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Full Length Research Paper

Assessment of the Effect of Log Diameter and Inherent Characteristics of Four Timber Species on the Yield of Sliced Veneer

Kojo Agyapong Afrifah* and Kwasi Frimpong-Mensah

Department of Wood Science and Technology, Faculty of Renewable Natural Resources (FRNR), Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

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Forest timber resources have dwindled in the last few decades with its attendant reduction in the supply of large diameter logs of commercial species for processing. This study therefore assessed the effect of the declining log sizes and inherent characteristics of the logs on the yield of high quality sliced veneer. The study was conducted in an industrial setting and determined the sliced veneer recovery factors for *Khaya species, Aningeria species, Entandrophragma cylindricum,* and *Pterygota macrocarpa.* Low percentage recoveries of 32.5 % for *Khaya species,* 39.3 % for *Aningeria species,* 39.6 % for *Entandrophragma cylindricum,* and 27.9 % for *Pterygota macrocarpa* were obtained. Strong negative correlations were observed between log diameter and yield of veneer implying that large diameters resulted in lower yield of veneer. By contrast strong positive correlation coefficient values were obtained between log diameter and volume of residue generated due to the high incidence of natural defects in the large diameter logs. Observations revealed that straight bole and medium sized diameter logs of relatively young trees which possess few inherent defects would be most preferred to produce high quality sliced veneer with improved yield for the studied species.

Keywords: Log, Veneer, Timber, Species, Sliced

INTRODUCTION

The role that the timber industry plays in the socio-economic development of a country need not be emphasized. It is a source of employment, supplies wood to the construction industry, and a foreign exchange earner. In Ghana, it contributes about 5 to 7 % of the Gross Domestic Product (GDP) (IDRC 1999).

There are nearly seven hundred different tree species in Ghana with only a few of commercial value (TEDB 1994). The high demand for these few commercial species has put pressure on them leading to their over exploitation. Consequently, there is a decline of large diameter logs of these prime species on the timber market (IDRC 1999). To check the excessive logging and ensure sustainable supply of quality large diameter logs, the Ministry of Lands and Forestry (MLF) of Ghana instituted an annual gross wood production or annual allowable cut of 1.2 million cubic meters from both reserved and off-reserved forests (TEDB 1994; FPIB 1995). This annual allowable cut is however inadequate and just a small fraction of the about 5 million cubic meters of installed sawmill capacity. Hence, the use of this limited wood resource must be maximized in order to reduce waste and limit the pressure on the forest.

*Corresponding author Email: kagyapong@gmail.com

Unfortunately, reported recoveries for some wood products in Ghana have been low. For instance, lumber and rotary veneer recoveries of 36 % and 52.87 % (for *Ceiba pentandra*), respectively have been reported at sawmills in Ghana (Foli 1988; Afrifah 1997). These low recoveries may not be different for the other manufactured sawmill products and are expected to even worsen with the declining log sizes. This assertion is supported by the studies of Ayarkwa and Mensah (1999) on the effect of log diameter, sawing pattern and some bole variables on lumber recovery of small diameter logs where they observed decreased yield as log diameter decreased. In addition to log diameter, Huang et al. (2012) and Melo et al. (2014) have reported that stem conicity and straightness, knots and cracks or splits are the most important raw material quality characteristics affecting recovery and production of high-quality veneers.

Government of Ghana's policy currently is to increase value addition on wood products for improved earnings (FPIB 1995). This culminated in the establishment of value addition timber industries subsequently leading to increased wood products manufacturing especially veneer and its related products (MLF 1996). For the forest resources to support this increased demand of timber for wood products and veneer production on sustainable basis, the supplies should be utilized efficiently to minimize waste and improve recovery. Increased recovery will also ensure higher revenue from a unit volume of raw material.

