Chemical components content of seven Indonesian bamboo species

M I Maulana¹, M Marwanto¹, D S Nawawi¹, S Nikmatin²,³, F Febrianto¹*, N H Kim⁴

¹Department of Forest Products, Faculty of Forestry and Environment, IPB University (Bogor Agricultural University), Bogor 16680, Indonesia
²Department of Physics, Faculty of Mathematics and Natural Sciences, IPB University (Bogor Agricultural University), Bogor 16680, Indonesia
³Surfactant and Bioenergy Research Center, IPB University (Bogor Agricultural University), Bogor, Indonesia
⁴Department of Forest Biomaterials Engineering, College of Forest and Environmental Science, Kangwon National University, Chuncheon 200-701, Republic of Korea

*Email: febrianto76@yahoo.com

Abstract. Chemical components content of seven Indonesian bamboo species were investigated. Bamboo species used in this study including Andong bamboo (Gigantochloa pseudoarundinacea), Tali bamboo (G. apus), Hitam bamboo (G. artoviolacea), Betung bamboo (Dendrocalamus asper), Ampel bamboo (Bambusa vulgaris), Sembilang bamboo (D. giganteus), and Kuning bamboo (B. vulgaris var. striata). Holocellulose, alphacellulose, Klason lignin, acid-soluble lignin, extractives content, and pH value were determined. The highest holocellulose and alphacellulose content were found in Ampel and Hitam bamboo, respectively. Sembilang bamboo has the highest lignin content. Generally, Ampel bamboo has the highest extractives content. The pH value of the seven bamboo species showed that all bamboo species tend to be acidic.

1. Introduction

Bamboo is a potential biomass resources as an alternative to wood. As a lignocellulosic plant, bamboo was grown with high species diversity, and its culm has similar characteristics to wood. In Indonesia, there are 160 bamboo species in which 122 species are endemic [1]. Bamboo has a short growing cycle and is easy to grow in various types of soil [2], so it has high productivity and can be classified as fast growing species. In 2018, Indonesia produced up to 20 million bamboo culms [3].

Indonesian bamboo has been widely used by the community. Bamboo can be used as a raw material for musical instruments, furniture, traditional handicrafts, and lightweight construction [4]. Some research also showed the use of bamboo as a raw material for biomaterials and composites such as ply-bamboo [5,6], bamboo oriented strand board [2,7,8], and bamboo zephyr boards [9,10]. Bamboo is also potentially used as raw material for pulp [11] and nanocellulose [12].

However, among the various species of bamboo, only a few species have been used intensively. It can be caused by the lack of information about the characteristics of some species of bamboo. In order to optimize the use of bamboo in various applications and processing, the basic
properties of bamboo need to be known. Chemical properties are one of the basic properties that can affect the material properties of woody materials and their processing. The cell wall chemical components content such as cellulose and lignin will affect the yield, efficiency, and properties of the product resulting from the pulping and extraction of nanofiber processes [11,13]. Meanwhile, the acidity and extractive content in woody material influence the adhesion process in processed wood and composites [7,14,15]. Therefore, in this study, the chemical components content and acidity of seven bamboo species in Indonesia were investigated.

2. Materials and Methods

2.1. Materials

Seven bamboo species (4-5 years old) include Andong bamboo (Gigantochloa pseudoarundinacea), Tali bamboo (G. apus), Hitam bamboo (G. atroviolacea), Betung bamboo (Dendrocalamus asper), Sembilang bamboo (D. giganteus), Ampel bamboo (Bambusa vulgaris Var vulgaris), and Kuning bamboo (B. vulgaris Var striata) were harvested from bamboo arboretum at Center for Research and Development (P3) Biomaterials, Indonesian Institute of Sciences, Bogor, Indonesia. Bamboo culms were cut at the second node above the ground and the branched top parts were removed. One-third on the bottom part of the remaining bamboo culms were chopped, ground, and screened into 40-60 mesh size powders. All chemicals used in this study were analytical grade.

2.2. Methods

Holocellulose and alphacellulose content determination were referred to the Browning methods [16]. Determination of lignin content referred to Dence [17]. Extractives soluble in water were determined according to TAPPI T-207 cm-99 [18]. Determination of Ethanol-benzene soluble extractive referred to ASTM D-1107-96 [19]. The solubility of bamboo in 1% NaOH solution were determined according to TAPPI T-212 om-02 [20]. The pH value was determined according to SNI 06-6989.11-2004 [21].

