Sanding and Shaping Characteristics of *Gmelina arborea* Grown in two Ecological Zones in Ghana

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ABSTRACT

Poor machining of wood generates more residues which leads to low recovery in wood processing. Therefore, the availability of appropriate wood machining techniques would promote efficient utilization of logs. This study looked at the shaping and sanding properties of *Gmelina arborea* - a lesser-known species in Ghana - in order to promote its efficient utilization. Six trees from plantations at the Wet Evergreen and Dry Semi-Deciduous Forest Zones were extracted and processed into lumber using LT 15 horizontal wood-mizer. The average moisture content of samples just before the test was 14.57%. Specimens were prepared in accordance with ASTM D 143-83 and ASTM D 1666-87 (2004) for the sanding and shaping tests. The effects of tree location, grit size and spindle speed on sanding and shaping properties of *Gmelina arborea* wood were assessed using the visual approach. For the sanding test, grit size P80 was the best sandpaper to remove chipped and torn grain defects from the surfaces of *Gmelina arborea* lumber after planing. Spindle speed 10,000 rpm gave the best shaping output so it was recommended for shaping *Gmelina arborea* timber grown in Ghana. For the shaping operation, wood samples obtained from the Dry Semi-Deciduous Forest Zone had better surface quality than those obtained from the Wet Evergreen Forest Zone. A similar trend was obtained for the sanding test. The most common defects observed during grading of the shaped specimens were raised, chipped and fuzzy grains and those observed for the sanded specimen were fuzzy and scratchy defects. At 5% level of significance, tree location and spindle speed had significant effect on the surface quality of the shaped specimen.

Keywords: Ecological zone; *Gmelina arborea*; grit size; shaping; sanding; spindle speed

1. INTRODUCTION

Wood as a natural resource possesses several advantages than other materials like metal, concrete and plastics. Some of these are its sustainability, ease of working with, aesthetical appeal and biodegradability. It is therefore necessary, in the face of dwindling timber species, to promote the utilization of lesser-used timber species (LUS), lesser-known timber species (LKS) and the technologically unknown timber species (TUS) in order to keep the timber industry in business.

In Ghana *Gmelina arborea* is a lesser-known timber species on the domestic timber market. This is because its properties and uses are not well known to wood users. The introduction of *Gmelina arborea* on the timber market will increase the resource base of lumber and make a lot more raw materials available to the timber industry while taking some of the pressure off the primary species. However, this among other things will largely depend on adequate knowledge of its physical, anatomical, chemical and machining properties [1].

Wood machining is a process that is used to assess the performance of any wood species after it has gone through planing, shaping, turning, boring, mortising and sanding. Currently, wood machining is of great importance in the timber industry, in that poor machining could lead to generation of more residue. It is therefore important that studies that could inform wood users of efficient wood machining techniques for both secondary and tertiary wood processing are undertaken by wood scientists.

The surface quality of wood - characterized by its surface roughness - is one of the important properties that affect other wood manufacturing processes like finishing, strength of a glued joint, glue bonding and its durability [2, 3, 4]. A report by Sandak and Negri [5] indicates that surface roughness affects the aesthetic appeal of a wood product in terms of touch and appearance. This suggests that any surface defect resulting from an improper machining process could result in increased cost of production if good finishing is to be achieved.

According to Taylor *et al*. [6], the surface quality of any finished wood product is determined by the sanding operation and this subsequently affects the overall perceived quality of the product. Sanding operation has long been the standard practice in the joinery industry to remove machining imperfections and to achieve a homogeneous surface prior to coating application.

Besides, it levels the joints, creates a smooth surface and prepares the wood to take stains easily by providing a uniform texture and increasing the adhesion ability of the wooden surface. According to Koch [7] and Kollman and Cote [8], the smoothness of a sanded surface depends mainly on (1) the size, shape and quality of the particles of grit, (2) the speed of sander and (3) work piece, type of machine sander and moisture content. Saloni [9] also reported on factors that influence sanding as pressure, belt speed, abrasive type, grit size, wood species, physical and chemical wood properties and wood anatomy. Thus, in order to achieve high quality finish, there is the need to consider the correct type and grit of sandpaper [10].

Shaping is chiefly done in the furniture industry. The commonest is the cutting of patterns on some curved edge like that of a round table. There are power-fed automatic shapers, but the most commonly used type is the spindle moulder [11]. Davis [12] indicated that spindle shapers are typically hand-fed machines, although power-fed attachments are available on the market. Additionally, cutter head speed between 3,600 rpm and 7,200 rpm has little influence. However, if trade opinion is right, it could be significant between 7,200 rpm and 15,000 rpm.

