

Effect of Age and Longitudinal Culm Section of Legi Bamboo (*Gigantochloa atter* (Hassk.) Kurz) on Its Properties as Furniture and Handicraft Materials

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Abstract

Legi bamboo (*Gigantochloa atter* (Hassk.) Kurz) is a common and commercially important bamboo species for furniture and craft material. The aims of this research were to investigate the optimum processing quality for furniture and craft materials of 3- and 4-year-old Legi bamboo in each culm section including processing properties and supporting information such as physical, mechanical, as well as bonding properties. The result showed that optimal processing properties of Legi bamboo had average sawing defect of 1.93% (very good); drilling defect of 26.68% (good); planing defect of 4.70% (very good); lathing defect of 7.95% (very good), and sanding defect of 2.14% (very good), considered as I – II class of processing. The results of this study indicate that the top section of 3-year-old Legi bamboo had the best physical, mechanical, and processing properties for its utilizations.

Keywords: culm height, craft, furniture, processing defect.

Introduction

Bamboo (*Gramineae*, sub-family *Bambusoideae*) is a commonly utilized tropical and sub-tropical lignocellulosic plant. It is able to live in mixed forest as a pure stand as well as cultured in plantation. Bamboo is favored for its fast growth and potential for future sustainable material, with harvest age ranged 2-5 years (Nath *et al.* 2009). In 2010, there is over 31.5 million hectares of bamboo stand or 0.8% of total area of forest in the world (Partey *et al.* 2017). *Gigantochloa atter* or Legi bamboo is a commercially important bamboo species in Indonesia. This bamboo species has been used as material for various uses such as food (shoots), handicraft, furniture, and construction material (Wahyudi 2013; Pandey *et al.* 2013). Bamboo is a versatile material that has also been processed further into various engineered products such as laminated bamboo and bamboo fiber (Imadi *et al.* 2014; Shah *et al.* 2018).

The properties of bamboo vary between age, culm height, and species. Bamboo is usually harvested at 2-5 years, but for some crafts such as bamboo cane work, utensils, and artwork require younger bamboo, usually just a few months old (Widyaningsih *et al.* 2020). Previous study by Wulandari (2019) reported that young *Dendrocalamus asper* (<2-year-old) showed weaker mechanical strength compared to mature (2-3-year-old) and old (>3-year-old) bamboo. Further, different properties and quality is also known to be varied between the culm height. In *Neosinocalamus affinis* bamboo, fiber proportion, specific gravity, vascular bundle density, as well as compression strength parallel to grain were reported to increase from bottom to top culm of the bamboo (Qi *et al.* 2014). In previous studies on other bamboo species (*Gigantochloa apus*, *G. atroviolacea*, and *D. asper*) found better

processing properties on the base section of its culm (Ahmad *et al.* 2014).

Several studies on the effect of age and culm section of bamboo has been done on several species (Ahmad *et al.* 2014; Qi *et al.* 2014, Wulandari 2019). However, there are still less information on *G. atter* (Nilansari 2014). The objective of this study was to investigate the effect of age and culm section on mechanical, physical, bonding and processing properties of *G. atter* grown in Yogyakarta, Indonesia.

Materials and Methods

Materials

Two age groups (3- and 4-year-old) Legi bamboo (*Gigantochloa atter* (Hassk.) Kurz) from Tlogoadi Village (175 m above sea level), Sleman Regency, Yogyakarta Province, Indonesia, were used as material. The bamboo culms were cut 10 cm above the ground. Each culm was cut to a length of 6 m leaving out the top part of bamboo culm (Ahmad *et al.* 2014). The bamboos were then cut at axial direction into three sections: base, middle, and top, with 2 m length in each section. The bamboos were then cut into each section of 30 cm, air dried, split, and further cut to sample sizes accordingly (Figure 1). The adhesive used was epoxy.

