CHEMICAL COMPONENT AND ANATOMICAL FEATURES OF THREE SPECIES OF BAMBOOS

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Abstract

As a versatile plant, the basic properties of bamboo are vary depend on species, site, and position inside the stem. This study was conducted at three sites (Buria, Morekao, Tala), on three species (*Dendrocalamus asper*, *Schizostachyium brachycladum*, *Schyzotachium lima*), and three position of the stem (base, middle, top). Objective of the study is to measure chemical component and anatomical features of three species of bamboos (*Dendrocalamus asper*, *Schizostachyium brachycladum*, *Schyzostachyium lima*) of West Ceram's sub-district (Taniwel, Piru, Kairatu), and three part of stem (base, middle, top). Factorial experiment in split plot design was applied in the study with 3 replications.

Result of the study indicated that there was significant effect of location to the lignin content, diameter of fiber and fiber cell lumen, and proportion of parenchyma cell; species of bamboos to the length and diameter of fiber cell; and portion of stem to the extractive soluble in hot water, soluble in alcohol benzene, length and diameter of fiber cell, and diameter of fiber lumen. Extractive soluble in cold water was 3.10%-3,79%; hot water was 5,43%-6,23%; alcohol benzene was 3,37%-4,10%; alpha cellulose was 44,22%-46,94%; holo cellulose was 71,97%-75,57%; lignin was 26,00%-27,37%; length of fiber cell was 3,40mm-3,96mm; diameter of fiber cell was 4,34micron-4,91micron; diameter of fiber cell lumen was 2,74micron-3,23micron; cell wall thickness of fiber cell was 0,76micron-0,91micron; proportion of parenchyma cell was 51,95%-56,85%; proportion of fiber cell was 27,81%-62,66%; and proportion of pore was 12,39%-14,60%.
Keywords : bamboos, chemical component, extractive, cellulose, lignin, anatomical features.

Introduction

At Ceram island , people can find naturally wild bamboo especially several at sub district Taniwel, Piru and Kairatu. At Taniwel, chopstick company was used wild bamboo as raw material unfortunately it had been closed because of mismanagement even though there is big potential of bamboo.

There is several furniture and handicraft producer made of bamboo as a household business at Piru. Traditionally, local people was used wild bamboo for daily life based on their experiences such as Petung (*Dendrocalamus asper)*, Sero (*Schizostachyium brachycladum)*, and Tui (*Schizostachyum lima)*. The value and suitable of bamboo to form one product was not depend only the experiences but also basic properties of bamboo which is not common recognize by people and industry. One of basic properties are chemical component and anatomical features of bamboo. Based on the basic properties, the use bamboo as raw material in such product might be encourage that the kind of product is common practice traditionally by local people. In the other hand, such product might be developed with reliable technology and processes that promoted in the future. Together with the study is to collect data and information about the relationship between basic properties of bamboo with location, species and portion of the cane.

Objective of the study was to determine chemical component and anatomical features of 3 (three) species of bamboo such as petung (*Dendrocalamus asper)*, sero (*Schizostachyium brachycladum)*, and tui (*Schizostachyium lima)* at 3 (three) sub districts such as Taniwel, Piru and Kairatu, and 3 (three) portion of the cane (bottom, middle, top).

Materials and methods

Bamboo cane was collected from 3 (three) village (Buria, Morekao and Tala) of West Seram District, Mollucas. Chemical component analyses was conducted at Laboratorium Kimia Dasar Unpatti, and anatomical features at Faculty of Forestry, UGM Jogya. 3 (three) bamboo cane was cut from the clump, then it was cut into 3 (three) portions (bottom, middle, top). 3 (three) specimen of bamboo as replication was cut from each portion of the cane to determine chemical component and anatomical features. Kinds of the specimen comply the standard requirement such as,

a. Samples for chemical component of bamboo was made in form of sawdust. Solvent and reagent was used such as alcohol benzene, H_2O; glacial acetic acid, $NaCl_2$, ice, acetate acid 1% and 10%, acetone, NaOH 17,5%, water, H_2SO_4 72%, hot water and filter.
b. Samples for anatomical features was made in form of thin slice of bamboo which is cut by microtome and small pieces of bamboo for maceration. Solvent and reagent was used such C_2H_5OH, H_2O_2, safranin, xylol (C_5H_{10}), H_2O, canada balsam and acetate acid glacial.