Gmelina arborea, an exotic species, is a potential source of raw material for the wood industry [13]. It is a deciduous tree and grows to 12-30 m in height and 60-100 cm in diameter. It is a medium-density timber species and has excellent strength, planing and turning properties [14, 15]. Studies have indicated that *Gmelina arborea* wood is suitable for use as plywood, particleboard, mining props, timber and telecommunication transmission poles and also serves as a fuel source [14]. In Ghana, hectares of *Gmelina arborea* plantations have been established by individuals, CSIR-Forestry Research Institute of Ghana and the Forestry Commission, of which some have been cultivated by Subri Industrial Plantations Limited (SIPL) at Daboase near Sekondi-Takoradi. The Daboase *Gmelina arborea* plantation was originally cultivated to serve as a wood resource base for a proposed paper-processing factory in Ghana [15]. However, the factory was never established and the plantation was left unused. It was later realised that *Gmelina arborea* could be used as timber in various applications. Despite this, it is not common on the local timber market due to a lack of basic and technological properties about the species [15]. *Gmelina arborea* is among the ten species that the Forestry Commission has selected for plantation establishment in Ghana. This indicates that the species will be in abundance in the near future, hence the need to determine all the needed properties for its efficient promotion and utilization. This paper which forms part of a report from a wider study aims at determining the shaping and sanding characteristics of *Gmelina arborea* cultivated in Ghana. It therefore provides scientific information for the potential use of *Gmelina arborea* wood grown in Ghana.

2. MATERIALS AND METHODS

2.1 Material selection

One group of three *Gmelina arborea* trees was obtained from a plantation in Daboase, in the Western Region of Ghana which was established in 1977. Daboase is located in the Wet Evergreen Forest Zone (WEFZ), which has an average annual rainfall of 1500 mm. Another group of three *Gmelina arborea* trees was obtained from the plantation in Abofour in the Ashanti Region of Ghana which was established in 1975. Abofour is in the Dry Semi-Deciduous Forest Zone (DSDFZ), which has an average annual rainfall of 1400 mm. In both cases, trees with a breast-height diameter of 40-60 cm were sampled for the study.

2.2 Material preparation

The trees from both plantations were crosscut into three sections - top, middle and butt - using a chainsaw machine. Each section measured 2.5 m and was labelled accordingly. Subsequently, a narrow bandsaw Wood Mizer was used to saw each of the logs into boards of thickness 2.6 cm. The boards were stacked in a drying shed to air dry. The moisture content of the lumber was checked at regular intervals with a moisture metre until 15-16% moisture content was attained. The air dried samples were then rip-sawn into dimensions in accordance with ASTM standard D 143-94 [16] and ASTM standard D 1666-87 [17] for the sanding and shaping tests.

2.3 Moisture content

Before the sanding and shaping tests were conducted, boards were randomly sampled to determine moisture content using the oven-dry method, in accordance with European standard EN 13183-1 [18]. Fifteen *Gmelina arborea* specimens with dimensions of 20 mm x 20 mm x 30 mm were weighed and placed in a laboratory oven at a temperature of 103 °C. The samples were dried until the difference in mass between two successive weighings separated by an interval of two hours was 0.01 g or less. The moisture content of the specimens was then computed as follows:

$$Moisture\ content\ (\%)\ db = \frac{M_1 - M_o}{M_o} \times 100$$

where M_1 and M_o are the masses (g) of the specimens before oven drying and after oven drying, respectively.

2.4 Sanding quality test

Sanding process, which is classified into two major activities include the reduction of the rough surfaces of a previously machined workpiece to relatively smooth and flat surfaces, and the preparation of the relatively smooth and flat surfaces for a subsequent application of finishing material [7]. Boards used for the sanding test were prepared in accordance with ASTM standard D 1666-87 [17]. Before the sanding operation the boards were planed using a surfacing and thickness planer machine of type 610 x 230 mm DAA; knife with cutting angle 30 degrees and feed speed of 14 m/min. These cutting angle and feed speed were selected based on studies by Mitctual *et al.* [15] and it was intended to generate more defective (chipped/torn) samples for the sanding test. For each ecological zone the total number of boards sampled for the sanding text was 135. Next, using a belt sander (a 3 - phase model CL300 type), boards from the two ecological zones were sanded with grit sizes 80, 100 and 120. For each sanding operation a new abrasive paper was fixed onto the machine. The sanded boards (Figure 1) were then inspected with the aid of a hand lens in order to determine the quality of surfaces (the level of elimination of chipped/torn grain defects) generated and evaluated.

Figure 1: Samples of sanded boards

Grading was done on a numerical scale of 1 to 5 (Grade 1 – excellent: defect free; Grade 2 - good: minimal defects, which can easily be rectified by sanding; Grade 3 – fair: minimal defects, which cannot be easily removed by sanding; Grade 4 – poor: high degree of defects, which can be removed with difficulty; Grade 5 – reject: very difficult to remove defects and thickness is affected.) to indicate the degree of any defect that was present on the surfaces of the sanded boards, in accordance with ASTM standard D 1666-87 [17]. The mean percentage of defect-free (excellent) samples for each ecological zone was estimated.

After the assessment, 138 of the defect-free sanded samples, with relatively smooth and flat surfaces (the minimum number of excellent samples recorded by one of the forest zones), were sanded again using only grit size 120 to observe the scratching and fuzzing tendencies. The percentage of scratch-free and fuzzy-free samples was then estimated. The speed of the belt sander and mean moisture content of the samples for all samples at test were 1,750 rpm and 14.57% respectively. The grits of sandpapers used for all the tests were from aluminium oxide which were available to the furniture industry at the time of the tests. The objective of this test was to remove chipped/torn grain defects, which are machining defects that were generated after planing and also determine the surface quality with grit 120 for the application of finish.