Physical, Mechanical, Bonding and Processing Properties

Processing properties were tested according to ASTM D-1666-64 (1985), while physical, mechanical, and bonding tests were referring to British Standard B.S.373 (1957). Moisture content (MC) and specific gravity (SG) samples were cut into 2 x 2 x thickness cm in size; width shrinkage

and volumetric shrinkage samples were cut into 2 x 4 x thickness cm. Each sample for mechanical properties testing hardness was cut into dimensions of 2 x 4 x thickness cm; compressive strength parallel to grain was tested with the dimensions of 2 x 8 x thickness cm; compressive strength perpendicular to the grain was tested with the dimensions of 2 x 6 x thickness cm. Sample for bonding quality test was performed in air dry condition and prepared with the dimension of 3.81 x 5.08 x thickness cm

by gluing together two unskinned bamboo strips. Each strip glued on one side then pressed for 72 hours. Further, whole bamboos were used for lathing test (30 cm length) while bamboo strips without the skin were used for sanding and planing tests (5 x 30 x thickness cm). Lastly, samples for sawing and drilling test have the dimensions of 5 x 30 x thickness cm (Figure 1-2). All tests were replicated three times.

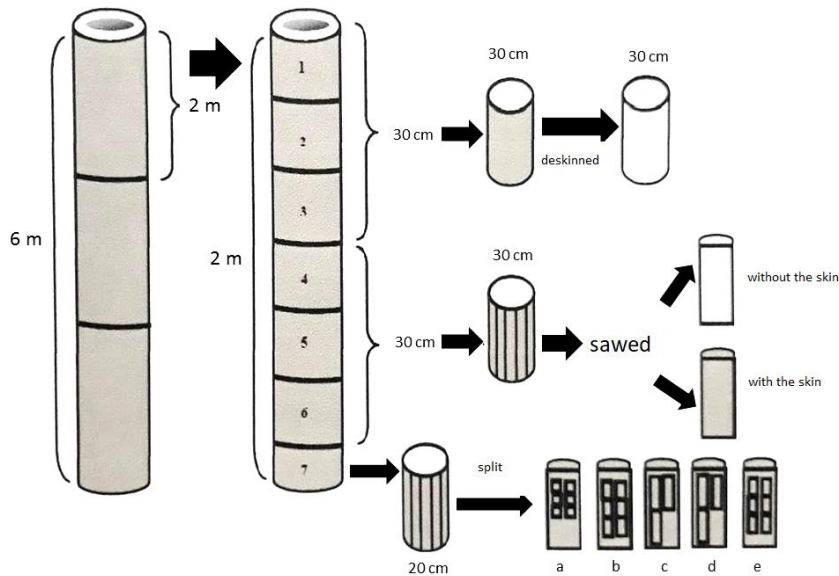


Figure 1. Sample preparation diagram

Note:

- 1-3 : whole bamboo without the skin for lathing test.
- 4-6 : bamboo strip without the skin for sanding and planing test; bamboo strip with the skin for sawing and drilling test.
- 7 : a. moisture content (MC) and SG samples (bamboo strip with the skin).
 b. shrinkage and hardness test (bamboo strip with the skin).
 c. compressive strength parallel to wood fiber (bamboo strip with the skin).
 d. compressive strength perpendicular to the grain (bamboo strip with the skin).
 e. bonding quality test (bamboo strip without the skin).