2.3. Data analysis

Four replicates were carried out for each bamboo species. Analysis of Variance (ANOVA) was used to test the influence of bamboo species on the chemical component and pH value. If the results show significant influence, Duncan Multiple Ranged Test was carried out to determine the significantly different values.

3. Results and Discussion

3.1. Holocellulose

Holocellulose is the total fraction of polysaccharides consisting of alphacellulose and hemicellulose. Alphacellulose refers to cellulose with a degree of polymerization above 200 and does not dissolve in a strong base solution. Holocellulose, alphacellulose, and hemicellulose content of seven bamboo species were 69.41-82.77%, 34.60-53.12%, and 24.30-48.17% (Figure 1). Andong bamboo has the lowest holocellulose content while Ampel bamboo has the highest holocellulose content. The highest and the lowest alphacellulose were found in Hitam bamboo and Andong bamboo, respectively. Analysis of variance showed that bamboo species significantly affected holocellulose, alphacellulose, and hemicellulose content.

All bamboo species in this study showed high holocellulose content. Meanwhile, the alphacellulose content of the seven bamboo species belongs to different classes. The alphacellulose content of Ampel bamboo and Andong bamboo were classified low (<40%). In comparison, Sembilang bamboo and Kuning bamboo have moderate alphacellulose content (40-45%), and others have high alphacellulose content (>45%) [22]. Li et al. [23] reported that five-year-old Phyllostachys pubescens planted in Louisiana, USA, had a holocellulose content of about 69.94% and alphacellulose of about 46.08%. High holocellulose and alphacellulose content were also found in Gigantochloa scortechinii from Kedah, Malaysia, with values of 81.4% and 55.2%, respectively [24]. High holocellulose content
could be produced high pulping yield [25]. Ampel bamboo has high holocellulose content but low alphacellulose content. It shows that Ampel bamboo has very high hemicellulose content. Bamboo with high hemicellulose content is very susceptible to organism attacks. Febrianto et al. [26] reported that Ampel bamboo has low durability (class IV) against termites and powder post beetle.

3.2. Lignin
In this study, lignin is expressed as Klason lignin and acid-soluble lignin. Klason lignin is a residue resulting from hydrolysis and condensation reaction using 72% and 3% sulfuric acid, while acid-soluble lignin is the fraction of soluble lignin during the reaction. Klason lignin and acid-soluble lignin of seven bamboo species were 21.86-30.43% and 0.94-2.37%, respectively (Figure 2). Sembilang bamboo has the highest lignin content, while Tali bamboo has the lowest lignin content. Analysis of variance showed that bamboo species has significant influence on lignin content.

The seven bamboo species have different lignin content values. Differences in the value of acid-soluble lignin can be caused by differences in the ratio of the lignin monomers. Bamboo Lignin is classified as syringyl-guaiacyl-p hydroxphenyl lignin [27]. Nawawi et al. [28] reported that there is a positive correlation between the acid-soluble lignin values and the syringyl-guaiacyl ratio (S/G ratio) in the bamboo lignin. Bamboo with high lignin content has the potential to be used as bio energy raw materials. Lignin content has a positive correlation with calorific value [29]. However, in pulping and cellulose isolation processes, high lignin content can increase the energy and chemicals needed [30].
3.3. Extractives

Extractives soluble in water consist of tannin, gum, low molecular weight carbohydrates, dyes, and starch. Meanwhile, ethanol-benzene solvent dissolves wax, fat, oil, and a little gum. The cold water and hot water-soluble extractives content of seven bamboo species were 3.30-17.34% and 5.33-23.34%, respectively (Figure 3). The ethanol-benzene soluble extractive of seven bamboo species were 4.45-10.15% (Figure 4). The highest water and ethanol-benzene soluble extractive were found in the Ampel bamboo and the lowest water and ethanol-benzene soluble extractive were found in Tali bamboo and Kuning bamboo, respectively. Analysis of variance showed that bamboo species significantly affected water and ethanol-benzene soluble extractive.