2.5 Shaping quality test

The shaping test was conducted using a spindle moulder (type Swdgwick SM4) and a narrow band saw machine of type Wadkin C5. Test specimens were prepared to the dimension 20 mm x 75 mm x 300 mm (Figure 2). A jig was used to make the outline of the shape to be sawn on the boards which were then sawn using a narrow bandsaw machine. Thereafter, each of the 135 shaped specimens for each of the ecological zones was fastened to a jig and fed past the cutters of the spindle moulder manually. Spindle speeds of 4500 rpm, 6000 rpm and 10000 rpm were used for the shaping operation after which they were graded on the basis of the degree of raised, fuzzy, chipped grain and rough–end grain defects.

Figure 2: Specimens of *Gmelina arborea* wood prepared for shaping

Figure 3: Samples of shaped *Gmelina arborea* wood

This was done on a scale of 1 - 5 (Grade 1 - excellent: defect free; Grade 2 - good: minimal defects, which can easily be rectified by sanding; Grade 3 - fair: minimal defects, which cannot be easily removed by sanding; Grade 4 - poor: high degree of defects, which can be removed with difficulty; Grade 5 - reject: fibre tear outs and broken corners.). The percentage excellent and good specimens was then determined. Figure 3 shows samples of shaped *Gmelina arborea* wood.

2.6 Data Analysis

After visual examination and grading, the data resulting from sanding and shaping tests were transformed using log transformation to convert the data into a continuous data prior to statistical analysis. Version 9 of the SAS statistical software program was used to perform the statistical analysis.

3. RESULT AND DISCUSSION

3.1 Density and moisture content *Gmelina arborea*

The average oven-dry density of the top, middle and butt portions of *Gmelina arborea* obtained from the Daboase plantation in the WEFZ as reported by Mitchual *et al*. [15] was 515 kg/m^3, with a range of 413 kg/m^3–599 kg/m^3, while the one obtained from the Abofour plantation in the DSDFZ was 455 kg/m^3, with a range of 390 kg/m^3–500 kg/m^3. On the average, the moisture content of the specimen before the sanding and shaping test was 15.5%. Previous studies by Davis [12] as cited in Mitchual *et al*. [15] suggested that best wood machining results could be obtained at 6% moisture content and the poorest at 20% or more moisture content. Pinheiro *et al*. [19] also observed that the surface roughness of wood increases with increasing moisture content. Therefore, the moisture content of the samples for this study could be considered adequate.

3.2 Sanding characteristics of *Gmelina arborea*

The oldest and best-known coated abrasive is the familiar "sand-paper" in which the mineral is quartz. Sanding is done to remedy a slight mismatch where different parts of a finished product join, such as the vertical and horizontal members in a solid door or the sides and front of a drawer [12].

Elimination of chipped and torn grain defects

Chipped grain defect consists of depressions below the general surface where short particles are broken out below the line of cut during machining processes. Torn grain is similar but more pronounced in degree. For all the tree sections, the top section recorded the highest percentage of defect-free samples when all the three sandpapers were used. This was followed by the middle and then the butt sections (Figure 4). This shows that at the same moisture content the ease with which grits sizes of sandpapers cut through the wood fibres decreased towards the butt section. This result supports the findings by Benson [20] which indicated that for the same species of wood there is considerable variation in the smoothness of surface that may be obtained under uniform working condition.

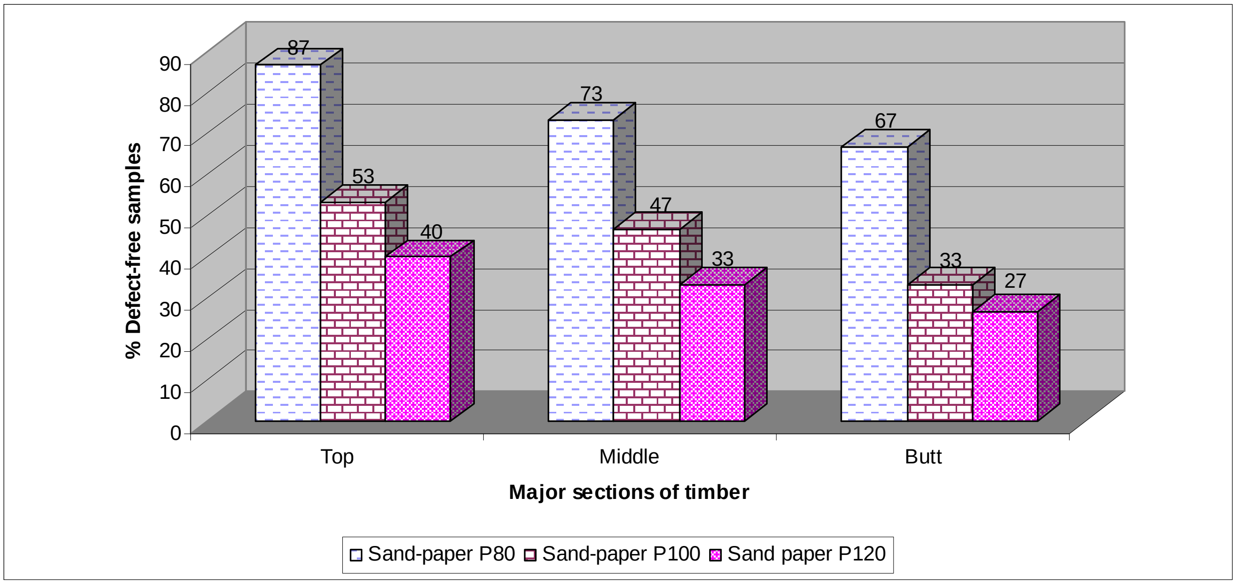

Figure 4: Percentage of defect-free samples of sanded boards of three sections of *Gmelina arborea* trees from WEFZ using P80, P100 and P120 sandpapers to eliminate chipped/torn grain defects

