Physicochemical Characteristics Analysis of Biomass and Calorie Values of Several Types of Bamboo in Typologies of Altitude in Different Growing Sites

Aisman and Novizar Nazir
Department of Agricultural Product Technology, Faculty of Agricultural Technology, Andalas University, Kampus Limau Manis Padang, West Sumatera, Indonesia.
Corresponding author: aisman@yahoo.co.id

Abstract. Bamboo plants in West Sumatra spread from the lowlands to the highlands elevation with the varieties that are very diverse and their usefulness to the community is also very diverse. Some varieties of bamboo plants in the highlands of West Sumatra are currently used by the community as a source of energy (fuel) in the agricultural processing industry. The type of bamboo that is often used as fuel is betung and buluh. There are differences in the characteristics of biomass in the three types of bamboo plants that are important to be considered as a source of biomass. Type of Betung which is grown in the highlands has an average stem height of 15 m with the number of stems per ha approximately between 60,968 – 76,800 stems. The aim of the study was to see the physiochemical characteristics of different types of bamboo in various typologies of elevation of growing site. There are variations in the physicochemical properties of bamboo at different varieties and at different elevations of growing sites.

1. Introduction
Bamboo plants are a potential source of agricultural biomass because bamboo is easily cultivated, can be harvested at a relatively shorter age, and once cultivated, it can be harvested repeatedly. Each clump of bamboo plants can produce dry biomass weighing 139.73 - 177.53 kg per year, and produce carbon stocks weighing 75.06 - 94.83 kg / year. Each hectare has approximately 168 clumps of bamboo plants, with a weight of dry biomass that can be produced at approximately 26.30 tons / ha / year and an average carbon stock of 14.08 tons / ha / year [1].

Bamboo stems have long been used as fuel, among others, by traditional sugar cane processing actors in West Sumatra. This is possible because bamboo stems have a considerable calorific value of 4,729 Kcal / kg greater than that produced by Eucalyptus plants which is only 4,681 Kcal / kg [2]. The use of bamboo as fuel in the processing of folk sugar cane in Nagari Pandai Sikek, Tanah Datar District, West Sumatra, was able to reduce fuel costs by Rp. 9 million per year for every 6 ha of sugar cane which is processed into brown sugar compared to using firewood. Besides that, the results of the analysis carried out on betung type of bamboo growing in the valleys at Nagari Pandai Sikek, Tanah Datar District, gave a calorific value of around 3,700 Kcal / kg [3]. Aside from being a direct fuel, bamboo culms are also being developed as an energy source in electric power plants using a gasification system [4].

The basic study was conducted in the Mentawai Islands Regency of West Sumatra Province is projected that until 2035 the total demand for electrification in this area is estimated at 52,218.8 KW. It is suspected that
this area will experience a shortage of electrification of 47,714.2 KW in 2035. If the electrification needs in 2035 using bamboo as raw material, then an area of approximately 23,857.1 ha is needed for bamboo plantation [5].

In West Sumatra several types of bamboo plants can be found at various elevations of land from the sea surface, from lowlands to highlands. Bamboo plants are relatively tolerant of various conditions of land and land for their growth, but differences in the conditions of land height and type of bamboo will produce different physical and chemical characteristics.

Bamboo biomass produced in Eastern Thailand differs based on differences in growing locations and cultivation management systems, where bamboo plants that grow on marginal land and without land management will result in lower productivity. In the case of bamboo species where the caloric content of the *Dendrocalamus membranaceus* type of bamboo is much higher than that of the *Bambusa beecheyana* bamboo species [6].

Based on the description above, it can be seen that differences in the place of growth and differences in the types of bamboo plants will cause differences in the characteristics of biomass and calorific value. By looking at the potential of bamboo to be used as a biomass-based energy source, it is necessary to seek the potential of local bamboo which has a relatively large biomass potential and an ideal place to grow to be developed as an alternative biomass-based energy source. The aim of the study was to see the physiochemical characteristics of different types of bamboo in various typologies of elevation of growth.