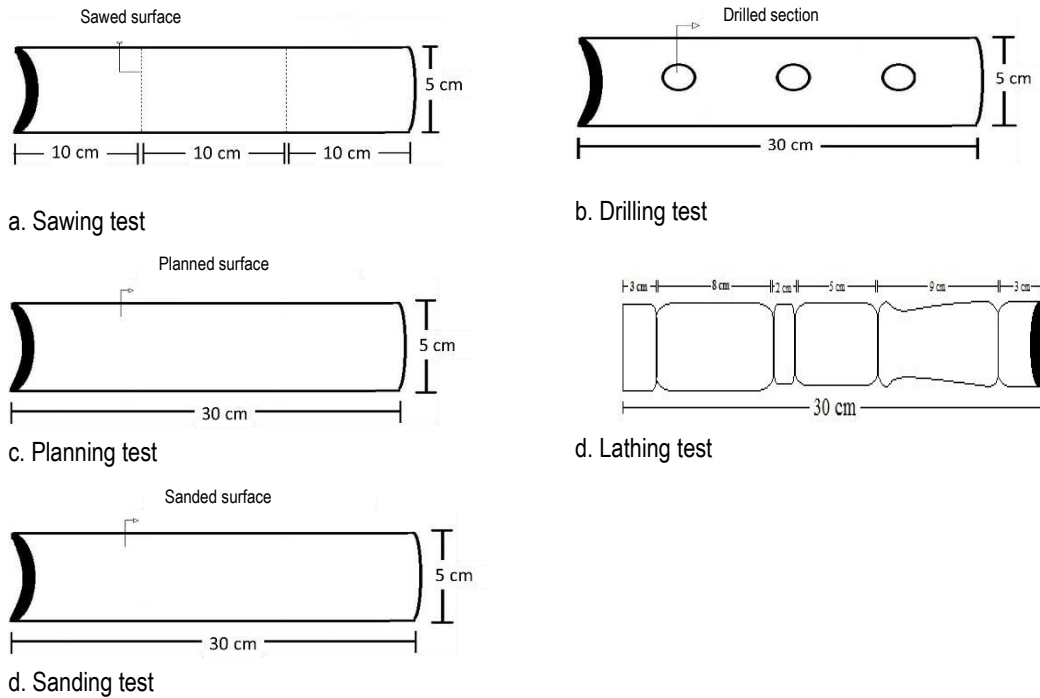


Figure 2. Processing properties test samples.

Data Analysis

Completely Randomized Design was used as experiment model with two factors: age (3-year-old and 4-year-old) and culm section (base, middle, and top). The data were analyzed with SPSS (IBM, USA) with F test in 5% and 1% confidence level and HSD (Honestly Significance Different) as post-test.

Results and Discussion

Physical Properties

The result of physical properties of Legi bamboo are showed in Table 1. Air dried moisture content varied from 12.10 - 13.40% with an average of 12.73%. This moisture content was sufficient for the equilibrium moisture content of 12 - 14% (humidity 60%) in Yogyakarta, Indonesia (Kasmudjo 2012). The moisture content was also sufficient for mechanical properties testing according to ISO 22157 (2004). The results showed that the average air dried moisture content of 3-year-old bamboo (12.29%) was lower compared to that of 4-year-old bamboo (13.18%). Further ANOVA test showed that the age factor between bamboos gave significant difference. This finding is in agreement with previous study by Falayi and Soyoye (2014) on *Phyllostachys pubescens* bamboo where 3-year-old bamboo

showed lower moisture content (37.13%) compared to 5-year-old (46.20%).

The average specific gravity value of Legi bamboo in 3-year-old (0.77) and 4-year-old (0.73) showed similar value in all culm sections. In general, top section showed the highest average specific gravity followed by middle and base section where this effect was more apparent in 4-year-old bamboo. Previous study by Qi *et al.* (2014) showed similar results where specific gravity value increase as the culm height increase in *Neosinocalamus affinis* bamboo. This effect might be showed due to the increase of cell wall thickness as the height increase in bamboo.

The average width and volumetric shrinkage on 3-year-old bamboo showed higher value compared to 4-year-old whereas 3-year-old showed width and volumetric shrinkage of 0.74% and 16.98%, respectively, and 4-year-old showed width and volumetric shrinkage of 0.59% and 16.52%, respectively (Table 1). The results showed that generally high specific gravity had high volumetric shrinkage but low width shrinkage, which especially apparent in 3-year-old bamboo. These results differ from previous studies by Qi *et al.* (2014) and Kamruzzaman *et al.* (2008), that might be caused by lower vascular bundles and other microstructure factors such as the stiffness perpendicular to the wall of Legi bamboo cells (Schulgasser and Witztum 2015).