Removal of chipped/torn grain defects from *Gmelina arborea* wood samples for the various sections of the trees obtained from the WEFZ at Daboase was easier with sandpaper of grit size P80, followed by P100 and P120 (Figure 4). This means that elimination of chipped and torn grains was more effective with decreasing grit size, where the grits are coarser thereby making cutting of fibres easier. This result is supported by a study conducted by Owusu *et al*. [21] on the sanding properties of seven lesser-used timber species in Ghana which concluded that grit size P120 is not capable of removing chipped/torn grain defects of wood species with medium to high densities. There were also significant differences between and within all the wood sections for the three grit sizes of sandpapers at 5% level of significance.

Figure 5 which indicates the result of the sanding test on wood obtained from the DSDFZ shows that the order of performance of the grit sizes followed the same trend as that of WEFZ in Figure 4, but comparatively with higher performances. The exception to this is the middle section using grit P120 and the butt section using grits P100 and P120 where the same percentage of defect-free samples were recorded for samples obtained from the WEFZ and DSDFZ (Figures 4 and 5). Within and between sections of the wood species there were significant differences between the three grits at 5% level of significance. This could be attributed to the longitudinal changes in the characteristics of the wood species.

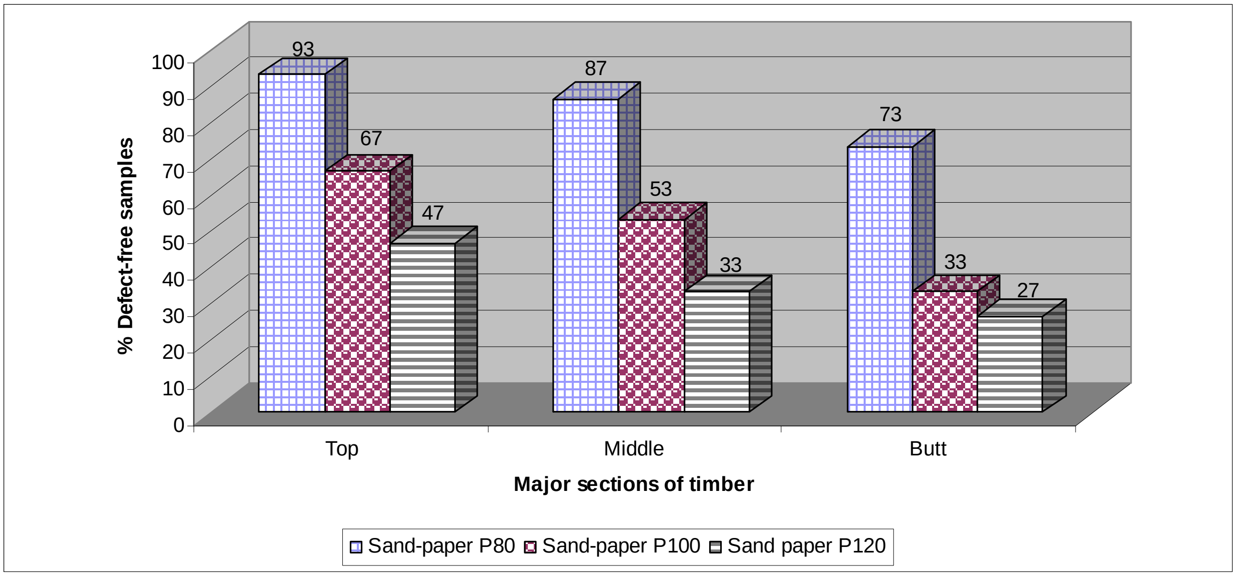

Figure 5: Percentage of defect-free samples of sanded boards of three sections of *Gmelina arborea* trees from DSDFZ using P80, P100 and P120 sandpapers to eliminate chipped/torn grain defects

Figure 6, illustrates the overall defect-free samples for the two ecological zones using the three grit sizes of sand paper. Generally, the average percentage of defect-free samples generated from the DSDFZ were higher than that obtained from the WEFZ with the overall mean of tree sections for the DSDFZ being 57% and that of WEFZ being 51%.