However, as the quantity of large diameter logs continue to shrink, the expected improved recovery seems unattainable due to the observed negative effect of small diameter logs on timber products yield (Ayarkwa and Mensah 1999). Obviously, the nominal volume of timber products yield from a large diameter log would potentially be higher than a small diameter one. What to the best of our knowledge has not been verified is whether the yield in terms of the percentage of the raw material input recovered would be superior for large diameter logs which come from older trees. Determination of this is an important pre-requisite to assess the proportion of the volume of wood raw material input that potentially goes to waste at the end of production. This will inform decisions on the selection of suitable log diameter classes that will ensure higher yields of wood products. It was therefore imperative to conduct studies into the effect of log diameter on recovery of manufactured timber products. Consequently, this study focused on establishing the relationship between log size and sliced veneer recovery. It also sought to improve the understanding and knowledge into the factors affecting sliced veneer yield from tropical timber species in order to address the drawbacks. Sliced veneer was selected for this study due to its high exported volume from Ghana.

The studies involved four prime wood species exported as sliced veneer in large quantities from Ghana. They were *Pterygota macrocarpa* (Pterygota), *Aningeria species* (Aningeria), *Khaya species* (Mahogany), and *Entandrophragma cylindricum* (Sapele). Specifically, these wood species were assessed in an industrial setting for their sliced veneer recovery and the effect of log diameter or size and inherent natural defects on their yield.

METERIALS AND METHODS

Study Mill

The study was carried out at Logs and Lumber Limited (LLL), Kumasi, Ghana. As one of the leading sawmills in the country, LLL produces large quantities of sliced veneer using horizontal slicers for both export and plywood production. Feasibility studies carried out at the mill showed the availability of the selected species in large quantities for processing into sliced veneer and the willingness of management to cooperate.

Determination of Input Logs and Flitches Volume

The study considered 28 logs. Seven logs of each of the 4 species studied were randomly selected from a pile and assessed. The logs were initially converted into bolts and finally to flitches. Prior to conversion of logs into bolts, log diameter and length measurements were taken for volume determination. Two diameter measurements were taken at approximately right angles to each other at both ends of each log. Diameter readings at each end were averaged and denoted as D_1 and D_2. Logs lengths (L) were obtained by taking measurements on two opposite sides and averaging them. Using the Smalian formulae (Equation 1) which takes into consideration the taper in the log, the volume of the logs were determined.

$$V_{Log} = \frac{\pi L}{12}\left(D_1^2 + D_2^2 + D_1 D_2\right) \quad \text{Equation 1}$$

where D_1, D_2, and L are as defined earlier.

Logs were first converted into bolts and then to flitches of varied shapes depending on the form of the log and the sliced veneer grain pattern required. To facilitate easy and accurate volume measurements, the two end faces of each flitch were divided into convenient shapes for area calculation. The sum of the areas of the shapes that occurred at each end face of a flitch gave the surface area of that end face. The areas of the two end faces of each flitch were averaged and multiplied with the length of the flitch to derive the volume (Equation 2).

$$V_{Flitch} = Average\ \ End\ \ Face\ \ Area \times Average\ \ Flitch\ \ Length$$

Equation 2

Subsequently, total volume of flitches obtained from a log was calculated. Slabs and sawdust produced at this stage were obtained by finding the difference between the log volume and the total volume of flitches as in

Table 1 Average proportions of sliced veneer and residues generated from the logs of the four species studied.

Species	Log diameter (m)	Log volume (m^3)	Slabs and sawdust (%)	Slicer boards and veneer trimmings (%)	Total residue (%)	Veneer recovery factor (%)
Sapele	0.88 (0.19)	6.2 (3.2)	32.6 (7.4)	27.8 (9.0)	60.4 (14.0)	39.6 (14.0)
Mahogany	0.98 (0.16)	7.5 (2.8)	33.1 (3.7)	34.4 (10.4)	67.5 (9.9)	32.5 (9.9)
Pterygota	0.77 (0.15)	4.8 (1.4)	25.7 (3.7)	46.4 (2.9)	72.1 (2.5)	27.9 (2.5)
Aningeria	0.70 (0.16)	4.9 (2.2)	22.2 (6.1)	38.5 (6.2)	60.7 (4.9)	39.3 (4.9)

*The values in parentheses are standard deviations.

Table 2 Correlation coefficient values between log diameter and percentage residues and veneer recovered for the four species studied.