2. Materials and Methods

2.1. Place and Time

The location of identification and sampling of bamboo is divided into three typologies of altitude above the sea level (asl), namely the lowlands (<400 m asl), temperate plains (400 - <800 m asl) and the plateau consists of two typologies namely (800 - 1,000 m asl and > 1,000 - 1,700 m asl). Location selection is done by purposive based on the variety of types and the large number of bamboo plants that develop in the area. Analysis of biomass and calorific value characteristics was carried out at the Agricultural Technology Laboratory of Andalas University.

2.2. Materials and tools

The material analyzed was bamboo stems identified in the study area. The tools used in this study include cutting tools, meters, callipers, ovens, desiccators, analytic scales, cup tongs, porcelain saucers, furnaces, and bomb calorimeters.

2.3. Research methods

The study began by conducting a survey to observe and conduct interviews with the community at the research site to identify the types of bamboo plants with potential biomass and relatively large calorific values. The initial indicator used was plant height, stem diameter and wall thickness of bamboo sticks. The study was designed with a descriptive approach [7].

2.4. The types of data collected are:

Many types of bamboo plants are found in each region with different land height typologies. Detailed identification of bamboo species that have biomass potential and large calorific value, including:

- The area of bamboo clumps
- The number of bamboo stems in one clump
- The age of bamboo plants that are suitable for harvest according to the habits of the local community.
- The potential amount of bamboo biomass to be used as an energy source by calculating:
  - Plant height and diameter of bamboo circles
  - Section length and thickness of bamboo flesh
- Weight of bamboo stems
• Potential number of bamboo culms in 1 ha
• Potential heavy biomass produced in 1 ha of bamboo per year
• Calorific value produced by various types of bamboo plants (SNI 01/6235/2000)
• Moisture content of bamboo stems when harvested (Gravimetric Method / SNI 01/6235/2000)
• Bamboo Rod Ash Content (Gravimetric Method / SNI 01/6235/2000)
• Bamboo stem carbon content (SNI 01/6235/2000).

Determination of the base, the middle and the top of the bamboo plant based on the length distribution of bamboo culms that are commonly used as 3 [8], one third of the total length of the stem at the base is called the base, one third of the total length of the stem in the middle is called the middle, and one third of the total length of the stem at the end is called the end.

3. Results and Discussions

3.1. Types of Bamboo Plants
The survey found three types of bamboo plants with relatively large biomass potential, namely betung (Dendrocalamus asper), aur (Bambusa vulgaris) and buluh (Schizotachyum brachycladum Kuez). Betung plants are found in all land height typologies, while aur plants are only found on land with an altitude of <400 m asl and at altitudes > 1,000 - 1,700 m asl and buluh plants are only found at an altitude of 400 - <800 m asl and at an altitude of 800 - 1,000 m asl.

The three types of bamboo plants found to grow clumped with clump patterns tend to form a circle. The area of each clump varies from approximately 8 m per square to 14 square meters. The distance between bamboo culms and other stems in one clump ranges from 23-25 cm with a circle of rootstock, each type of bamboo is also different. This affects the number of bamboo culms in each clump and will also affect the population of bamboo culms in each ha of plants.

3.2. Physical Characteristics of Bamboo Plants
The measured physical characteristics include plant height, bamboo tree population per ha, stem circumference of the base, middle and end, wall thickness of the bamboo stem at the base, the middle and the top, the length of the base, the middle and the top and the weight of bamboo trees. Based on the physical observation data, the biomass potential of bamboo plants can be calculated per ha. The results of the observations are shown in Table 1 and Table 2.