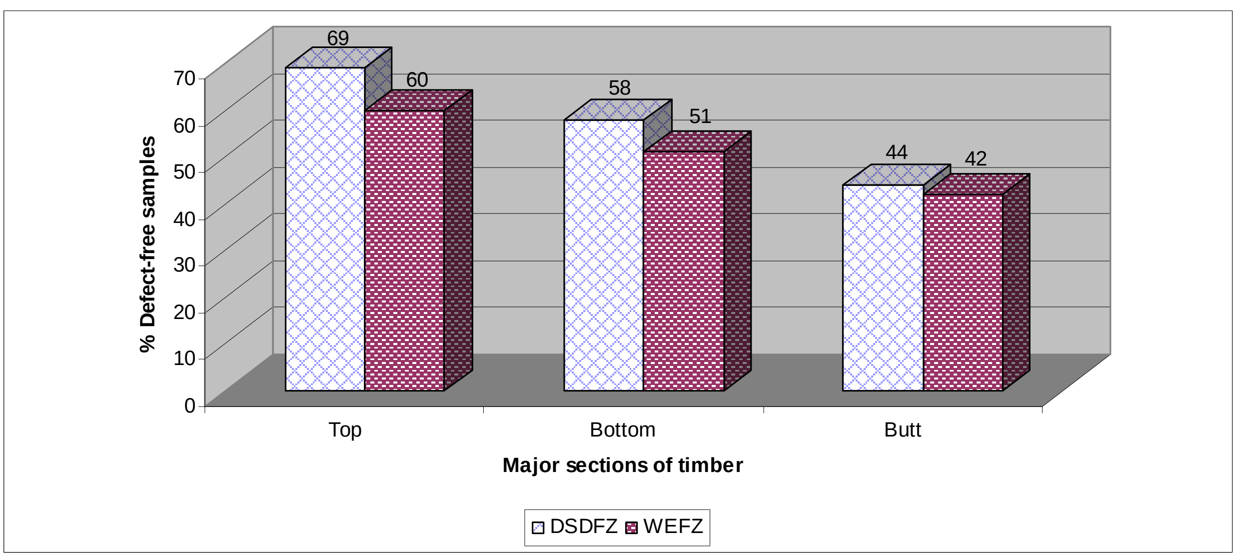

Figure 6: Overall percentage of defect-free samples for sections of *Gmelina arborea* trees of two ecological zones using P80, P100 and P120 sand papers to eliminate chipped/torn grain defects

This could be attributed to the differences in the density of the wood samples obtained from the two ecological zones for the study [WEFZ = 515 kg/m^3; DSDFZ = 455 kg/m^3]. This finding is supported by a result of a study by Owusu *et al*. [21], which indicated that elimination of the chipped/torn grain defects is easier with low density species than with higher density species. Statistically, there was no significant difference within sections of the trees but between sections at 5% level of significance.

Scratching tendency

Belt sanders used for sanding generate scratches of straight lines unlike drum sanders. Therefore, wood species could be sanded without any visible scratches on condition that grit sizes of sufficiently fine sandpaper are used [12]. Figure 7 indicates both the scratching and fuzzing tendencies of *Gmelina arborea* wood samples obtained from WEFZ and DSDFZ of Ghana. The percentage of scratch-free samples generated from DSDFZ (88%) was higher than that of WEFZ (82%). Generally, coarse-textured timber species show scratches less than fine-textured woods when sanded under the same conditions [22]. Since the texture of the samples obtained from the two ecological zones were similar - coarse textured - the variations in their scratching tendencies could be attributed to the difference in the densities of the samples obtained from the two ecological zones (WEFZ = 515 kg/m^3; DSDFZ = 455 kg/m^3). This means that the denser wood samples from the WEFZ comparatively generated more scratches than those from the DSDFZ.

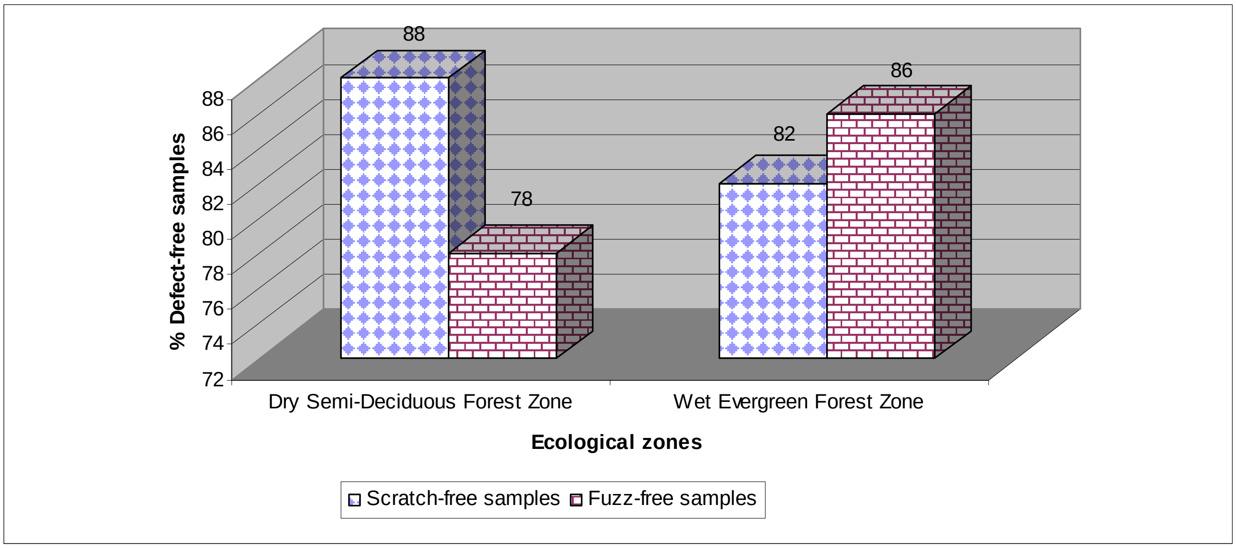

Figure 7: Percentage of scratch-free and fuzz-free samples of *Gmelina arborea* from two ecological zones in Ghana