Species	Correlation coefficient			
	Veneer recovery factor (%)	Slabs and sawdust (%)	Slicer boards and veneer trimmings (%)	Total residue (%)
Sapele	-0.78	0.90	0.47	0.78
Mahogany	-0.76	0.05	0.71	0.76
Pterygota	-0.86	0.77	-0.24	0.86
Aningeria	-0.70	0.73	-0.16	0.70

Equation 3.

$$V_{Slabs\ and\ Sawdust} = V_{Log} - V_{Flitches} \quad \text{Equation 3}$$

Determination of Volume of Veneer Output

Flitches obtained from the logs were processed into sliced veneer of various thicknesses after warming them up in steaming pits. Veneers with thicknesses of 0.5 – 1.0 mm were arranged in packs of 32 sheets and those with thicknesses of 1.2 mm and up in packs of 17 sheets at the kiln drier. These packs were treated as a unit in further processing. For instance, at the guillotines sheets of each pack of veneer were cut to the same size. Similarly, veneer sheets from a particular flitch were treated as a unit maintaining the sequence of cut. Using Equation 4 the volume of veneer sheets in a pack was determined.

$$V_{veneer} = L \times B \times H \times N \quad \text{Equation 4}$$

where L – length, B – width, H – thickness, and N – number of veneer sheets.

Summing up the pack volumes, the total volume of veneer yield for a flitch and subsequently the log was determined. The volume of the flitches for a particular log that went into residue as trimmings and slicer boards were determined with Equation 5.

$$V_{trimmings\ and\ slicerboard} = V_{flitch} - V_{veneer} \quad \text{Equation 5}$$

where V is volume.

The veneer recovery factor for the logs was computed using Equation 6.

$$Veneer\ Recovery\ Factor = \frac{V_{veneer}}{V_{\log}} \times 100\% \quad \text{Equation 6}$$

Statistical Analysis

Regression analysis was carried out on the data to determine the correlation between the diameter of the logs and the veneer recovered, volume of slabs and sawdust, and volume of total residue generated. Additionally, analysis of variance (ANOVA) was used to assess the differences that existed between the proportions of recovered veneer, slabs and sawdust, and total residue for each species.

RESULTS AND DISCUSSION

Yield of Veneer from the Four Species

The average veneer recovery factors for the four species studied are presented in Table 1. These values which are from 27.9 % to 39.6 % are lower than some of the recovery values obtained for other wood products and confirm the observation by Tsoumis (1991), that the volume of veneer sheets recovered from a log may be less than 50 % of the original round-wood volume.

These low yield of veneers obtained for the various species of wood could be attributed to the high quality requirements of sliced veneer (i.e. they were mostly used as face veneer, therefore a lot were clipped off or

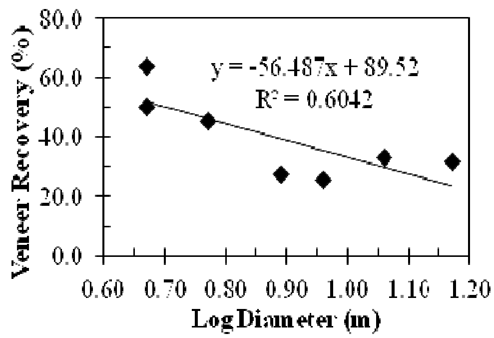

Figure 1 Relationship between sliced veneer recovery and average log diameter for Sapele

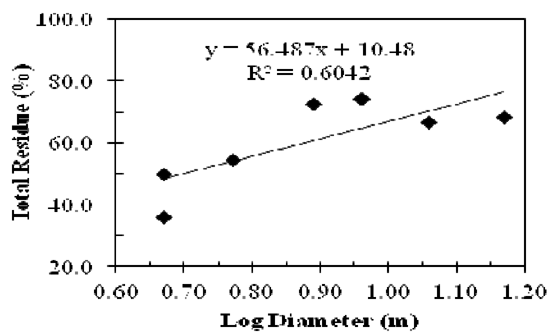

Figure 2 Relationship between total residue generated during sliced veneer production and average log diameter for Sapele