Table 1. Physical, mechanical, and bonding properties of Legi bamboo.

No.	Sample	Physical				Mechanical			Bonding quality	
		Air dried moisture content (%)	Specific gravity	Shrinkage (%)		Hardness (kg cm ⁻²)	Compressive strength perpendicular to grain (kg cm ⁻²)	Compressive strength parallel to grain (kg cm ⁻²)	Bonding strength (kg cm ⁻²)	Bamboo failure (%)
				Width	Volumetric					
1	3-year-old, base section	12.28	0.74	0.76	14.96	96.82	166.00	494.32	53.35	21.32
2	3-year-old, middle section	12.10	0.75	0.78	15.82	112.10	126.05	570.65	33.24	47.69
3	3-year-old, top section	12.49	0.83	0.67	20.17	135.88	145.25	418.50	33.59	64.89
	Average	12.29	0.77	0.74	16.98	114.93	145.77	494.49	40.06	61.30
4	4-year-old, base section	13.40	0.73	0.50	18.55	86.62	171.90	443.80	33.49	61.98
5	4-year-old, middle section	13.18	0.75	0.58	15.47	105.31	120.91	435.66	37.84	72.95
6	4-year-old, top section	12.96	0.71	0.28	15.52	70.21	88.30	435.96	43.10	87.33
	Average	13.18	0.73	0.45	16.52	87.38	127.04	438.47	38.14	74.09
	Total average	12.73	0.75	0.59	16.75	101.16	136.40	466.48	39.10	67.69

Table 2. ANOVA result on the effect of age and culm section on the properties of Legi bamboo

Factor	df	F								
		Air dried moisture content	Specific gravity	Width shrinkage	Volumetric shrinkage	Hardness	compressive strength parallel to grain	compressive strength perpendicular to grain	Bonding strength	Bamboo failure
Age	1	9.02739 *	5.440129*	4.515755 ns	0.983556 ns	3.879871 ns	5.626462*	0.348594 ns	0.412763 ns	6.843677 *
Culm section	2	0.145461 ns	0.877023 ns	1.045822 ns	7.817549**	0.509654 ns	3.458118 ns	1.067217 ns	2.380209 ns	3.252048 ns
Interaction between factors	2	0.52097 ns	4.003236*	0.363967 ns	27.98381**	1.861655 ns	3.4864118 ns	0.37283 ns	9.238044 **	4.719 *

Note: ns = not significant; * = significant; ** = very significant

Mechanical and Bonding Properties

Mechanical and bonding properties of Legi bamboo are shown in Table 1. Hardness, perpendicular and parallel compression strength of Legi bamboo between age 3 and 4 were not significantly different (Table 2). Average value of Legi bamboo hardness was 101.16 kg cm⁻² (strength class IV); compression strength parallel to grain of 466.48 kg cm⁻² (strength class II); and compression strength perpendicular to grain of 88.30 - 171.90 kg cm⁻² (strength class V). Between culm sections, generally middle section had the highest hardness, where top section had the highest compression strength. Similar results were reported by Correal and Arbelaez (2010) on *Guadua angustifolia* bamboo, where middle and top section of the bamboo had the highest mechanical strength compared to base section. Between ages, 3-year-old bamboo had higher compression

strength perpendicular to grain compared to 4-year-old, which was also in line with the specific gravity value. This results were also in agreement with the previous study carried out by Falayi and Soyoye (2014) where MOR and MOE of the bamboo were highly related with specific gravity.

The average bonding strength of Legi bamboo in this study was 39.10 kg cm⁻² with 67.69% bamboo failure. Interaction between age and culm section factors showed significant difference with ANOVA (Table 1 and 2). Bonding strength of 4-year-old bamboo was lower than 3-year-old bamboo. Between culm section, base had the highest bonding strength, followed by top and then middle section. Further, bamboo failure of 4-year-old bamboo showed higher value compared to 3-year-old. Between culm section,

top had the highest bamboo failure, followed by base and then middle.