Methods

Determination of chemical component such as soluble cold water and hot water extractives based on ASTM D1110-56 (1985) procedures, soluble alcohol benzene extractives based on ASTM D1105-96 (1985) procedures; holo cellulose based on ASTM D 1104-56 (1985) procedures; alpha cellulose based on ASTM D1103-60 (1985) procedures; and lignin based on ASTM D110-84 (1985) procedures.

$$\text{Extractives (\%)} = 1 - \frac{\mathbf{BKO_e(1+K_a)}}{\mathbf{B_b}}\mathbf{x100\%} \quad \text{.. (1)}$$

$$\text{Holo cellulose (\%)} = \frac{\mathbf{BKO_h}}{\mathbf{BKO_{SBE}}}\mathbf{x100\%} \quad \text{.. (2)}$$

$$\text{Alpha cellulose (\%)} = \frac{\mathbf{BKO_a}}{\mathbf{BKO_{SBE}}}\mathbf{x100\%} \quad \text{.. (3)}$$

$$\text{Lignin (\%)} = \frac{\mathbf{BKO_{Lignin}}}{\mathbf{BKO_{SBE}}}\mathbf{x100\%} \quad \text{.. (4)}$$

Note :

BKO_e = oven dry weight of sawdust after extraction (gram)
K_a = moisture content of sawdust (%)
B_b = early weight of sawdust (gram)
BKO_{SBE} = oven dry weight of sawdust without extractives (gram)
BKO_h = oven dry weight of holo cellulose (gram)
BKO_a = oven dry weight of alpha cellulose (gram)
BKO_{Lignin} = oven dry weight of lignin (gram)

Determination of anatomical features based on procedures by LPHH (Silitonga dkk, 1972) and Kaakinen methods (2004), and Nugroho dkk (2005) such as fiber dimension and cell proportion. Formula to measure one hundred of fiber based on Kasmudjo (1998) as follow,

$$N = \frac{4S^2}{L^2} \quad \text{and} \quad S^2 = \frac{fiXi^2 \quad \frac{(fixi)^2}{n}}{n \quad 1} \quad \text{and} \quad L = \frac{fiXi}{n}x0{,}05 \quad \text{......................... (5)}$$

N = number of fiber to be measure
S = standard of deviation
L = fiber length's average multiply by 0,05 (5 percent error is adequate)
Xi = fiber length
Fi = fiber frequency which possess the same dimension.
N = number of fiber which had been measure at the beginning of one hundred fiber

Determination of fiber diameter and lumen had been measure directly using *Image Pro Plus V 4.5* program. Cell proportion measurement based on *Image Pro Plus V 4.5* program with *spacing* horizontal and vertical for one hundred cell and photo of cell anatomy at cross section plate (x). Based on the photo, number of dot grid have to be measure by using manual tag. Result of the measurement had to be transfer to Microsoft Excel program (Nugroho et al, 2005).

Data was analyzed using factorial experiment in split plot design with 3 (three) replication. Kinds of chemical component of bamboo was analyzed such as extractives soluble in cold water, soluble in hot water, soluble in alcohol benzene, alpha cellulose, holo cellulose and lignin. Anatomical feature such as fiber dimensions (length of fiber, diameter of fiber, diameter of fiber lumen, cell wall thickness of fiber), proportions of fiber cell, parenchyma cell and pores.

Linier model of equation was made based on effect of 3 (three) factors such as location, species and portion of the cane, such as

$Y_{ijk} = \mu + A_i + B_j + C_k + (AB)_{ij} + (AC)_{ik} + (BC)_{jk} + (ABC)_{ijk} + \sum_{ijk}$ …………………………………..……… (6)

A, comprised of (3) three location such as Buria (Kecamatan Taniwel. Morekao (Kecamatan Piru) dan Tala (Kecamatan Kairatu).