The potential of dry biomass of betung plants is relatively higher than that of buluh and aur plants. The lowest potential of dry biomass of betung plants is approximately 671 tons/ha and the highest is 1,412 tons/ha. The potential of buluh biomass ranges from 388 - 396 tons/ha while the potential of dry biomass of aur plants is between 398 - 755 tons/ha. If the cutting cycle of bamboo plants can be done every 3 years, the annual dry biomass potential for the lowest betung plants is 224 tons/ha/year and the highest is 385 tons/ha/year. While the potential of annual dry biomass of buluh is between 129 - 132 tons/ha/year and the annual dry biomass potential of aur plants is 133 - 252 tons/ha/year. This result is relatively higher than that found by other researchers [1] where the average dry bamboo biomass is more or less by 26.30 tons/ha/year.
Table 1. Physical Characteristics of Different Types of Bamboo in Various Typologies of Height of a Growing Sites from Sea Level, for Betung species.

| DESCRIPTION                                      | BETUNG                  |
|--------------------------------------------------|-------------------------|
|                                                  | < 400 m asl  | 400 - < 800 m asl | 800 - 1000 m asl | >1000 -1.700 m asl |
| Plant height (m)                                 | 12          | 20              | 15               | 15.1                |
| Population (stem/ha)                             | 41.997      | 37.102          | 48.796           | 44.596              |
| size of stem circumference (cm)                   |             |                 |                  |                     |
| - The Base                                       | 27.30       | 36.77           | 35.62            | 39.46               |
| - The Middle                                      | 25.68       | 28.73           | 28.42            | 32.99               |
| - The Top                                        | 21.67       | 17.70           | 18.33            | 19.54               |
| - Average                                        | 24.88       | 27.73           | 27.46            | 30.66               |
| Stem thickness (cm)                               |             |                 |                  |                     |
| - The Base                                       | 1.75        | 2.31            | 2.81             | 1.79                |
| - The Middle                                      | 1.09        | 1.15            | 1.36             | 1.12                |
| - The Top                                        | 0.83        | 0.79            | 0.79             | 0.81                |
| - Average                                        | 1.18        | 1.35            | 1.65             | 1.24                |
| Section length (cm)                               |             |                 |                  |                     |
| - The Base                                       | 32.83       | 34.92           | 36.33            | 31.72               |
| - The Middle                                      | 54.63       | 39.64           | 38.17            | 28.22               |
| - The Top                                        | 58.50       | 37.50           | 30.50            | 32.85               |
| - Average                                        | 48.65       | 37.35           | 35.00            | 30.93               |
| Tree weight (kg/stem)                             | 36.23       | 86.89           | 58.12            | 61.18               |
| Biomass Potential (ton/ha)                        | 1.522       | 3.224           | 2.836            | 2.728               |
| Dry biomass potential with 15% moisture content (ton/ha) | 671         | 1.412           | 782              | 1.154               |

Bamboo biomass has the potential to be used as an energy source because it is easily cultivated, environmentally friendly and productivity of bamboo biomass per unit area is higher compared to most other types of plants, which is around 33.4 - 109.2 tons / ha / year, with a harvest period which is quite short which ranges from 1-3 years and can be harvested throughout the year so that the continuity of this raw material is always maintained [9].

For the three types of bamboo plants, it is seen that the water content at the base of the plant is relatively large compared to the middle and the end of the plant, and the water content of the middle part of the plant is relatively higher than the end of the plant. The potential of carbon stocks found in betung species ranges from 95.24 - 186.08 tons/ha/year, the potential of carbon stocks buluh plants ranges from 29.47 - 55.85 tons/ha/year and the potential for carbon stocks in aur plants range from 38.37 - 92.25 tons/ha/year. These results are relatively higher than the result reported by other researchers [1] where the carbon stock of bamboo plants found was 14.08 tons/ha/year.

Biomass accumulation of a plant are influenced by age, nutrient availability, soil, and local climate. Variations in carbon stocks at various levels of plant height are more determined by variations in plant carbon stocks. The higher the plant and the older the age of the carbon stock plant increases. Carbon reserves contained in a part of the plant are derived from carbohydrates as a result of leaf photosynthesis. Photosynthesis in leaves is a source of carbohydrates that will be translocated to other organs (stems, twigs and leaves) [10].
Table 2. Physical Characteristics of Various Types of Bamboo in Various Typologies of Elevation of Growing Sites from Sea Level, for species of Buluh and Aur