Processing Properties

The average processing defect value of Legi bamboo are showed in Table 3. ANOVA test showed significant different in the interaction between factor on sawing defect and significant difference in age factor in lathing defect (Table 4). Legi bamboo processing in this study showed sawing defect of 11.04% (very good); drilling 26.68% (good); planning 4.69% (very good); lathing 7.95% (very good) and sanding 2.14% (very good) and overall classified as processing class I – II. Furthermore, the most common defect on sawing and planning were found to be raised grain defect. In drilling, torn grain defect was the most common. In

lathing and sanding, fuzzy grain is the most common defect. Processing properties of Legi bamboo showed the highest defect in lathing in both ages (5.09% and 10.81% for 3-year-old and 4-year-old, respectively). In both ages, 4-year-old generally showed higher processing defects except for drilling and sanding defect which was higher in 3-year-old. This result might be caused by the thickness of cell wall which is higher in older bamboo (Schulgasser and Witzum 2015). Compared to previous research by Ahmad *et al.* (2014), Legi bamboo in this study showed better processing properties than Apus (*Gigantochloa apus*), Tutul (*Bambusa vulgaris* Schrad), and Wulung (*Gigantochloa vercillata* Munro) bamboo except for the sanding property.

Table 3. Processing properties of Legi bamboo.

No.	Factor	Defect (%)					Average (%)
		Sawing	Drilling	Planning	Lathing	Sanding	
1	3-year-old, base section	0.81	32.38	6.90	6.00	3.50	13.75
2	3-year-old, middle section	0.00	23.78	3.50	5.01	1.70	8.39
3	3-year-old, top section	3.46	24.33	1.62	4.28	1.54	7.20
	Average		26.83	4.00	5.09	2.25	9.78
4	4-year-old, base section	0.86	27.06	10.10	12.36	2.11	12.71
5	4-year-old, middle section	6.43	25.68	2.69	13.23	2.66	11.21
6	4-year-old, top section	0.00	26.85	3.36	6.84	1.32	9.75
	Average		26.53	5.39	10.81	2.03	11.22
	Total average		26.69	4.37	8.83	1.68	10.49

Table 4. ANOVA result on the effect of age and culm section on processing defects of Legi bamboo.

Factor	Df	F				
		Sawing	Drilling	Planning	Lathing	Sanding
Age	1	0.339912 ns	0.017709 ns	0.472 ns	9.764 **	0.22317 ns
Culm section	2	0.354265 ns	0.854299 ns	3.601 ns	1.709 ns	0.546441 ns
Interaction between factors	2	15.09317 **	0.614808 ns	0.339 ns	0.827 ns	0.218785 ns

Note: ns = not significant; * = significant; ** = very significant

Conclusions

Interaction of age and culm section had significantly different values in specific gravity, volumetric shrinkage, bonding strength, bamboo failure, and sawing defect values. Moisture content, specific gravity, compressive strength parallel to grain, and lathing defect values are significantly influenced by age of bamboo. Moreover, culm section had significantly different values in volumetric shrinkage only. The 3-year-old bamboo had significantly lower air-dried moisture content and higher compressive strength parallel to grain. Further, the highest specific gravity, volumetric shrinkage, and bamboo failure was showed by the top section of 3-year-old bamboo, while the highest bonding strength was showed by the base section of 3-year-old bamboo. Width shrinkage and compressive strength perpendicular to grain showed similar value in all samples. In processing properties, the highest sawing defect was showed by the middle section of 4-year-old bamboo, while lathing defect was higher in 4-year-old bamboo. Drilling,

planning, and sanding defect were similar in all ages and stem sections of the samples. Legi bamboo in this study can be classified as processing class I-II. These results indicate that 3-year-old bamboo, especially at the top section, showed the best physical, mechanical, and processing properties for its utilizations.

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