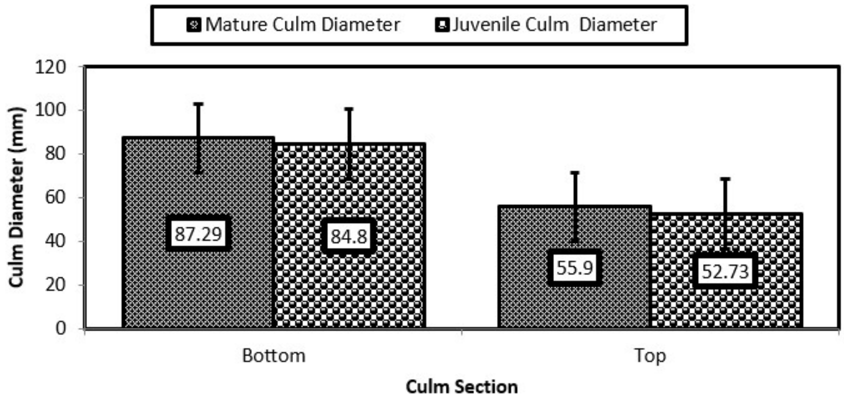

Fig 2. Culm diameter of *Bambusa vulgaris*; N= 10

This has therefore necessitated the study of the basic properties of bamboo, especially on *Bambusa vulgaris* species since little or no work has been done on it in order to the utilization of this versatile raw material. The objectives of the study seek to determine the differences in the morphological and physical properties of juvenile and mature *Bambusa vulgaris* and evaluate their utilization potential for industrial applications. The study on the morphological and physical properties is also important for the selection of suitable bamboo for industrial use, construction and housing (Abd Latif *et al*., 1990).

Materials and Methods

Bambusa vulgaris Culms

Bambusa vulgaris culms used for this study were obtained from Bibiani in the Western North Region of Ghana. Bibiani is located between latitude 6° N, 3° N and longitude 2° W, 3° W. Bibiani falls within the Equatorial Rain Forest Zone and the natural vegetation is moist-deciduous forest. The equatorial climatic zone with annual rainfall averages between 1200mm and 1500mm. The pattern of the rainfall is bimodal, falling between March-August and September- October. Humidity is relatively high averaging between 75 percent in the afternoon and 95 percent in the nights and early mornings. The culm age was determined based on the features of culm sheath, the development of branches and leaves, and the external colour of the culm (Singnar *et al*., 2017). *Bambusa vulgaris* culm of 2-years and 4-years old were randomly selected based on its straightness and culm diameter before harvesting for the study. Twelve culms were selected from the clump consisting of 6 juvenile and 6 matured for the study. The culms were cut 30cm above ground level and were coated with wax immediately to reduce sap evaporation and prevent fungal and insect attacks. Each culm was cut to a twenty-one internodes height. These culms were later subdivided into three equal lengths of bottom, middle and top portions of 7 internodes each. Wax was applied to the cut surfaces of each portion to reduce sap evaporation. The study only focused on the bottom and top parts of the culms for the tests conducted. These culms were sent to the Forestry Research Institute of Ghana (CSIR-FORIG) in Kumasi for further processing, sampling and subsequent studies.

1. Determination of Morphological Properties

The determination of internode length, internode diameter and culm wall thickness were based on the measurement of 2 samples each randomly selected from both the bottom and top portions of juvenile and matured bamboo culms. Each portion of the culm sample was assigned a unique number for easy identification. The first five internode lengths were measured internode lengths for the bottom and top portions by internode for both juvenile and matured using steel tape measure. Similar measurement was made for culm diameter and culm thickness using digital caliper. The average results were used for internode length, culm diameter and culm wall thickness for both juvenile and matured bamboo culms respectively.