A solution of 1% NaOH dissolves extractive substances, some part of lignin, and low molecular weight hemicellulose. The degree of fungal decay or degradation of wood can be indicated by solubility in 1% NaOH solution [20]. Solubility in 1% NaOH solution of seven bamboo species were 21.64-30.99% (Figure 5). Tali bamboo has the lowest value and Sembilang bamboo has the highest value of solubility in 1% NaOH solution. Analysis of variance showed that bamboo species significantly influence the solubility in 1% NaOH.
Bamboo extractive content varies between species. In the gluing process of composite products such as particle boards and plywood, high extractive content can inhibit adhesive penetration, resulting in low mechanical strength [31]. In the pulping process, the presence of extractives in the form of wax and fat will reduce the strength of bonds between fibers, increase consumption of alkali, and slow down delignification. The lower extractives content in the material, the easier chemicals to penetrate the materials, so that pulping is more optimum [11].

3.4. Acidity
Bamboo acidity is determined based on the pH value of the bamboo. The pH value of seven bamboo species were 4.94-6.49 (Figure 6). Sembilang bamboo has the highest pH value while Tali bamboo has the lowest pH value. Analysis of variance showed that bamboo species affected the pH value. In general, bamboo has an acidic pH. The pH value of bamboo which tends to be acidic could be influenced by free acids and acid groups such as acetyl and other acids from hemicellulose [32]. The pH value of bamboo will affect the curing of the adhesive on certain adhesive types. The curing of urea formaldehyde adhesives will be optimum under acidic conditions [33]. Meanwhile, the curing of phenol formaldehyde adhesives is more optimum starting at pH 8 [34].

Figure 5. Solubility in 1% NaOH solution of seven Indonesian bamboo species

![Figure 5](image)

Figure 6. pH value of seven Indonesian bamboo species

![Figure 6](image)
4. Conclusion
The chemical components content of bamboo was different among species. The highest holocellulose and alphacellulose content were found in Ampel and Hitam bamboo, respectively. Ampel bamboo has the highest hemicellulose content. Sembilang bamboo has the highest lignin content. Generally, Ampel bamboo has the highest extractives content. The pH value of the seven types of bamboo shows that all bamboo species tend to be acidic.

References
[1] Widjaya EA 2012 The utilization of bamboo: at present and for the future Proc. of International Seminar Strategies and Challenges on Bamboo and Potential Non Timber Forest Products
[2] Febrianto F, Sumardi I, Hidayat W, and Maulana S 2017 Papan Untai Bambu Berarah Material Unggul Untuk Komponen Bangunan Struktur (Bogor: IPB Press)
[3] [BPS] Badan Pusat Statistik 2018 Statistik Produksi Kehutanan. (Jakarta: Badan Pusat Statistik Indonesia)
[4] Sudarnadi H 1996 Tumbuhan Monokotil (Jaktata: Penebar Swadaya)
[5] Jasri J and Sulastiningsih IM 2018 The prevention of the powder post beetle dinoderus minutus farb. infestation on plybamboo and plywood J Trop. Wood Sci. Technol. 3(2) 68-72.
[6] Suryana J, Massijaya MY, Hadi YS, and Hermawan D 2017 Fundamental properties of ply bamboo. J Trop. Wood Sci. Technol. 9(2) 153-65
[7] Fatrawana A, Maulana S, Nawawi DS, Sari RK, Hidayat W, Park SH, Febrianto F, Lee SH, and Kim NH 2019 Changes in chemical components of steam-treated betung bamboo strands and their effects on the physical and mechanical properties of bamboo-oriented strand boards Eur. J. Wood Prod 1-9
[8] Maulana S, Gumelar Y, Fatrawana A, Maulana MI, Hidayat W, Sumardi I, Wistara NJ, Lee SH, Kim NH, and Febrianto F 2019 Destructive and non-destructive tests of bamboo oriented strand board under various shelling ratios and resin contents J. Korean Wood Sci. Technol. 47(4) 519-32
[9] Gopar M and Sudiyani Y 2018 The change of physical and mechanical properties of zephyr bamboo panel after exposed to out-door weathering J. Trop. Wood Sci. Technol. 2(2) 90-4
[10] Subyakto S, Gopar M, Ismadi I, Nugroho A, Sumarno A, Widodo E. and Sudarmanto S 2017 Pembuatan dan karakterisasi komposit zephyr bambu dengan perekat kempa dingin Journal of Lignocellulose Technology 1(1) 32-6
[11] Fatriasari W and Hermiati E 2008 Analisis morfologi serat dan sifat fisik-skimia pada enam jenis bambu sebagai bahan baku pulp dan kertas J. Forest Prod. Sci. Technol. 1(2) 67-72
[12] Jang JH 2015 Nanoscopic Morphology and Physicochemical Properties Of Lignocellulose Nanofibers and Their Utilization (Chuncheon: Kangwon National University)
[13] Seo PN, Han SY, Park CW, Lee SY, Kim NH, and Lee SH 2019 Effect of alkaline peroxide treatment on the chemical compositions and characteristics of lignocellulosic nanofibrils BioResources 14(1) 193-206
[14] Maulana MI, Nawawi DS, Wistara NJ, Sari RK, Nikmatin S, Maulana S., Park SH, and Febrianto F 2018 Change of chemical components content in andong bamboo due to steam treatment. J. Trop. Wood Sci. Technol. 16(1) 82-90
[15] Maulana MI, Murda RA, Purusatama BD, Sari RK, Nawawi DS, Nikmatin S, Hidayat W, Lee SH, Febrianto F, and Kim NH 2020 J. Korean Wood Sci. Technol.
[16] Browning BL 1967 Methods of Wood Chemistry Vol. I (New York: Wiley)
[17] Dence CW 1992 The Determination of Lignin in Methods in Lignin Chemistry Ed. Lin SY and Dence CW (Berlin: Springer-Verlag) pp. 33-61
[18] Technical Association of the Pulp and Paper Industry 1999 T-207 Water Solubility of Wood and Pulp (Atlanta: TAPPI)
[19] [ASTM] American Society for Testing and Materials Standard Test Method for Ethanol- Toluene Solubility of Wood D1107-96 2013 (West Conshohocken: ASTM International)
[20] Technical Association of the Pulp and Paper Industry 2002 T-212 One Percent Sodium Hydroxide Solubility of Wood and Pulp (Atlanta: TAPPI)