Fuzzing tendency

Fuzzy grain is a type of raised grain in which wood fibers are projected above lumber surfaces most specially after sanding thereby making it difficult to secure a smooth finish. Sanding is responsible for more fuzzing than planing because the grains of the sandpaper grits tear up parts of the fibers, whereas the planing machine cuts more frequently through the fibers and consequently leaves fewer loose ends sticking up. Generally, hardwoods generate less fuzzy defect than the softwoods [20]. Fuzzy grain could also results from factors such as tool geometry, machining parameters, moisture content and species type [23]. Figure 7 which indicates the fuzzing tendency of *Gmelina arborea* shows that samples obtained from the WEFZ had higher percentage of fuzzy-free surface than those obtained from the DSDFZ. This trend is likely due to the difference in the density of the *Gmelina arborea* extracted from the two ecological zones. This confirms the conclusion on "Machining and related characteristics of United States Hardwoods" by Davis [12] that high density wood species fuzz less than low density ones. It is also supported by the studies of Owusu *et al*. [21] which indicated that the sanding quality of timber species under fuzzing tendencies is better with increasing density.

3.3 Shaping characteristics of *Gmelina arborea*

In the furniture industry, shaping is usually done and the commonest is the cutting of patterns on some curved edge like that of a round table. A band saw is mostly used to saw the wood before being shaped using the spindle moulder. There are other power-speed automatic shapers but the most common type is the spindle moulders [11]. Davis [12] reported that cutter head speed has significant influence between 3600 rpm and 7200 rpm but if trade opinion is right, it would be significant between 7200 rpm and 15000 rpm. In this study the comparison of shaping properties of tree sections of the *Gmelina arborea* trees obtained from the WEFZ and DSDFZ was based on percentages of grades 1 and 2 (Excellent and good specimens) as acceptable grades.

Table 1 indicates the results of shaping test of *Gmelina arborea* obtained from WEFZ. The top section recorded the highest percentage of acceptable grade (46.7%) which corresponded to spindle speeds of 6000 rpm and 10000 rpm. Spindle speed 4500 rpm did not produce any acceptable grade. The highest percentage of acceptable grade (66.7%) for the middle portion was obtained at spindle speed of 10000 rpm. Generally, the percentage acceptable grades increased with increasing spindle speed.

Table 1: Percentage grade of shaped specimens of *Gmelina arborea* from WEFZ

Location	Tree section	Surface grades	Spindle speed		
			4500 rpm	6000 rpm	10000 rpm
WEFZ	Top	Grade 1	-	6.7	-
		Grade 2	-	40.0	46.7
		Grade 3	93.3	53.3	53.3
		Grade 4	6.7	-	-
		Grade 5	-	-	-
		Grades 1&2	-	46.7	46.7
	Middle	Grade 1	-	-	-
		Grade 2	6.7	20.0	66.7
		Grade 3	80.0	80.0	33.3
		Grade 4	13.3	-	-
		Grade 5	-	-	-
		Grades 1&2	6.7	20.0	66.7
	Butt	Grade 1	-	-	6.7
		Grade 2	-	20.0	40.0
		Grade 3	86.7	80.0	53.3
		Grade 4	13.3	-	-
		Grade 5	-	-	-
		Grades 1&2	-	20.0	46.7

This means that the surface quality of the shaped *Gmelina arborea* wood was better with increasing spindle speed. It could be deduced from the result that spindle speed 10,000 or more would be most appropriate for shaping *Gmelina arborea* wood. This result confirms the observation made by Davis [12] that spindle speeds between 7200 rpm and 15000 rpm produce significant levels of acceptable grades.

Table 2 provides a summary of the shaping test for *Gmelina arborea* specimens obtained from DSDFZ. The top section produced the highest percentage of acceptable grade (100.0%) at 10000 rpm and the least (13.3%) at 4500 rpm. Same order of acceptable grade performance was obtained for the middle section. On the contrary, the butt section produced the highest percentage of acceptable grade (93.3%) with a spindle speed of 6000 rpm and least (40.0%) at 4500 rpm. On the whole the mean percentages of good and excellent shaped specimens obtained for the spindle speeds 4500 rpm, 6000 rpm and 10000 rpm were 22.2%, 71.1% and 86.7% respectively. This trend is similar to that obtained for the WEFZ which indicated that the surface quality of shaped

Gmelina arborea increased with increasing spindle speed. This implies that surface roughness decreases with increasing spindle speed as has been reported by Abdullah *et al*. [24].