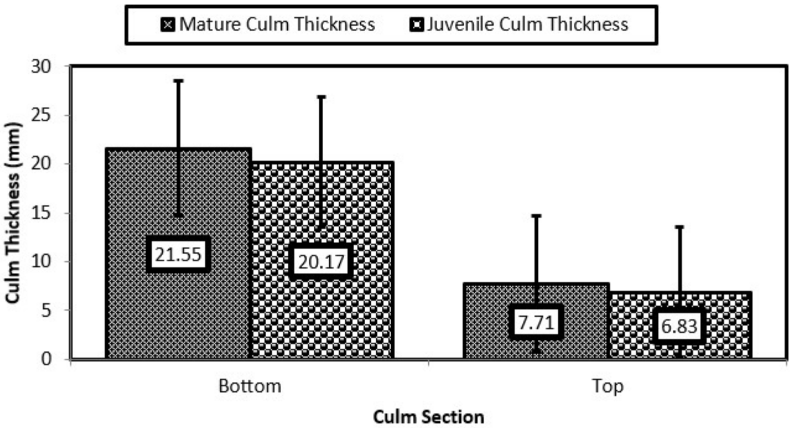

Fig 3. Culm thickness of *Bambusa vulgaris*; N= 10

2. Determination of Physical Properties

Moisture Content (MC)

The moisture contents (MCs) of matured and juvenile *Bambusa vulgaris* culms were determined in accordance with EN 13183-1 (2002). The samples were randomly selected from the bottom and top portions of both matured and juvenile bamboo culms. In all 30 replicates were cut from the prepared strips of each culm sections for the determination of moisture content (MC) with the samples sized 20mm x 20mm x culm wall thickness (mm). Each sample was assigned a unique number. The MC for each culm type was obtained by first measuring its initial weight before drying using an electronic weighing balance. The test samples were then oven dried for 24 hours at a temperature of 103 ± 2ºC. The specimens were oven-dried until the final weight of the specimens were is constant after two successive weighing. The initial and oven-dry mass of each specimen were recorded and the MC was then calculated using equation 1:

$$MC (\%) = [(W1 - W2) / W2] \times 100 \quad \text{------- (1)}$$

Where W1 is the initial weight before drying (g) and W2 is the oven-dried weight (g). The mean moisture content was then obtained by finding the mean value of MC for all the specimens of each bamboo type sections respectively.

Basic Density

Determination of basic densities for the matured and juvenile *Bambusa vulgaris* culms were carried out in accordance with ISO 13061-2 (2014). In all 30 replicates were cut from the prepared strips of each culm type sections for the determination of basic density (BD) with the samples sized 20mm x 20mm x culm wall thickness (mm). Each sample was assigned a unique number. The basic density for each culm type was obtained by first measuring its initial weight using an electronic weighing balance as well as its dimensions using digital caliper before drying. The test samples were then oven dried for 24 hours at a temperature of 103 ± 2ºC until a constant weight was attained. The test sample specimens were then weighed to give the oven dried weight. The volume of sample specimens was obtained using the water displacement method. The weight displaced was converted to volume of the sample as a green volume. The density of each test sample is given by equation 2:

$$\text{Density } (\rho) = m / v \quad \text{----------- (2)}$$

Where,

ρ = the density by green volume in kg/m^3,

m = the mass in grams (g) of the test samples oven dried

v = the green volume of the test samples in mm^3

3. Statistical Analysis

Statistical analysis was performed using Microsoft excel and SPSS software 16.0 version. Two-way factorial analysis with descriptive statistics was

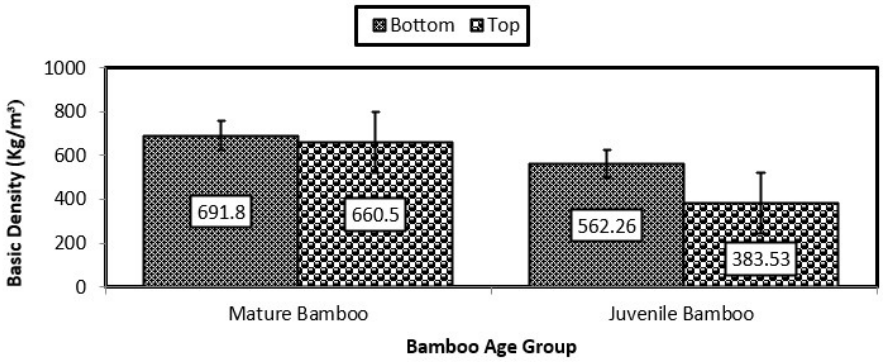

Fig 4. Basic density of *Bambusa vulgaris*; N=30

used to summarize the results. ANOVA was further used to determine significant differences between specimens at $p<0.05$.