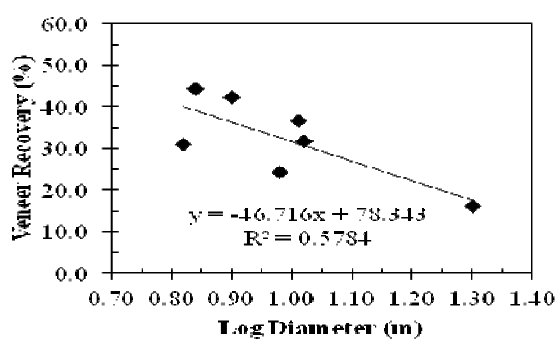

Figure 3 Relationship between sliced veneer recovery and average log diameter for Mahogany.

rejected due to manufacturing or natural defects) and the inherent natural defects or quality of the logs as has been reported by other researchers (Huang et al. 2012; Melo et al. 2014).

Effect of Log Diameter on Veneer Recovery

The results of the correlation between log diameter and veneer recovery and residues generated for the four species studied (Sapele, Mahogany, Pterygota, and Aningeria) are presented in Table 2. The results show strong negative correlation between log diameter and yield of veneer (Table 2). This implied that as log diameter increased, the proportion of the recovered wood as sliced veneer decreased (Figures 1, 3, 5, and 7). By contrast, with the exception of Mahogany (for slabs and sawdust only), the results show a strong positive correlation between proportions of slabs and sawdust and total residue (Table 2) implying that as log diameter

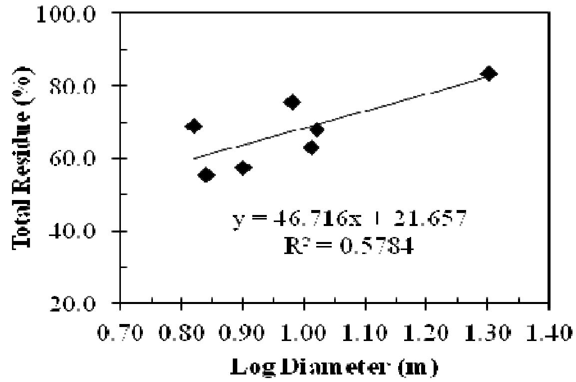

Figure 4 Relationship between total residue generated during sliced veneer production and average log diameter for Mahogany.

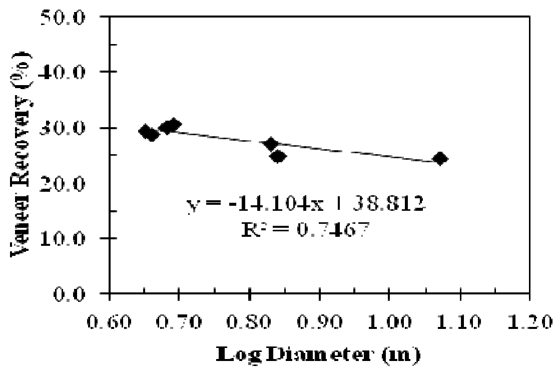

Figure 5 Relationship between sliced veneer recovery and average log diameter for Pterygota.

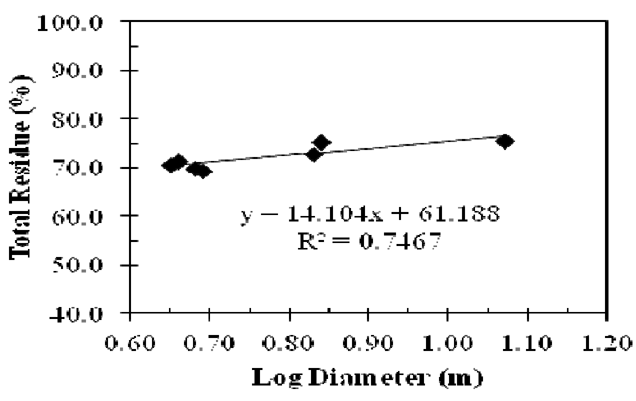

Figure 6 Relationship between total residue generated during sliced veneer production and average log diameter for Pterygota.

increased the proportion of residue generated also increased (Figures 2, 4, 6, and 8). The high amount of residue produced and the strong positive correlation with log diameter was partly due to the high incidence of natural defects in large diameter logs. Detailed discussion of the factors that contributed to the above observation in the studied species is presented below.