Comparing the results from the two ecological zones and spindle speeds, the percentage of good and excellent samples produced from the DSDFZ was higher than that obtained from the WEFZ. This could be attributed to the different climatic conditions at the two ecological zones which could have influenced the physical properties of the two materials. The mean moisture content of the samples just before the test was 14% and 15% for WEFZ and DSDFZ respectively. Reports indicate that samples at lower moisture content have better machining qualities than at higher moisture content [19, 8, 12], indicating that samples from WEFZ should have performed better than those from DSDFZ but showed otherwise. This could mean that surface quality depends on moisture content to some extent and in this case shaping at 14% or below could generate more machining defects. Therefore samples from DSDFZ with moisture content 15% performed better than those from WEFZ.

Table 2: Percentage grade of shaped specimens of *Gmelina arborea* from DSDFZ

Location	**Tree section**	**Surface grades**	**Spindle speed**		
			4500rpm	**6000rpm**	**10000rpm**
DSDFZ	Top	Grade 1	-	33.3	26.7
		Grade 2	13.3	20.0	73.3
		Grade 3	86.7	46.7	-
		Grade 4	-	-	-
		Grade 5	-	-	-
		Grades 1&2	13.3	53.3	100.0
	Middle	Grade 1	-	20.0	20.0
		Grade 2	13.3	46.7	60.0
		Grade 3	80.0	33.3	20.0
		Grade 4	6.7	-	-
		Grade 5	-	-	-
		Grades 1&2	13.3	66.7	80.0
	Butt	Grade 1	13.3	26.7	20.0
		Grade 2	26.7	66.6	60.0
		Grade 3	60.0	6.7	20.0
		Grade 4	-	-	-
		Grade 5	-	-	-
		Grades 1&2	40.0	93.3	80.0

With respect to the effect of density and moisture content on the surface quality of shaped wood, the results obtained were contrary to that indicated by Dinwoodie [25] and Kollman and Cote [8]. Dinwoodie [25] and Kollman and Cote [8] reported that surface quality is dependent on the wood species and it increases with increasing density and decreasing moisture content and that timber of high moisture content does not machine well like that with lower moisture content due to high elasticity of the thin-walled cells under wet condition. On the contrary, Owusu and Ayarkwa [1] who conducted studies on the shaping qualities of Khaya and Kane reported that Khaya had better shaping quality than Kane even though their densities at 16% moisture content were 661 kg/m^3 and 750 kg/m^3 respectively. According to Owusu and Ayarkwa [1], the lower the density of a wood, the easier the wood is cut with a tool, hence a reason for the *Gmelina arborea* wood obtained from the DSDFZ recording a better surface quality than that of the WEFZ. The most common defect observed at the various directions of cut on the specimens was raised, chipped and fuzzy grains.

Table 3: ANOVA of effect of location, tree section and spindle speed on surface quality of shaped specimens

Source	**DF**	**ANOVA SS**	**Mean Square**	**F – Ratio**	**p-value**
Location	1	3.8142	3.8142	52.50	0.0001*
Tree section	2	0.1217	0.0608	0.84	0.4340†
Spindle speed	2	0.7708	2.3854	32.83	0.0001*
Location x TS	2	0.2321	0.1161	1.60	0.2045†
Location x SS	2	0.4260	0.2130	2.93	0.0552†
TS x SS	4	0.1975	0.0494	0.68	0.6067†
Loc x TS x SS	4	0.4397	0.1099	1.51	0.1991†
Error	238	17.2911	0.0727		

*Statistically significant at 0.05 level of significance; †Not statistically significant at 0.05 level of significance

Legend: TS = Tree section
SS = Spindle speed

Table 3 which indicates the ANOVA of the effect of ecological zone, tree section, spindle speed and their interaction on the surface quality of the shaped specimens shows that at 5% level of significance, ecological zone and spindle speed had significant effect on the quality of the shaped surface. This result is supported by the outcome of a study by Abdullah *et al*. [24], Addae-

Mensah and Ayarkwa [11] and Davis [12], which indicated that surface quality increases with increasing spindle speed to a maximum of 15000 rpm.

4. CONCLUSIONS

The study has shown that *Gmelina arborea* from the two ecological zones have good sanding and shaping characteristics. For the sanding test, grit size P80 was the best sandpaper for removing chipped and torn grain defects from the surface of *Gmelina arborea* lumber after planing. The performance of grit size P120 was limited and hence should not be used for elimination of chipped/torn grain defects. The ease of removal of the defects was best for the top section, followed by the middle section and the butt end for all samples extracted from the two ecological forest zones. The DSDFZ produced higher scratch-free percentage of surface quality compared to that of WEFZ. The major defects observed for the sanding operation were fuzzy and scratchy defects. Spindle speed 10000 rpm generated higher percentages and most acceptable shaping quality for specimen obtained from both ecological zones. Therefore spindle speed 10000 rpm is recommended for shaping *Gmelina arborea* timber grown in Ghana. Additionally, samples obtained from DSDFZ performed better using the three spindle speeds than those from WEFZ. The most common defects observed at the various directions of shaping on samples obtained from both ecological zones were raised, chipped and fuzzy grains. To ensure that comprehensive scientific information exists on *Gmelina arborea* grown in Ghana for its efficient utilisation it is recommended that studies be conducted on the mechanical and other utilization properties of the species. Finally, *Gmelina arborea* having exhibited better shaping and sanding qualities, indicates it to be a potential substitute for some traditional and over utilized timber species on the domestic timber market. This could reduce pressure on the dwindling natural timber resources, slow down the extinction rate of key timber species, keep the timber industry in business, support the policy on sustainable forest management and contribute to an increase in government revenue.