RESULTS AND DISCUSSION

1. Morphological properties

a. Internode length of *Bambusa vulgaris* culm

Figure 1 shows the internode length for the bottom and top portions of both matured and juvenile *Bambusa vulgaris*. The internode length of the bottom part of the matured bamboo culm was 365.60mm whilst that of the top part was 442.20mm. Similarly, the internode length of the bottom part of the juvenile bamboo culm was 300.60mm whilst that of the top part was 355.96mm. For both the matured and juvenile *Bambusa vulgaris*, the internode length for the top part was longer than that of the bottom portion. Additionally, the study indicates that both the bottom and top internode length of the matured bamboo were longer than that of the juvenile ones. Furthermore, it can be seen that the matured top culm had the highest value of internode length with 442.20mm compared to the other sections. Comparatively, the internode length of the bottom part of the mature bamboo culm was 65mm longer than that of the juvenile one whilst for the top portion the matured one was 86.24mm longer than that of its corresponding juvenile bamboo.

The result of this study compares to a similar study conducted by Razak *et al*., (2010). Their study reported that the internode length for juvenile bottom culm was 245.3mm and its corresponding top culm was 358.1mm while that of mature bottom culm was 222.7mm and its corresponding top culm was 339.3mm. Ebanyenle & Oteng Amoako, 2007; Tekpetey, 2011; Dessalegy *et al.,* 2021 reported similar trend of result. Generally, internode length gradually increases from bottom portion through to the top portion in both juvenile and mature bamboo culms (Razak *et al*., 2010; Atmawi & Apri, 2018).

The differences in internode length for both the bottom and top portions of the matured and juvenile bamboos studied could be as a result of the general structure of the culm that tapered from the bottom portion towards the top (Huang *et al*., 2015). Differences in bamboo properties by species, age, location, and portion can influence processing procedures and affect the performance of end products (Hisham *et al*., 2006). Internode of *Bambusa vulgaris* could be used for the production of engineering composites due to its culms' high growth rate, abundantly available, renewable nature, and short maturity period (Qi *et al*., 2014). Internode length could indicate higher strength of mechanical properties of engineering composite products due to its continuous fibre length. According to Shahril and Mansur (2009), the fibre length is a good predictor of MOR and MOE and where the shortest fibre at nodes contributed to the lowest mean values of these properties. Qi *et al*., (2015) also reported that, engineered composite manufactured from bamboo fibre mats without nodes had greater tensile strength, compressive strength, MOE and MOR. Research has shown that internode distance fibre orientation strengthens the engineered composite especially laminated bamboo due to the

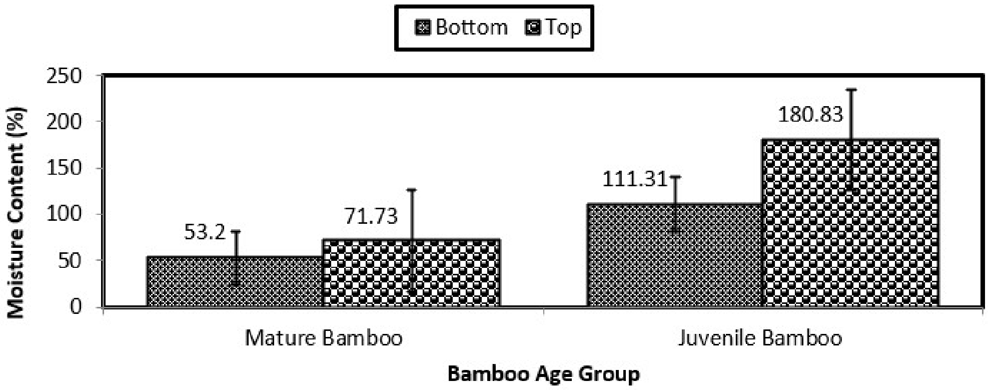

Fig 5. Moisture content of *Bambusa vulgaris*; N=30

strip arrangement within the board, and therefore the direction of the radial fibre density is randomly placed within in the board (Sharma *et al*., 2015). The inherent strength of bamboo is maintained by maintaining the longitudinal fibre orientation (Sharma *et al*., 2015). It is therefore useful to utilize internode of *Bambusa vulgaris* for the production of engineered composites such as bamboo-ply, laminated boards, (Bhat *et al*., 2011; Huang *et al*., 2013; Appiah-Kubi *et al*., 2014; Sharma *et al*., 2014).