The positive correlation between log diameter and proportions of slabs and sawdust and total residue and the negative correlation between log diameter and percentage recovery of veneer for Sapele as in Table 2 and Figure 1and 2 may be accounted for by the irregular shape of the logs, and the presence of bumps, knots and splits in the large diameter logs. These defects had to be removed in order to get the desired flitches for processing, thus generating a lot of slabs and sawdust

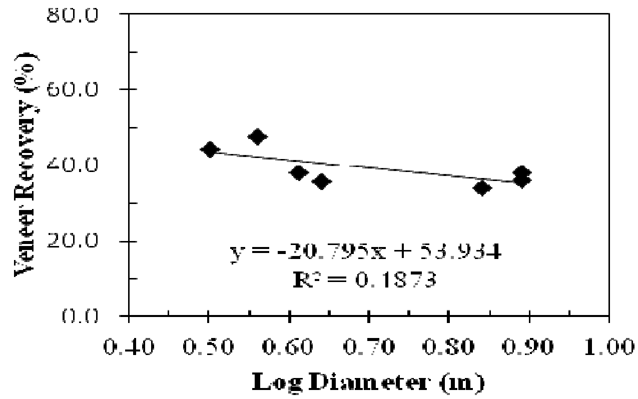

Figure 7 Relationship between sliced veneer recovery and average log diameter for Aningeria.

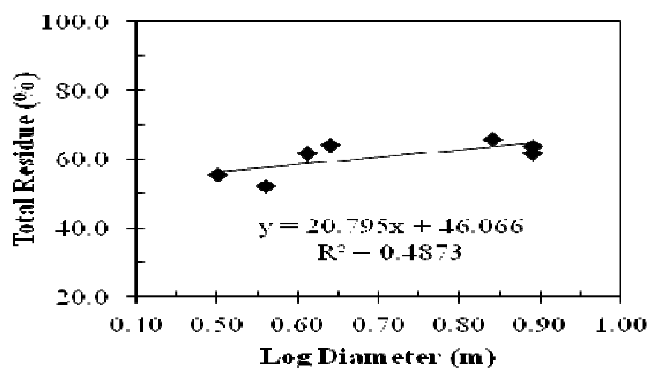

Figure 8 Relationship between total residue generated during sliced veneer production and average log diameter for Aningeria.

(Table 1). Large diameter logs further had to be broken down into more flitches than their small diameter counterparts. Therefore, more saw lines were created in large diameter logs increasing the proportion of sawdust produced by the many saw kerfs. During the processing of the dried veneer at the guillotines a lot of the sheets were also clipped off due to splits, knots and irregular grain. Additionally, thicker slicer boards which are left over boards after slicing the veneer were discarded due to irregular grain defect. The high loses due to grain defect was not surprising as the species has been observed to be inherently prone to interlocked, wavy or sometimes spiral grain defects (TEDB 1994). Figure 1 and 2 shows that logs of diameters from 65 to 75 cm may ensure minimum waste generation and higher sliced veneer yields for Sapele.

The logs of Mahogany which were processed were generally large with bumps on them and had poor shape. This observation confirmed the assertion by Farmer (1972), that most of the logs of *Khaya species* do not have a good shape. These bumps and sapwood had to be removed during the conversion into flitches generating a lot of slabs and sawdust (Table 1). The very weak positive correlation (0.05) between log diameter and percentage of slabs and sawdust produced shows that the form of the logs was not good irrespective of size (Table 2). The strong positive and negative correlation between log diameter and proportions of total residue and veneer recovered (Table 2 and Figure 3 and 4) respectively, was due to among other factors the prevalence of knots, grain defects and resin streak in large diameter logs. The grain pattern of this wood species has been reported to be usually interlocked even though it is sometimes straight (Farmer 1972). Removing these defects generated a lot of trimmings and invariably increased total residue with increase in log diameter (Figure 4). Figure 3 and 4 shows that medium sized logs of diameters of about 90 cm and below would result in lower residues and consequently higher yields of sliced veneer.

