Comparison of fiber characteristic and sound intensity of bamboo culms used as sound tube in angklung gubrag in Cipining Village, Bogor

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Abstract. Angklung Gubrag is an ancient angklung that originated from Cipining Village, Bogor. The community of Cipining believes that *Gigantochloa pseudoarundinacea* is preferred as angklung’s raw material compared to *Gigantochloa atroviolacea*. This study aimed to compare the fiber characteristic and sound intensity of *G. atroviolacea* and *G. pseudoarundinacea* culms as raw material of Angklung Gubrag. The study was conducted between February to December 2016. Methods used to compare the fiber characteristic of bamboo culms was maceration, while sound intensity was measured by sound level meter. Maceration samples were observed under microscope at Bio Imaging Laboratory, Department of Biology, Universitas Indonesia. The results showed that sound tube of Angklung Gubrag *G. atroviolacea* have lower sound intensity than Angklung Gubrag *G. pseudoarundinacea*. Fibre length of *G. atroviolacea* is longer that *G. pseudoarundinacea*. We also found that the fiber diameter, lumen diameter, and fiber wall thickness of *G. pseudoarundinacea* sound tube at third note was higher than *G. atroviolacea* sound tube at the same note. These showed similar results with the perception of Cipining community in choosing *G. pseudoarundinacea* as a raw material of Angklung Gubrag.

Keywords: Angklung Gubrag, fibers, *Gigantochloa atroviolacea*, *Gigantochloa pseudoarundinacea*, sound intensity

1. Introduction
About 143 species of bamboo are found in Indonesia, and 60 of them grow in Java [1]. Bamboo culms are hollow and segmented, and the cells are lignified which makes bamboo culms is hard and woody [2, 3]. That characteristic makes bamboo become an alternative for wood in building construction and also used for musical instruments [4, 5]. Several musical instruments made from bamboo including rengkong, zither and angklung which are typical of West Java [6].

Angklung is a musical instrument which has only two to four sound tube which produce sound from clash between sound tube and its own frame [7, 8]. Angklung is usually played for ritual activities and entertainment, especially in West Java. There are two groups of Angklung in West Java, the ancient angklung and modern angklung. The difference between those two are showed that the ancient angklung have pentatonic scales, while modern angklung have diatonic scales. Ancient Angklung consists of various types, including Angklung Dogdog Lojor, Angklung Badeng and Angklung Gubrag [9, 10].
Angklung Gubrag is originally comes from Kampung Cipining, Argapura Village, Bogor Regency. Based on the preliminary survey, Angklung Gubrag is much larger than modern angklung. Angklung Gubrag has only three tone scales called gancling, kurulung, and engklok, which gancling was the smallest angklung (first tone) and having higher pitch. In addition, the species of bamboo that used as it material is different with modern angklung. Generally, modern angklung is made from black bamboo (Gigantochloa atroviolacea Widjaja) [9], while the Angklung Gubrag is made from bambu gombong (Gigantochloa pseudoarundinacea (Steud.) [11].

Macroscopic and microscopic structure made the basic characteristic of bamboo as a raw material of angklung [12]. The macroscopic structures of bamboo include diameter, wall thickness, and length of segments on bamboo culms. Meanwhile, the microscopic structure of bamboo are exodermis (the outermost layer of the surface), parenchymal cells and vascular bundles including fibers [13]. Research on the basic characteristics of bamboo through anatomical observation has been made by Nuriyatin (2000), by examining five species of bamboo which two of them are G. atroviolacea and G. pseudoarundinacea. Nuriyatin (2000) showed that G. atroviolacea is the most excellent raw material for musical instruments, due to the distribution of vascular densities which are prevalent in G. atroviolacea than other bamboo species. Vascular densities are supports good sound vibrations on bamboo culms [14]. However, it has not done an analysis about the relationship between bamboo fiber dimensions and sound quality that produce by bamboo musical instruments, especially angklung.