[21] [BSN] Badan Standardisasi Nasional 2004 pH meter SNI 06-6989.11-2004 (Jakarta: Badan Standardisasi Nasional)

[22] Departemen Pertanian 1976 Vademecum Kehutanan Indonesia (Jakarta: Departemen Pertanian)

[23] Li XB, Shupe TF, Peter GF, Hse CY, and Eberhardt TL 2007 Chemical changes with maturation of the bamboo species Phyllostachys pubescens Journal of Tropical Forest Science 6-12

[24] Salim R, Wahab R, and Ashaari Z 2008 Effect of oil heat treatment on chemical constituents of Semantan bamboo (Gigantochloa scortechinii Gamble) Journal of Sustainable Development 1(2) 91-8

[25] Pasaribu G, Sipayung B, and Pari G 2007 Analisis komponen kimia empat jenis kayu asal Sumatera Utara JPHH 25(4) 1–11

[26] Febrianto F, Gunilang A, Maulana S, Busyra I, and Purwantiningsih A 2014 Natural durability of five bamboo species against termite and powder post beetle J. Tropical Wood Sci. Technol. 12(2) 146-56

[27] Sjostrom E 1991 Wood Chemistry: Fundamentals and Applications (San Diego: Academic Press)

[28] Nawawi DS, Sari RK, Wistara NJ, Fatrawana A, Astuti P, and Syaffii W 2019 Lignin characteristic of four bamboo species J. Tropical Wood Sci. Technol. 17(1) 1-7

[29] White RH 1987 Effect of lignin content and extractives on the higher heating value of wood J. Wood Fiber Sci. 19(4) 446-52

[30] Mutia T, Risdianto H, Sugesty S, Hardiani H, and Kardiansyah T 2017 Serat dan pulp bambu Tali (Gigantochloa apus) untuk papan serat Tekstil 31(2)

[31] Maloney TM 1993 Modern Particleboard and Dry Process Fibreboard Manufacturing (Madison: Forest Products Society)

[32] Iswanto AH, Sucipto T, and Febrianto F 2011 Keasaman dan kapasitas penyangga beberapa jenis kayu tropis J. Forest Prod. Sci. Technol. 4(1) 22-5

[33] Nawawi DS, Priadi T, and Murventianio B 2017 The change of wood acidity during drying process J. Tropical Wood Sci Technol. 10(2) 195-200

[34] Pizzi A 1983 Wood Adhesives (New York: Marcel Dekker INC)

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