B, comprised of (3) three species of bamboo such as petung (*Dendrocalamus asper)*, sero (*Schizostachyium brachycladum)* dan tui (*Schizostachyum lima)*.

C, comprised of (3) three portion of the cane such as bottom, middle and top portion

Result and Discussion.

Chemical component and anatomical features according to location, species and portion of the cane.

Table 1 was listed down chemical component, anatomical features and whether or not there was significant effect of 3 (three) factors.

Chemical component and anatomy features	Significancy	Location			Species			Portion of the cane		
		B	M	TL	P	S	T	bottom	middle	top
CHEMICAL COMPONENT (%)										
Soluble cold water	n – n – n	3.70	3.61	3.32	3.59	3.46	3.59	3.59	3.65	3.30
Soluble hot water	n – n - **	6.23	5.77	5.50	5.92	5.88	5.70	6.52	5.44	5.43
Sol. Alcohol benzene	n – n - **	3.74	3.79	3.49	4.10	3.43	3.49	3.89	3.82	3.37
Alpha cellulose	n – n - n	44.22	44.91	45.76	44.94	44.30	45.65	46.04	44.98	43.89
Holo- cellulose	n – n - n	75.57	73.31	72.48	73.63	71.96	72.77	72.54	73.14	72.67
Lignin	* - n - n	27.17	26.42	26.00	27.37	26.18	26.05	26.67	26.57	26.36
ANATOMICAL FEATURES										
CELL DIMENSION (mm, micron)										
Fiber length	n - * - **	3.79	3.56	3.70	3.90	3.55	3.57	3.96	3.67	3.40
Fiber diameter	** - ** - **	4.91	4.44	4.59	4.91	4.60	4.44	4.97	4.72	4.34
Lumen diameter	** - tn - **	3.10	2.92	2.98	3.10	3.00	2.90	3.23	3.02	2.74
Fiber wall thickness	n – n - n	0.91	0.76	0.80	0.90	0.80	0.77	0.91	0.80	0.77
CELL PROPORTION (%)										
Parenchyma	* - n - *	55.44	53.10	56.71	54.79	56.85	53.61	56.83	55.67	51.95
Fiber	n – n - **	32.31	62.66	29.99	32.64	29.03	33.30	27.81	31.84	35.31
Pore	n – n - n	12.39	14.33	14.05	12.58	14.96	13.23	14.60	13.43	13.13

Note ** = higlly significant * = significant , n = no significant; B = Buria; M = Morekao TL = Tala
P = Petong (*Dendrocalamus asper)*; S = Sero (*Schizostachyium brachycladum)*, T = Tui (*Schizostachyum lima)*.

Lignin component of bamboo from Buria was 27,17% which is bigger than bamboo from Morekao (26.42%) and Tala (26,0%). Alpha cellulose, holo cellulose and extractives component of bamboo from Buria, are similar to the Morekao and Tala. Content of alpha cellulose, holo cellulose and extractive content of bamboo's Buria was equal to Morekao and Tala. Holoselulosa content (75,57%), lignin (27,43%), soluble cold water extractives (3,70%) and soluble hot water extractives (6,23%) of bamboo from Buria was higher than Morekao (72,31%; 26,42%; 3,61%; 5,77%) and Tala (72,48%; 26,0%; 3,32%; 5,50%). Lignin and holocellulose content of bamboo from Buria was higher than Morekao and Tala. The reason of this caused by cell wall thickness (0,91 micron) and fiber length (3,79 mm) of bamboo's Buria higher than Morekao (0,76 micron; 3,56 mm) and Tala (0,76 micron; 3,70 mm) although there was no significant different between those features (Figure 1).