In contrast to the results of Nuriyatin’s research (2000), the inhabitant of Cipining contends that G. pseudoarundinacea is more appropriate as raw materials than G. atroviolacea as Angklung Gubrag [14] as they are more robust, durable and produces a loud sound. Because of these differences in the perception, scientific research must be done through an approach of comparative anatomy characters of G. atroviolacea and G. pseudoarundinacea which affect their election as raw materials of Angklung Gubrag. Therefore, this the objective of this study is to compare the fiber characteristic and sound of G. atroviolacea and G. pseudoarundinacea as raw materials of Angklung Gubrag. The final results of this study are expected to be used to understand the reasons for selection of bamboo for Angklung Gubrag and their utilization as raw material for angklung.

2. Materials and method
Sampling was carried out from Kampung Cipining, Argapura Village, District Cigudeg, Bogor, West Java. Samples were taken from randomly by the manufacturer's recommendations for Angklung Gubrag. Sampling point was at the coordinates 6°27.810’S, 106°31.788’T for G. atroviolacea and 6°27.676’S, 106°31.64’T for G. pseudoarundinacea. Maceration was carried out in the Plant Development Laboratory, and fiber observations was carried out in the Laboratory of Bio Imaging Department of Biology, Faculty of Mathematics and Natural Sciences, University of Indonesia, Depok. The study was conducted over 6 months, starting from May to October 2016.

The tools that used are scissors, knife, camera, measuring meter, stationery, sample bottles, bamboo identification book (Identikit Jenis-jenis Bambu di Pulau Jawa, Widjaja 2001), sound level meter (3M TM SoundPro SE/DL Series), laptop, beaker glass, vials tube, hot plate (Multi-Block Heater Lab-Line 2056-1), ruler, razor blades, tweezers, pipette, petri dish, glass slide, cover glass, and microscope (Leica DM500) Materials used are one culmof. G. atroviolacea (black bamboo), one culm of G. pseudoarundinacea (bamboo gombong), plastic samples, labels, tissues, formalin (Merck), glacial acetic acid (Merck), glycerin (Merck), distilled water, safranin (Merck), entelan (Merck), KOH 20 % nitric acid 20 % and chromic acid 20 % [Merck], alcohol 30 %, 50 % alcohol, 70 % alcohol, 80 % alcohol, 90 % alcohol, 95 % alcohol, 100 % alcohol and xilol (AnalaR).

Bamboo culms that chosen by the manufacturer was measured by its length, age, thickness, diameter and the portion that used for sound tube. Bamboo culms then were cut into appropriate size for angklung sound tube, the smallest sound tube for the first tone and third tone, respectively one piece for each Angklung Gubrag G. atroviolacea and G. pseudoarundinacea. Afterwards, the length of tube sound, the
sound tube diameter, wall thickness and length of the tongue was measured. Sound intensity was measured using sound level meter (3M TM SoundPro SE/DL Series) respectively 10 strokes at 3 repetitions for each sound tube.

Samples of sound tube were cut by half size of a matchstick for maceration, then the samples were inserted into the vial bottle. We boiled the samples in 20 % KOH for 3–5 minutes, then washed in running water for 15 minutes. Samples were then put into a mixed solution of nitric acid 20 %: 20 % chromic acid (1:1) for 2–3 hours while incubated at 60° C. When the samples became soft, then the samples were washed again in running water for 20 minutes. After that, dehydration was conducted using alcohol-rise (alcohol 30 %, 50 %, 70 %, 80 %, 90 %, 95 %, 100 %) alcohol-xilol, and xilol, then stained with safranin. Pieces that have been softened then taken a bit and placed on a glass slide, later separated using tweezer [15]. Preparations were spilled by entelan and closed by cover glass. 50 pieces of random fiber cells was chosen to observed and measured under a microscope.

3. Results and discussion
Bamboo culms that recommended by the angklung manufacturer was G. atroviolacea culms that has not changed color to black-purple, about 1 year old, and within 4.14 m from ground level. G. pseudoarundinacea culms that selected was about 1 year old, has not yet appeared green and yellow lines on a reed, and within 2.3 m of the groundlevel.