Even though the logs of Pterygota studied had good form, there was a strong positive correlation between its log diameter and proportions of slabs and sawdust and total residue generated (Table 2 and Figure 6).

Conversely, there was a negative correlation between log diameter and percent veneer recovered (Table 2 and Figure 5). This was because compared to the small logs, the large diameter logs had to be processed into more flitches consequently generating more sawdust in the numerous saw kerfs. Moreover, almost all the logs had heart rot which had to be removed. Generally, the intensity of the heart rot was highest in the large diameter logs resulting in higher proportions of slabs and sawdust. Thicker slicer boards and more trimmings were also discarded during processing due to the presence of resin streak, splits, knots, or grain defects (Table 1). However, the prevalence of knots, splits, and especially grain defects did not predominate in large diameter logs resulting in the weak negative correlation of 0.24 between log diameter and trimmings and slicer board residues (Table 2). Grain defects have been observed as a major limitation in this species as they inherently have interlocked grain and coarse texture (Farmer 1972; TEDB 1994). Generally it could be inferred from Figure 5 and 6 that the preferable log diameters to ensure higher sliced veneer yields and lower residues are about 60 to 75 cm.

Aningeria recorded a negative correlation coefficient between log diameter and yield of veneer (Table 2 and Figure 7) and a positive correlation between log diameter and proportion of total residue produced (Table 2 and Figure 8). The negative correlation for the recovery of veneer implied that as the log diameter increased the percentage yield of veneer decreased and hence more total residue was generated. The volume of slabs and sawdust which was a constituent of the total residue gave a strong positive correlation with the diameter of logs. This was because large diameter logs of Aningeria had a lot of bumps and splits in them, which had to be removed in the form of slabs and sawdust. The percentage trimmings and slicer boards generated were also high (Table 1). However, the weak negative correlation (-0.16) between log diameter and the percentage trimmings and slicer boards for Aningeria shows that log size did not have significant effect on the amount of this waste generated (Table 2). Generally, silica deposits, wavy grain, and splits (due to brittleness of this species) resulted in the generation of the trimmings and slicer boards. These defects which resulted in high lose in trimmings and slicer boards have been observed as inherent defects characteristic of this species (Farmer 1972; TEDB 1994). Observations show that for this species, log diameters of 50 to 60 cm would produce low residues and higher yield of sliced veneer (Figure 7 and 8).

Generally from the results it could be inferred that as the log diameter increased, the proportion of residue generated increased for all the species. Implication of this observation is that medium sized diameter logs of relatively young trees with straight bole and possessing fewer inherent defects such as bumps, mineral deposits, irregular grain, rot, mineral streak, splits, and knots would be most preferred to produce high quality sliced veneer with improved yield for the studied species.

Statistical Analysis

A test to find out whether there were significant differences between the percentage recovery of veneer and the percentage total residue for the species studied, showed no significant differences between them at 5 % level of significance. This implied that species had no influence on the veneer recovered and the total residue generated. However, there were significant differences between the percentage of slabs and sawdust produced from the various species. Implications are that species kind influenced the amount of slabs and sawdust produced during processing due probably to differences in the form of the logs and inherent defects.

CONCLUSION

This study was necessitated by the need to maximize yield of products from the limited timber resources available currently. The study looked at the production of sliced veneer with the view of identifying the effects of the size of the logs and their inherent characteristics on yield.

The yield of veneer obtained for the four species studied at the mill were very low due to the presence of inherent growth defects in the logs such as knots, mineral deposits, resin streak, irregular grain, bumps, splits, and rot. High natural defects prevalence in the logs used for the production of sliced veneer demonstrated the diminishing supply of quality timber in recent times.

Indications were that mostly logs with relatively large diameters which were presumably from older trees possessed more inherent natural defects. It is therefore inferred that if proper processing techniques and conditions were put in place, the use of medium sized logs with good form would ensure reduced residue generation and higher yields of sliced veneer for the species studied.

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