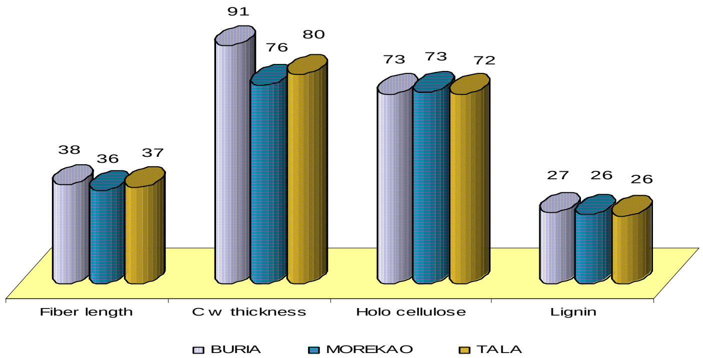

Figure 1. Comparison of bamboo based on location in term of fiber length (mm), cell wall thickness (micron), holocellulose (%) and lignin (%).
Note : fiber length multiply by 0.1
cell wall thickness multiply by 0.01

The more thick of the cell wall may cause increase of alpha, holo cellulose and lignin content which is mayor component of cell wall. In the other hand, higher lignin content of bamboo from Buria may cause increasing of chemical solution to separate lignin from pulp which is raw material in paper making.

Soluble hot water (6,23%) and cold water extractives (3,70%) of bamboo's Buria was higher than Morekao (5,77%; 3,61%) and Tala (5,50%; 3,32%). The reason of this caused by diameter lumen of fiber (0,91 micron) from bamboo's Buria that it was higher than Morekao (0,76 micron) and Tala (0,80 micron). Almost all of the extractives fill up cell lumen of pores and fiber. Although proportion of pores (12,39%) from Buria's bamboo was lower than Morekao (14,33%) and Tala (14,05%) (Figure 2).

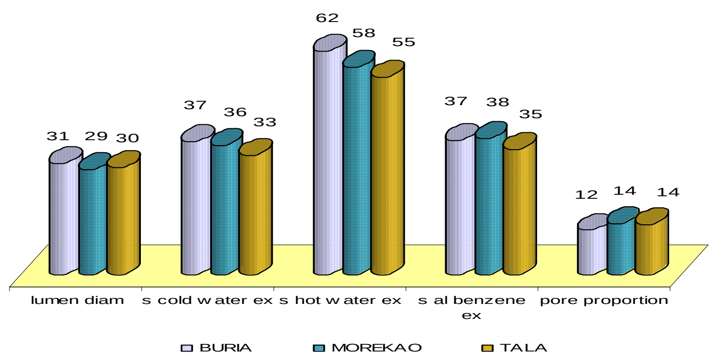

Figure 2. Comparison of bamboo based on location in term of cell lumen (micron), soluble cold water extractives (%), soluble hot water extractives (%), soluble alcohol benzene extractives (%), and pore proportion (%).
Note : lumen diameter and extractives content multiply by 0.1

Extractive content may increase fill up the pore cell although it's proportion was low. Generally, sugar and starch fill up pore cell of bamboo's cane. It is important to study bamboo preservation in relation to the diameter of pore cell and its content which is affect the right time to cut bamboo's cane. Traditionally, people cut bamboo's cane at dry season because sugar and starch content is minimum that it may prevent powder post beetle's attack.

Soluble alcohol benzene extractives of bamboo's Morekao (3,79%) was higher than Buria (3,74%) and Tala (3,45%) caused by pore cell proportion of bamboo's Morekao (14,33%) was higher than Buria (12,39%) and Tala (14,05%). Bamboo's Morekao may resist termite's attack but it can not be powder post beetle if its sugar and starch content higher than Buria and Tala. To verify this findings, it is important to study soluble NaOH extractives, diameter of pore cell, sugar and starch content of bamboo and buried test of bamboo against powder post beetle, termite, and fungus.

Chemical component and anatomical features according to species.