The results macroscopic measurements in table 1 shows that Angklung Gubrag sound tube that made from G. atroviolacea for first tone was nearly the same as sound tube that made from G. pseudoarundinacea, while sound tube that made from G. atroviolacea for third tone was shorter than sound tube that made from G. pseudoarundinacea. Our results also suggested that the wall thickness of G. atroviolacea sound tube for the first and third tone was thinner than G. pseudoarundinacea sound tube. The tongue length of G. atroviolacea sound tube for first tone is shorter than the tongue length of G. pseudoarundinacea sound tube for first tone, while the tongue length of G. atroviolacea sound tube for third tone is longer than the tongue length of G. pseudoarundinacea sound tube for third tone.

Based on the results of sound intensity measurements in table 2, sound tube from G. atroviolacea has lower sound intensity than the sound tube from G. pseudoarundinacea. Higher pitch frequency that produced by sound tube on angklung influenced by the shorter length of sound tube and tongue of sound tube [16]. The irregular incerase patterns of tongue length from that two types of sound tubes can be caused by tuning process. Tuning process aims to adjust the tone, so that the increasing pattern arised irregular [17]. Culm wall of G. pseudoarundinacea that used as a sound tube was thicker than G. atroviolacea. Thicker culm wall will absorb higher sound waves than reflect it [18]. Differences in sound intensity of Angklung Gubrag can be influenced by sensitivity of listener while receiving frequency of sound [19] and the distance from the source of sound [17]. In this case, the Angklung Gubrag manufacturer rely on hearing and his feeling to determine the right tone when creating a sound tube for angklung, that caused differences sound intensity of Angklung Gubrag.

Moreover, these differences can be caused by different strength given when angklung was vibrated to be measured too [17].

| Table 1. Sound tubes macroscopic measurements. |
|-----------------------------------------------|
| Category         | 1st tone  |           | 3rd tone  |           |
|                  | G. atroviolacea | G. pseudoarundinacea | G. atroviolacea | G. pseudoarundinacea |
| Sound tube length (cm) | 68        | 67.6      | 76.4      | 78.1       |
| Diameter (cm)        | 3.9       | 5.2       | 6.9       | 6.4        |
| Sound tube thickness (cm) | 0.4       | 0.6       | 0.7       | 0.75       |
| Tongue length (cm)   | 41.2      | 42        | 38.9      | 38.6       |
There were no differences between fiber cells form of *G. atroviolacea* and *G. pseudoarundinacea* based on figure 1. The fiber cells were observed in the form of long-shaped cells with tapered ends [20]. Such cells have thick cell walls with small lumen diameter, caused by lignification that occurs in fiber cells [20-22]. The thickening of the fiber cell wall will increase at the age of 1–3 years, then become stable. Cell wall thickening influenced by accumulation and maturation of the secondary cell wall because of lamellae disposition on the cell wall fibers [23].

Based on the measurement results of fiber dimensions in table 3, the average ratio of fiber length from *G. atroviolacea* sound tube was higher than the average ratio of fiber length from *G. pseudoarundinacea*. Range of *G. atroviolacea* average fiber length is 2.4 to 3.6 mm, while range of *G. pseudoarundinacea* average fiber length is 2.5 to 2.7 mm. Dransfield and Widjaja stated that *G. atroviolacea* fiber length ranges at 3.6 mm, while *G. pseudoarundinacea* has a fiber length from 2.75 to 3.27 mm. This difference could be due to random position of maceration from bamboo culm’s section. Based on the literature, fiber cells on the outside of bamboo culms will be longer than fibers that located on the inner part of bamboo culms [20]. Also, fiber cells will be longer in the middle segment while shorter around the nodes of bamboo. Bamboo fiber elongation would be optimal at the age of 1 year [23].

The length of fiber cell can be a decisive factor in the mechanical strength of bamboo [25]. Long fiber cells can also affect the rapid propagation of acoustic waves in materials made from bamboo [26]. Based on the literature, sound tube that made from *G. atroviolacea* should have been able to produce higher sound intensity sound tube that made from *G. pseudoarundinacea*.