The ANOVA presented in Table 1 shows that at 5% level of significance, bamboo age (Mature or Juvenile) and culm section (bottom or top) have significant effect on the internode distance of the bamboo. The suggests that about 87.7% and 84.4% of the variability in the internode distance could be explained by the bamboo age and culm section respectively. This implies that the difference within and across the same bamboo species is significantly important in selecting *Bambusa vulgaris* for industrial utilization.

b. Culm Diameter of *Bambusa vulgaris*

Figure 2 shows the culm diameter for the bottom and top portions of mature and juvenile *Bambusa vulgaris*. The culm diameter of the bottom part of the matured bamboo was 87.29mm whilst that of the top part was 55.90mm. Similarly, the culm diameter of the bottom part of the juvenile bamboo was 84.80mm whilst that of the top part was 52.73mm.

According to Figure 2, matured bottom culm had higher value of culm diameter compared to the juvenile bottom culm while the matured top culm

Table 1. Summary of ANOVA on morphological properties of the *Bambusa vulgaris*

Source	df	Internode Distance		Culm Diameter		Culm Thickness	
		Sig.	Var. (%)	Sig.	Var. (%)	Sig.	Var. (%)
Bamboo Age (BA)	1	0.001**	87.7	0.199ns	10.1	0.001**	53.9
Culm Section (CS)	1	0.001**	84.4	0.001**	93.4	0.001**	99.4
BA×CS	1	0.153ns	12.3	0.874ns	0.2	0.346ns	5.6

Note: ** = Significant at p<0.01; * = Significant at p<0.05, ns = Not significant compared to the juvenile top culm. Additionally, it can be seen that the matured bottom culm had the highest value of culm diameter with 87.29mm compared to the other sections. The result further shows that the culm diameter for both the bottom and top portions, the matured bamboo were higher than their corresponding values for the juvenile bamboo. Besides, for both the matured and juvenile bamboos the culm diameter of the bottom sections was greater than their corresponding top sections. The result of this study compares favourably to a similar study conducted by Razak *et al.,* 2010 ; Dessalegn *et al*., 2021. Similar trend of result was reported by Ebanyenle and Oteng-Amoako (2007).

The bottom part of the bamboo being bigger than the top part could be as a result of the general structure of the culm that tapered from the bottom portion towards the top portion (Huang *et al*., 2015). Additionally, the bottom and top part of the matured bamboo being bigger than their corresponding parts of the juvenile ones might be due to the genetic make-up of the species or due to the wide range of rainfall, temperature, altitude, soil type in relation to the habitat (Pathak *et al*., 2017).

Unlike internode length, which increased until a considerable height from the bottom part, the internode diameter generally decreased gradually towards the tip of the culm (Schulltes & Kurz, 2018). Amada *et al.,* (1997) reported that the diameter and thickness of the bamboo culm decreases as the location of the culm is further from the ground. The outer diameter of the bamboo culm decreased from the bottom to the top portion (Atmawi &Apri, 2018).

Culm diameter of *Bambusa vulgaris* could be used for the production of engineering composites due to its culms' availability, renewable nature, and short maturity period (Qi *et al*., 2014). Liese (1985) reported that in the industrial utilization of bamboo particular for making engineered bamboo composites, bamboo species with large culm diameter are selected. This will contribute significantly due to the higher number of strips produced from large culm diameter in the production of engineering composite products especially with particleboard, laminated board, bamboo scrimber (Bhat *et al*., 2011; Huang *et al*., 2013; Appiah-Kubi *et al*., 2014; Sharma *et al*., 2014) and this could normally reduce the number of culms selected for the production of these engineered composite products. Studies have shown that, large diameter bamboo had been largely used in the bamboo-based panel, bamboo glue-laminated timber, and bamboo flooring industries as sustainable raw materials of wood (Zhang *et al*. 2013; Qi *et al*., 2014). According to Huang *et al*., (2019), engineered composite products such as bamboo scrimber can be produced using small-diameter bamboo.