Table 1 was listed down chemical component, anatomical features and whether or not there was significant effect of 3 (three) factors. Amount of pore cell affect the resistance of bamboo against powder post beetle. Sugar and starch are mainly fill up the pore cell, that it is the principle food substance of powder post beetle. According to Kusumaningsih (1997), starch content of *Bambusa vulgaris* was the highest that make it more damage by powder post beetle. In other word, not only amount and diameter of pore cell but also starch content is signify the resistance of bamboo.

It is easy to note that size of pore's bamboo is larger than wood by using of loupe or naked eye. Because of this reality, heat conductivity of bamboo is lower than wood, therefore furniture, mat, screen and wall paper made of bamboo feel cooler than wood. Generally, bamboo was brand as cool and nature substance compare to other construction material.

Alpha cellulose content (45,85%) of *Schyzotachium lima* was higher than *Dendrocalamus asper* (44,94%), and *Schizostachyium brachycladum* (44,30%), therefore its resistance against termite have to verify in laboratory and buried test. According to Munawar (2001), alpha cellulose content of *Gigantochloa apus* (46,36%) was higher than *Gigantochloa robusta* (44,23%). *Gigantochloa atroviolacea* (41,08%) *Bambusa vulgaris* (40,39%). *Gigantochloa apus* damage by termite was higher because of its alpa cellulose content. Termite is social insect that break down cellulose into simple compound in their intestinal tracts which it is absorb by body. It is possibly *Schyzotachium lima* might be more damage by termite compare to *Dendrocalamus asper*, and *Schizostachyium brachycladum*. Lignin content of *Schyzotachium lima* (26,05%) was lower than *Dendrocalamus asper* (27,37%), and *Schizostachyium brachycladum* (26,18%). Lignin is component of cell wall that difficult to break down by termite (Figure 3).

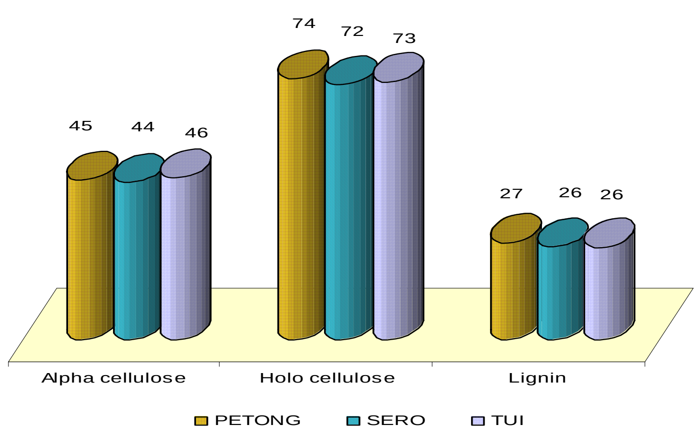

Figure 3. Comparison of bamboo based on species in term of alpha cellulose (%), holo cellulose (%), and Lignin (%).

Soluble cold water (3.59%), hot water (5.92%), and alcohol benzene extractives (4.10%) of *Dendrocalamus* asper was higher than *Schizostachyium brachycladum* (3.46%; 5.88%; 3.43%) because fiber lumen diameter (3.10 micron) of *Dendrocalamus* asper was higher than *Schizostachyium brachycladum* (0.80 micron) (Figure 4).

Extractives materials fill up lumen and cell wall of pore and fiber. Soluble alcohol benzene extractives of *Dendrocalamus* asper was higher than *Schizostachyium brachycladum* that makes *Dendrocalamus* asper might resist against termite attack. According to Munawar (2001), soluble alcohol benzene extractives of *Gigantochloa apus* was lower (3.05%) than *Bambusa vulgaris* (3.20%), *Gigantochloa atroviolacea* (3.14%) and *Gigantochloa robusta* (3.10%) that termite more prefer to attract *Gigantochloa apus*. In other word, the lower soluble alcohol benzene extractives reside in bamboo the more damage of bamboo by termite. It is possibly *Dendrocalamus* asper resist against termite than *Schizostachyium brachycladum*. According to Supriana (1983) cited by Munawar (2001), termite will look for other part of materials if it contain non toxic substance. Resistance of wood against termite depend on toxic substance within the extractives. Generally, extractives of bamboo contain non toxic substances, therefore it has to treat with preservatives to resist termite, fungus and powder post beetle.