**Table 2.** Sound intensity measurements of sound tubes.

| Tone  | *G. atroviolacea* | *G. pseudoarundinacea* |
|-------|-------------------|------------------------|
| 1<sup>st</sup> | 78.36 dB | 79.14 dB |
| 3<sup>rd</sup> | 84.64 dB | 85.71 dB |

**Figure 1.** Fiber cells (10x40 magnification) from *G. atroviolacea* and *G. pseudoarundinacea* sound tube(a) lumen diameter, (b) fiber diameter, (l) lumen (ds) fiber wall
Table 3. *G. atroviolacea* and *G. pseudoarundinacea* fiber dimensions.

| Category                  | 1<sup>st</sup> tone | 3<sup>rd</sup> tone |
|---------------------------|----------------------|---------------------|
| *G. atroviolacea*         | 2.462                | 3.613               |
| *G. pseudoarundinacea*    | 2.440                | 2.752               |
| Fiber length (mm)         | 20.82                | 15.4                |
| Fiber diameter (μm)       | 17.85                | 16.66               |
| Lumen diameter (μm)       | 4.09                 | 1.9                 |
| Fiber wall thickness (μm) | 3.53                 | 2.7                 |

Comparison of the average fiber diameter shows the sound tube of first tone from *G. atroviolacea* had wider fiber diameter than first tone sound tube from *G. pseudoarundinacea*, while the third tone sound tube from *G. atroviolacea* had narrower fiber diameter than third tone sound tube from *G. pseudoarundinacea*. Fiber wall thickness of first tone sound tube from *G. atroviolacea* had thicker fiber wall than first tone sound tube from *G. pseudoarundinacea*, while the third tone sound tube from *G. atroviolacea* had thinner fiber wall than third tone sound tube from *G. pseudoarundinacea*. Lumen diameter of first tone sound tube from *G. atroviolacea* had wider lumen diameter than first tone sound tube from *G. pseudoarundinacea*, while the third tone sound tube from *G. atroviolacea* had narrower lumen diameter than third tone sound tube from *G. pseudoarundinacea*. Based on Dransfield and Widjaja [24], *G. atroviolacea* fiber diameter was about 25.9 μm, lumen diameter about 16.8 μm and fiber wall thickness about 4.5 μm, while the fiber diameter of *G. pseudoarundinacea* around 38 μm, lumen diameter around 5.6 μm and fiber wall thickness about 6.2 μm [14]. Difference size between results and literature may be due to differences in growth rate factor where the samples taken, including soil and climatic conditions [23, 29].

The sound propagation in the acoustic material made from bamboo is usually affected by fiber diameter, lumen diameter and fiber cell wall thickness. Good propagation of sound waves happens on the wide fiber diameters [27] and low cell wall permeability [26]. Bamboo fiber cells were lignified so that the cell walls are thicker and have more than one layer [22, 28]. That condition can cause low permeability on fiber cells that could be expected to deliver good sound waves [26]. Fiber diameter, lumen diameter and fiber cell wall thickness of third tone sound tube made from *G. pseudoarundinacea* affect its high sound intensity production. Because there is no correlation based on the comparison measurement of fiber diameter, lumen diameter and wall thickness of fiber cells in the sound tube of *G. atroviolacea* and *G. pseudoarundinacea*, then the two species has the potential to produce good sound quality based on the designation to be used as a high or low pitch tone on Angklung Gubrag. [26].

4. Conclusion

Sound intensity of *G. atroviolacea* sound tube is lower than *G. pseudoarundinacea* sound tube. The longer fiber cells in *G. atroviolacea* might have an effect on the high-intensity sound production of the sound tube. Cipining society make choices based on their feelings and different perception of sound, because their opinion cannot yet be proven scientifically through anatomical approach, which is fiber dimensions. Maceration needs to be done from axial and radial parts of the *G. atroviolacea* and *G. pseudoarundinacea* culms to obtain more comprehensive fiber dimensions analysis that affect good sound quality of Angklung Gubrag.

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