The ANOVA in Table 1 shows that at 5% level of significant, the bamboo age did not have significant difference on the culm diameter. This implies that the culm diameter differences existing between the matured and juvenile bamboo was not significantly as a result of bamboo age. However, at 5% level of significance culm section had significant effect on the culm diameter of the bamboo and the coefficient of determination was 93.4%. This implies that the

Table 2. Summary of ANOVA for basic density and moisture content of *Bambusa vulgaris*

Source	df	Basic Density		Moisture Content	
		Sig.	**Var. (%)**	**Sig.**	**Var. (%)**
Bamboo Age (BA)	1	0.001**	69.5	0.001**	91.2
Culm Section (CS)	1	0.001**	25.3	0.001**	66
BA × CS	1	0.001**	13	0.001**	42.8

Note: ** = Significant at p<0.01; * = Significant at p<0.05, ns = Not significant.

sections of the bamboo greatly influenced its culm diameter.

c. Culm Thickness of *Bambusa vulgaris*

Figure 3 shows the culm thickness for the bottom and top portions of both matured and juvenile *Bambusa vulgaris*. The culm thickness of the bottom part of the matured bamboo culm was 21.55mm whilst that of the top part was 7.71mm. Similarly, the culm thickness of the bottom part of the juvenile bamboo culm was 20.17 mm whilst that of the top part was 6.83mm.

From the Figure 3, matured bottom culm had higher value of culm thickness compared to the juvenile bottom culm while the matured top culm had higher compared to the juvenile top culm. The result further shows that the culm thickness for both the bottom and top portions, the matured bamboo were higher than their corresponding values for the juvenile bamboo. Additionally, the culm thicknesses for the bottom portions were thicker than their corresponding top portions for both mature and juvenile bamboo. Furthermore, it can be seen that the mature bottom culm had the highest value of culm thickness with 21.55mm compared to the other sections. The result of this study is comparable to that of Razak *et al*., (2010) whose similar study reported that the culm thickness for juvenile bottom culm was 14.6mm and its top culm was 5.5mm whiles mature bottom culm was 15.4mm and its corresponding top culm thickness was 7 mm. Similar trend of result was reported by Ebanyenle and Oteng-Amoako (2007), Tekpetey (2011) and Dessalegn *et al*., (2021).

The variation in thickness between the bottom and top sections could be due to the general structure of the culm that tapered from the bottom portion through to the top that eventually affected the thickness of the culms (Biswas *et al*., 2011; Maya *et al*., 2013). Lybeer *et al*., (2006) reported that, the high variability within one culm and between culms of the same age from one year on is partly masking a clear increased cell wall at higher age. Additionally, the variation in thickness between the matured and the juvenile bamboos studied could be as a result of age.

The culm thickness plays a key role in the selection of bamboo culm for industrial application and thereby influenced the mechanical properties of engineered composites (Rassiah *et al*., 2015). This implies that, it is most appropriate to use matured bamboo culm than that of the juvenile bamboo culm for the production of engineering composites products (Bhat *et al*., 2011; Huang *et al*., 2013; Appiah-Kubi *et al*., 2014; Sharma *et al*., 2014).

The ANOVA in Table 1 shows that at 5% level of significance, bamboo age and culm section have significant effect on the culm thickness of *Bambusa vulgaris*. This suggests that both bamboo age and culm section have greater influence on culm thickness.

d. Basic Density

Figure 4 shows basic density results for the bottom and top portions of both matured and juvenile *Bambusa vulgaris*. The basic density of the bottom portion of the mature bamboo culm was 691.80 kg/m^3 whilst that of the top portion recorded 660.50 kg/m^3. Similarly, the basic density of the bottom portion of the juvenile bamboo culm was 562.26 kg/m^3 whilst that of the top portion was 383.53 kg/m^3.

According to Figure 4, matured bottom culm had the higher value of basic density compared to the juvenile bottom culm while the matured top culm also had higher value compared to the juvenile top culm. Additionally, the matured bottom culm had the highest basic density value of 691.80 kg/m^3 as compared to the other sections. It could be concluded from the study that for both the bottom and the top portions of the *Bambusa vulgaris* species studied the basic density of the matured bamboo culm was higher than that of the juvenile bamboo culm. This result is comparable to similar results reported by Krishnakumar *et al*., (2017), Sulaiman *et al*., (2018) and Dessalegn *et al*., (2021).

These variations could be attributed to the anatomical structure such as fibre proportions around the vascular bundle within the various culm heights (Razak *et al*., 2010; Vetter *et al*., 2015; Sulaiman *et al*., 2018). In addition, the variations in basic density of the bamboo species could also be due to the level of sections of the culm height for both the mature and juvenile bamboo. Santhoshkumar and Bhat (2015) reported that density varied with positions of the culm wall and different height levels of the culm in the species whiles Gebremariam and Assefa (2018) also similarly reported that, density of the culm increased with increasing height levels of the culms. However, the result of this present study suggested otherwise. The basic density of the culm rather decreased with increasing height levels of the culms for both juvenile and mature bamboo respectively.