| DESCRIPTION               | BULUH 400 - < 800 m asl | BULUH 800 - 1.000 m asl | AUR < 400 m asl | AUR >1.000 -1.700 m asl |
|---------------------------|-------------------------|-------------------------|-----------------|------------------------|
| Plant height (m)          | 17.5                    | 11.0                    | 14.4            | 16.0                   |
| Population (stem/ha)      | 43.737                  | 47.422                  | 45.005          | 42.300                 |
| Size of stem circumference (cm) |                       |                          |                 |                        |
| - The Base                | 31.1                    | 26.8                    | 32.8            | 27.0                   |
| - The Middle              | 26.8                    | 25.1                    | 31.2            | 26.2                   |
| - The Top                 | 15.2                    | 18.5                    | 18.9            | 12.7                   |
| - Average                 | 24.38                   | 23.46                   | 27.63           | 21.95                  |
| Stem thickness (cm)       |                         |                          |                 |                        |
| - The Base                | 1.1                     | 1.2                     | 1.2             | 1.7                    |
| - The Middle              | 0.7                     | 0.7                     | 1.1             | 1.3                    |
| - The Top                 | 0.5                     | 0.5                     | 0.6             | 0.8                    |
| - Average                 | 0.74                    | 0.81                    | 1.06            | 1.22                   |
| Section length (cm)       |                         |                          |                 |                        |
| - The Base                | 53.7                    | 43.0                    | 28.5            | 39.0                   |
| - The Middle              | 35.2                    | 44.1                    | 32.5            | 49.0                   |
| - The Top                 | 37.6                    | 41.6                    | 24.4            | 46.0                   |
| - Average                 | 42.17                   | 42.90                   | 28.45           | 44.67                  |
| Tree weight (kg/stem)     | 34.7                    | 20.4                    | 42.3            | 36.0                   |
| Biomass Potential (ton/ha)| 1.517,2                 | 966,9                   | 1.903,8         | 1.522,8                |
| Dry biomass potential with 15% moisture content (ton/ha) | 396 | 388 | 755 | 398 |

3.3. Chemical Characteristics of Bamboo Plants

Table 3. Characteristics of Chemical Properties of Various Types of Bamboo in Various Typologies of Elevation of Growing Sites from Sea Level, for species of Buluh

| DESCRIPTION               | BETUNG < 400 m asl | BETUNG 400 - < 800 m asl | BETUNG 800 - 1.000 m asl | BETUNG >1.000 -1.700 m asl |
|---------------------------|--------------------|---------------------------|--------------------------|-----------------------------|
| Kadar Air (%)             | 37.73              | 41.71                     | 64.65                    | 40.78                       |
| - The Base                | 32.72              | 31.15                     | 53.90                    | 34.60                       |
| - The Top                 | 31.68              | 29.90                     | 44.74                    | 31.02                       |
| Average moisture content (%) | 34.04              | 34.25                     | 54.43                    | 35.47                       |
| Ash content (%)           | 2.43               | 1.82                      | 2.04                     | 1.37                        |
| Flying substances (%)     | 83                 | 87.01                     | 79.77                    | 82.51                       |
| Carbon Content (%)        | 14.2               | 11.24                     | 18.19                    | 16.13                       |
| Calorie Value (Kcal/kg)   | 3.109,08           | 3.443,76                  | 3.477,55                 | 3.384,73                    |
Table 4. Characteristics of Chemical Properties of Various Types of Bamboo in Various Typologies of Elevation of Growing Sites from Sea Level, for species of Buluh and Aur

| DESCRIPTION                  | BULUH 400 - < 800 m asl | BULUH 800 - 1.000 m asl | AUR < 400 m asl | AUR >1.000 -1.700 m asl |
|------------------------------|--------------------------|--------------------------|-----------------|-------------------------|
| Kadar Air (%)                |                          |                          |                 |                         |
| - The Base                   | 59.01                    | 43.71                    | 39.78           | 70.00                   |
| - The Middle                 | 59.74                    | 34.43                    | 36.83           | 68.53                   |
| - The Top                    | 53.64                    | 34.13                    | 36.87           | 33.80                   |
| Average moisture content (%) |                          |                          |                 |                         |
|                             | 57.46                    | 37.42                    | 37.83           | 57.44                   |
| Ash content (%)              | 1.60                     | 3.47                     | 1.69            | 1.52                    |
| Flying substances (%)        | 90.97                    | 82.13                    | 86.09           | 88.84                   |
| Carbon Content (%)           | 7.44                     | 14.41                    | 12.22           | 9.65                    |
| Calorie Value (Kcal/kg)      | 2.393,62                 | 3.589,65                 | 3.288,68        | 3.911,83                |