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REFERENCES

[1] Owusu FW, Ayarkwa J, Machining characteristics of *Khaya senegalensis* and *Anongeisus leiocarpus.* Ghana J. Forestry. 2011;27(2):97-111.

[2] Söğütlü C, Determination of the effect of surface roughness on the bonding strength of wooden materials. BioResources. 2017;12(1):1417-1429.

[3] Malkoçoðlu A, Machining properties and surface roughness of various wood species planed in different conditions. Building and Environment. 2007; 42(7):2562-2567

[4] Richter K, Feist WC, Knaebe MT, The effect of surface roughness on the performance of finishes. Part 1: roughness characterization and stain performance. Forest Products Journal. 1995;45(7/8):91-96.

[5] Sandak J, Negri M, Wood surface roughness-what is it. 17th International Wood Machining Seminar, Rosenheim, Germany. 2005.

[6] Taylor JB, Carrano AL, Lemaster RL, Quantification of process parameters in a wood sanding operation. Forestry Product Journal. 1999;49:41-46.

[7] Koch P, Wood machining processes. The Ronald Press Company, New York. 1964;530p

[8] Kollman FP, Cote WA, Principles of wood Science and Technology 1. Solid Wood. Springler-verlag. Berlin-Heidelberg, New York. 1968;451-551.

[9] Saloni DE, Lemaster RL, Jackson SD, Process monitoring evaluation and implementation for the wood abrasive machining process. Sensor. 2010;10(11):10401-10412.DOI: 10.3390/s101110401

[10] Bryze R, The College of Wood Finishing Knowledge- A Guide to the Business of Finishing Wood, RonBryze.com, Illinois, United States. 2006.

[11] Addae-Mensah AG, Ayarkwa J, Some machining qualities of selected lesser used timber species of Ghana. Ghana Journal of forestry.1998;6(8).

[12] Davis EM Machining and related characteristics of US hardwoods. United States Department of Agriculture, Technical Bulletin No. 1267. United States Forest Products Laboratory. 1962;1-39.

[13] Nwoboshi LC, Growth and biomass production of *Gmelina arborea* in conventional plantations in Ghana. Ghana Journal of Forestry. 1994;1:5-6.

[14] Akachukwu AE, Wood properties of *Gmelina arborea*Roxb and their Biological control. In IUFRO symposium on productivity and utilization of *Gmelina arborea* in West Africa. University of Ibadan, Nigeria, May 7-10, 1990.

[15] Mitchual SJ, Minkah MA, Owusu FW, Okai R Planing and Turning Characteristics of *Gmelina arborea* Grown in two Ecological Zones in Ghana. Advances in Research. 2018;14(2): 1-11. DOI: 10.9734/AIR/2018/39024

[16] American Society for Testing and Materials, Standard test methods for small clear specimens of timber, ASTM D 143-94. In: Annual Book of ASTM Standards, 2008. Section 4, Construction Vol. 04.10. West Philadelphia, PA, USA. 2007;20-52.

[17] American Society for Testing and Materials, Standard test methods for conducting machining tests of wood and wood-base materials, ASTM D 1666-87. In: Annual Book of ASTM Standards 2008. Section 4, Construction Vol. 04.10. West Philadelphia, PA, USA. 2004;201-219.

[18] European standard EN 13183–1: Moisture content of a piece of sawn timber. Determination by oven-dry method, BSI, London. 2002.

[19] Pinheiro C, Cleber de Sampaio AM, Amaral SS, Moisture Content and its Influence on the Roughness and Noise Emission during Wood Machining. Advanced Materials Research. 2015;1088:680-685.

[20] Benson HP, Raised, loosened, torn, chipped, and fuzzy grain in lumber. Forest Products Laboratory and Forest Service U. S. Department of Agriculture. Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin. Report No. 2044. 1955:22.

[21] Owusu FW, Ayarkwa J, Frimpong-Mensah K Sanding properties of seven Ghanaian lesser-used timber species. Ghana Journal of Forestry. 2012;28(2):1-14.

[22] Adam KA, Krampah E, Gmelina arborea Roxb. Ex Sm. In:Louppe, D., Oteng-Amoako, A.A. and Brink, M. (Editors). Plant Resources of Tropical Africa 7(1). PROTA Foundation, Wageningen, Netherlands / Backhuys Publishers, Leiden, Netherlands/CTA, Waheningen, Netherlands. 2008;291-296.

[23] Stewart HA, How to minimize fuzzy grain. Woodworking Network. 2009;5pp

[24] Abdullah AB, Chia LY and Samad Z, The effect of feed rate and cutting speed to surface roughness. Asian Journal of Scientific Research. 2008;1(1):12 -21.

[25] Dinwoodie JM, Timber, its Nature and Behaviour. Van Nostrand Reinhold Ltd., Berkshire. 1980;190pp.