Influence of Site on Streak Patterns and Several Physical Properties of *Diospyros celebica* Bakh.

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**Abstract.** Ebony has a beautiful heartwood with black and brown streaks alternately. Each site has various streak pattern in which the industry classified it into two streak types namely *batang macis* (BM) and *sarang laba-laba/ bendera* (SL). This research was conducted to investigate the influence of site on streak patterns and several physical properties of the heartwood of ebony. Ebony from Parigi has BM streaks pattern and meet the grade B-A, meanwhile ebony from Poso has SL streaks pattern, qualified for grade C only. On the basis of t-test, only L* (lightness-darkness) was differed between the two streak patterns, while wood density and initial moisture content were not differed significantly. The BM streaks pattern has a darker of heartwood color, higher density but lower initial moisture content.

1. Introduction  
Ebony (*Diospyros celebica* Bakh.) is an endemic species of Sulawesi [1]. Ebony has a beautiful heartwood, displayed series of axial and alternating black and brown streakes. The streak pattern determines the quality of ebony especially for exports to Asian countries. Ebony exporters in South Sulawesi and Central Sulawesi have their own standards related to the streak pattern. Thin and parallel black streaks with almost the similar interval are considered to be the highest quality. In contrast, wide black streaks, varying thicknesses and irregular intervals have lower quality. In the realm of ebony industry, there is a type of *batang macis* (BM, matchstick), an ebony with thin, similar of width, and parallel black streak and *sarang laba-laba* (SL, spider web) for spaced and disorganized streak. Standar Nasional Indonesia 01-2028-1990 concerning processed ebony wood [2], does not specify the requirements of wood streaks but only requires straight and parallel streaks in each sortimen. Ebony wood is exported in the form of chopsticks, butsudan and boards sortimen.

The streak pattern is thought to be caused by site. Ebony in natural habitat produces different streaks [3-6]. Ebony BM has only been obtained in Donggala and Parigi Moutong Districts, Central Sulawesi. Outside these areas generally produce SL streaks. Previous researchers [7-8] presume that the width and color of the lines/streaks and the shape of the heartwood in the stems may be influenced by the site.

The influence of the site on streak patterns and the physical properties of the heartwood of ebony are unknown. Hence, the purpose of this study was to observe streak patterns, heartwood color, initial moisture content and the density of ebony BM and SL heartwood that grows at different sites.

2. Research Methods  
Ebony BM samples were taken from Sausu, Parigi Moutong District, coordinates 01° 04 '055 "S. latitude 120° 31' 687" E longitude and ebony SL in Towu, Poso District at 01° 19 '109 " S latitude 120° 36' 354" E longitude, Central Sulawesi Province. Two trees were collected from each site with an average diameter of 40 cm.

Wood samples were taken at the base of the tree in the form of disks as thick as 5 cm. The research procedure was as follows:

- To observe the streak pattern, the disks were sawn in quarter sawn trough the pith. In this study, the determination of quality is only focused on the streak pattern, while the length,
width and thickness of the specimen are ignored. Determination of the quality of the wood streak is based on the standards used by the ebony wood industry in Palu and Makassar. Quality A and B are classified as ebony BM. The standard used is based on visual observations (Figure 1).

![Figure 1. Classification of three grades of streak quality (class A, B and C, size 7 cm wide) (source of wood: PT. Saudara Indah Jaya Palu).](image)

- Wood color index measurement was carried out on air dry heartwood powder with NF333 spectrocolorimeter. The system used is CIEXYZ * a * b with 3 repetitions [9].
- Wood samples for measuring density and green/initial moisture content have sizes 2 x 2 x 2.5 cm (radial x tangential x longitudinal direction) using ISO standards [10]. The specific gravity was measured based on the oven dry weight and the oven dry volume. Procedure for measuring specific gravity and moisture content was based on SNI 03-6847 [11] and SNI 03-6850 [12].
- The influence of site on color index, initial moisture content and specific gravity were analyzed by independent t-test.

3. Result and discussion

Ebony has three wood zones i.e. sapwood, intermediate and heartwood. The intermediate zone is a transition zone from sapwood to heartwood and becomes a place for the synthesis of various chemical components to form a heartwood [13]. Intermediate wood has a thickness of 1-7 cm. Ebony BM has a thicker intermediate zone, while its sapwood is thinner than SL. The intermediate zone of ebony SL has the same thickness with ebony from Maros with 2-5 cm wide [14]. Intermediate zone is a formative stage of *D. celebica* which is not found in other Diospyros genus [15].

The colour of sapwood after being felled was cream to reddish brown, while the intermediate zone was reddish, and darker compared to sapwood. Ebony SL color was brighter than ebony BM (Figure 2). After drying in the room temperature, the color of both strike patterns were similar.

Ebony SL had a thickness of irregular black streaks between 1- 5 mm alternated with light brown streaks with a width of 4-15 mm. The number of black streaks was 17 per 8 cm. Ebony BM had a thin black streaks of 1 mm with light brown streaks 2-4 mm alternate regularly. The number of black streaks reached 28 strips in 7 cm (Figure 1). Based on local industry standards, ebony BM classified as grade B-A, while ebony SL classified as grade C. The interval between the black streaks (width of brown streaks) of *D. celebica* from Maros was 2-5 mm [15]. The better streaks quality are produced in drier agro-climate zones regions such as Donggala and Parigi Moutong. This requires further research [5]. The ebony industry acquires ebony BM from Domsol, Donggala District and Kasimbar and Sausu,
Parigi Moutong District which have agroclimate zones E1 and E2 according to Oldeman and Syarifuddin Classification [16].