The results of their study conducted in Thailand showed that intensively managed bamboo plants provided higher biomass yields than bamboo plants that were not managed well. Besides that, it was also reported that older bamboo plants had lower water content than younger plants, thus providing a higher calorific value and were preferred to be used as an energy source [6].

4. Conclusions
There are variations in the physicochemical properties of bamboo at different varieties and at different elevations of growing sites. The potential of carbon stocks found in betung species ranges from 95.24 - 186.08 tons/ha/year, the potential of carbon stocks buluh plants ranges from 29.47 - 55.85 tons/ha/year and the potential for carbon stocks in aur plants range from 38.37 - 92.25 tons/ha/year. These results are relatively higher than the result reported by other researchers [1] where the carbon stock of bamboo plants found was 14.08 tons/ha/year.

References
[1] Suprihatno, B., Hamidy, R., Amin, B. 2012. Analisis Biomassa dan Cadangan Karbon Tanaman Bambu Belangke (Gigantochloa Pruriens). Journal of Environmental Science Universitas Riau 2012:6 (1) SSN 1978-5283. hal 82-92.
[2] Vessia, O. 2005. Biofuels from Lignocellulosic Material. Faculty of Information Technology, Mathematics and Electrical Engineering Department of Electrical Engineering. NTNU, Norwegian University of Science and Technology. Trondheim- Norwegian.
[3] Olvi, Aisman, K. Sayuti. 2016. Identifikasi Jenis Bambu Sebagai bahan Bakar pada Industri Gula Merah Rakyat dan Nilai Ekonominnya di Kenagarian Pandai Sikek Kabupaten Tanah Datar (tidak dipublikasikan).
[4] Aisman dan N. Novizar. 2016(a). Kajian Dasar Potensi Energi Listrik Berbasis Biomassa Bambu Di Kabupaten Kepulauan Mentawai. Jurnal Agroindustri. Vol 6 No. 2, 2016. ISSN 2088-5369. Hal 65-72.
[5] Aisman dan N. Novizar 2016(b). Prospektif Pengembangan Elektrifikasi Berbasis Biomassa Bambu Di Kabupaten Kepulauan Mentawai. Prosiding Seminar Nasional Membangun Pertanian Modern dan Inovatif Berkelanjutan Dalam Rangka Mendukung MEA. ISBN 978-602-1276-17-4. Hal 1316 – 1325.
[6] Darabant, A., M. Haruthaithanasan, and W. Atkla. 2014. Bamboo biomass yield and feedstock characteristics of energy plantations in Thailand. Energy Procedia 59 (2014) 134-141.
[7] Nazir, Mohd. 2005, Metode Penelitian. Penerbit Ghalia Indonesia. Bogor.
[8] BSN [Badan Standarisasi Nasional] (2006). Uji ketahanan kayu dan produk kayu terhadap organisme perusak kayu. Rancangan Standar Nasional Indonesia. Badan Standarisasi Nasional SNI 01-7207-2006. Jakarta.

[9] Karman, J. 2012. Teknologi dan Proses Pengolahan BIOMASSA. Alfabeta. Bandung.

[10] Gust, D. 2011. Why Study Photosynthesis? Department of Chemistry and Biochemistry Foundation Professor of Chemistry and Biochemistry. http://bioenergy.asu.edu/photosyn/study.html. (24 April 2012).

[11] Scurlock, J.M.O., D.C. Dayton, and B. Hames. 2000. Bamboo: an overlooked biomass resource?. Biomass and Bioenergy 19 (2000) 229-244.