Higher density could indicate higher strength of both physical and mechanical properties for *Bambusa vulgaris* and therefore enhances the utilization of *Bambusa vulgaris* especially in selecting culms for the structural and non-structural applications. This property of higher basic density has generally influenced the acceptability of matured bamboo culm as compared to that of the juvenile bamboo culm as constructional material for both building and wood industry. The matured bamboo culm especially the bottom portions could be utilized for many applications such as furniture, basket, toothpicks, handicrafts products, papers, parquet, bamboo ply, laminated panels (Azmy *et al*., 2004; Asari & Suratman, 2010; Bhat *et al*., 2011; Huang *et al*., 2013; Appiah-Kubi *et al*., 2014; Sharma *et al*., 2014).

Table 2 presented the results of the ANOVA which shows that at $P \leq 0.05$ level of significance the bamboo age, culm section and their interaction have significant effect on the basic density of the bamboo. The level of variability was 69.50%, 25.30% and 13% respectively. This could explain by the bamboo age, the culm section and their interactions. This implies that their difference could contribute significantly towards basic density of bamboo species.

e. Moisture Content

The results as presented in Figure 5 show MC for the bottom and top portions of both matured and juvenile *Bambusa vulgaris*. The MC of the bottom part of the matured bamboo culm was 53.2% whilst that of the top part was 71.73%. Similarly, the MC of the bottom part of the juvenile bamboo culm was 111.31% whilst that of the top part was 180.83%.

From the Figure 5, the matured top culm had higher MC compared to the matured bottom culm whilst the juvenile top culm recorded higher MC compared to the juvenile bottom culm. Additionally, the juvenile top culm had highest MC compared to other three sections. The results further show that for both the bottom and top sections of the Bambusa vulgaris culms studied, the MC of the juvenile bamboo culm was higher than that of the matured bamboo culm. This result is similar to findings of Razak *et al.* (2012) and also compared favourable to the findings reported by Razak *et al*., (2010), Gebremariam and Assefa (2018), Sulaiman *et al.*, (2018) and Dessalegn *et al*., (2021).

The results again show that the age difference also contributed to the variations in MC. Study by Razak *et al*., (2010) indicates that the age, height and position in the culms wall thickness influence MC in *Bambusa vulgaris*. This study also shows that the MC decrease as bamboo matures as presented in Figure 5. This could explain the rationale involved in the growth of bamboo into its woody material state.

The results as indicated in Figure 5, the MC could influence the utilization potential of *Bambusa vulgaris* especially on the production of engineering composites products since it affects the dimensional stability of produced engineered composite products such as laminated board, particleboard, and bamboo-ply. It is therefore preferable to use matured bamboo culm for the production of engineering composites products (Bhat *et al*., 2011; Huang *et al*., 2013; Appiah-Kubi *et al*., 2014; Sharma *et al*., 2014;) than the juvenile ones since its green moisture content is lower than that of the juvenile bamboo culm.

The results of the ANOVA (Table 2) of the MC indicate that at 5% level of significance the bamboo age, culm section and their interaction have significant effect on the MC of the bamboo. The level of variability was 91.20%, 66% and 42.80% respectively and this could explain by the bamboo age, the culm section and their interactions. This implies that their difference could contribute significantly towards MC of bamboo species.

Conclusion

The comparative study of morphological and physical properties of juvenile and matured *Bambusa vulgaris* was investigated. The results show that the morphological properties of *Bambusa vulgaris* vary depending on the age and sections along the culms height. The culms taper from the bottom portion through to the top portion with a decrease in diameter and culm wall thickness. The age and section along in the culm thickness influence the present of moisture content in *Bambusa vulgaris*. Internode length with thicker culm thickness indicates higher strength of mechanical properties of engineering composite products. In addition, larger culm diameter is preferred for the production of engineering composite products. The results of the physical properties show that the juvenile had the higher level of moisture content compared to that of matured *Bambusa vulgaris*. The moisture content decrease when the age of the culm increase. The moisture content increases from the bottom section to top section. It could be further concluded that the basic density of the matured culm was higher than that of the juvenile *Bambusa vulgaris* and their differences were significant. In a whole, the matured bamboo culm had better morphological and physical properties than that of the juvenile bamboo. It is therefore useful to consider matured culm for the production of engineering composite products than that of the juvenile *Bambusa vulgaris*.

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