![Figure 2. Fresh cut color and streaks pattern of BM (A) and SL(B).](image)

The color and streak pattern of heartwood is considered in processing of ebony. Darker heartwood, smooth and dense black streaks and thin brown streaks (ebony BM) are preferred as raw materials for furniture including butsudan, while ebony which has a brighter, wider black streaks and brown streaks (ebony SL), suitable for crafts and carvings. Ebony which has regular and smooth black streaks is preferred by consumers in Japan and China, while ebony which has thick and rare black streaks or wide brown streaks is preferred by consumers in Europe [7].

The results of color observations with CIELab system on air dried samples were shown in Table 1. The average brightness index (L*) is 14.07 ± 1.80, redness (a*) 7.59 ± 0.79, yellowish (b*) 11.75 ± 0.96, chromium (C) 13.99 ± 1.21 and hue (h) 13.95 ± 1.11. The t-test results (Table 2) showed that only the L* parameter was significantly different, while the other parameters were not significantly different between the both streak types. The color of the ebony SL wood was brighter, because the proportion of brown strip on the ebony SL was higher than the BM heartwood.

**Table 1. Average of color index, moisture content and specific gravity.**

| Site | L*    | a*    | b*    | C    | H    | Initial Moisture Content | Specific Gravity |
|------|-------|-------|-------|------|------|-------------------------|-----------------|
| BM   | 12.58 | 7.28  | 11.67 | 13.76| 13.94| 43.74                   | 1.02            |
| SL   | 15.57 | 7.91  | 11.83 | 14.23| 13.96| 46.11                   | 0.99            |
| Total| 14.07 | 7.59  | 11.75 | 13.99| 13.95| 45.03                   | 1.00            |

**Table 2. Significance value for t-test (two-way) of color index, moisture content and specific gravity.**

| Source | L*    | a*    | b*    | C    | H    | Initial Moisture Content | Specific Gravity |
|--------|-------|-------|-------|------|------|-------------------------|-----------------|
| Site   | 0.042*| 0.538 | 0.914 | 0.777| 0.990| 0.240                   | 0.083           |

Remarks: Significance value <0.05, significantly different at α 0.05

The difference of wood color in *Acacia mangium* was related to extractive and phenolics contents. The lightness (L*) increased with decreasing phenolics contents. These means that darker color will be present in heartwood when higher phenolics contents is present [17]. Ebony BM has 12.96% and 13.15% of ethanol-toluene extraction and hot water extractive respectively, higher than ebony SL, 11.71% and 12.66% respectively [18]. In teak wood, the color index is more influenced by the site
compared to wood age and climate. Smaller yellowish index (b *) (darker color) was associated with dry climate, deeper and more fertile soil [17, 19, 20].

The average of specific gravity of ebony was 1.00 ± 0.02. Specific gravity of ebony BM was 1.02 ± 0.02, was not significantly different but higher than ebony SL 0.99 ± 0.03 (Table 1). This specific gravity is slightly lower than previous research [21], which gained specific gravity 1.09 (1.01-1.27), but higher than ebony from Mangkutana, East Luwu, South Sulawesi and Donggala, Central Sulawesi 0.92 and 0.98 respectively [4,22].

The site had no significant effect on the specific gravity of ebony (Table 2), however, the specific gravity of ebony BM was slightly higher than ebony SL. The same results were found in teak wood (Tectona grandis L.) [23, 24,25]. Specific gravity is thought to be affected by the intensity of rainfall in site. Eucalyptus globulus and coniferous wood that grown in higher rainfall region have lower specific gravity [26,27]. Ebony SL had lower in specific gravity because grown in the wetter agro-climate zone (D1) compared to ebony BM (E1) [16].

Specific gravity value was affected by the thickness of the cell wall, the position in the stem and the proportion of wood cell. Wood with thicker cell walls has a higher specific gravity [28,29]. Further research in ebony wood is needed to prove this correlation.

The average of initial moisture content of ebony was 45.03 ± 5.10%. This moisture content value was lower than ebony from Maros of 49.2% [14]. The site did not affect the initial moisture content. The moisture content of ebony SL was higher than ebony BM. This is related to the specific gravity of ebony SL is lower than ebony BM. Specific gravity is the major determinant of maximum moisture content. Increase of specific gravity must decrease the volume of the lumina because the specific gravity of wood cell walls is constant among species. This decreases the maximum moisture content because less room is available for free water [30].

Ebony companies in Makassar and Palu have obtained ebony BM from Donggala and Parigi Moutong Regencies. Therefore, cultivation of ebony to produce the best streaks should be prioritized in these areas. Nevertheless, further research is needed regarding the characteristics of ebony sites in wider areas that produce BM and SL streaks. This information will be useful in the cultivation of ebony to produce streaks as desired.

4. Conclusion
This study determined the relationship between site factor and wood properties of ebony. The results showed that differences in streaks quality and brightness of heartwood color of the ebony grown in different sites were significant (p<0.05). Ebony from Parigi Moutong with BM streak had a grade B-A, better than that ebony from Poso. Ebony BM had a darker color, higher specific gravity and lower initial moisture content.

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