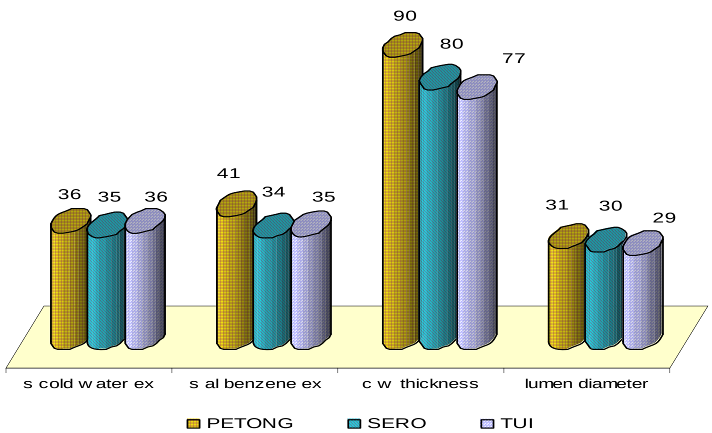

Figure 4. Comparison of bamboo based on species in term of soluble cold water (%), soluble alcohol benzene extractives (%), cell wall thickness (micron), and lumen diameter of fiber (micron).
Notes: extractives content and fiber lumen multiply by 0.1
cell wall thickness multiply by 0.01

Holo cellulose (73.63%), lignin (27.37%) content and cell wall thickness (0.90 micron) of *Dendrocalamus* asper higher than *Schizostachyium brachycladum* (71.96%; 26.18%; 0.80 micron) and than *Schizostachyium lima* (72.77%; 26.05%; 0.77 micron) (Figure 5). This findings indicate that *Dendrocalamus* asper could be transform into higher pulp than other species but its lignin is higher. The more higher lignin content of *Dendrocalamus* asper may cause increasing of chemical solution to separate lignin from pulp.

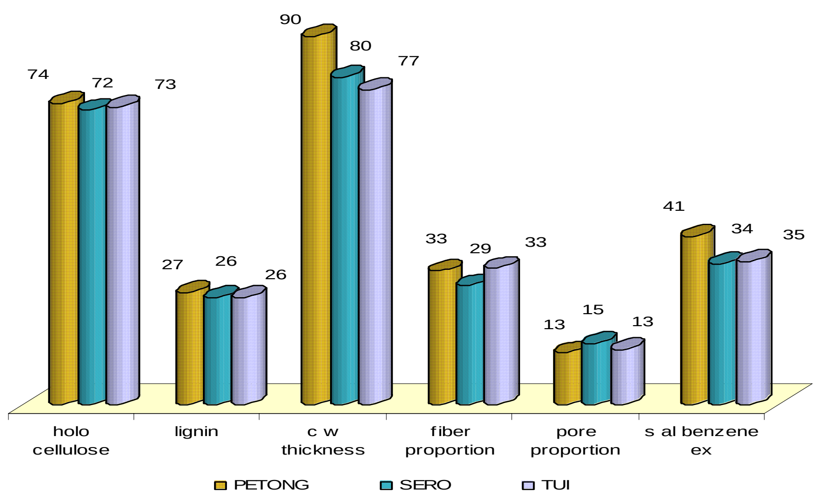

Figure 5. Comparison of bamboo based on species in term of holo cellulose (%), lignin (%), cell wall thickness (micron), fiber proportion (%), and soluble alcohol benzene extractives (%).
Notes: cell wall thickness multiply by 0.01
soluble alcohol benzene extractives multiply by 0.1

Alpha cellulose content, holo cellulose and lignin content depend on cell wall thickness and fiber proportion. The more lignin content of bamboo, the more resist bamboo against termite because lignin is difficult to break down. Holo cellulose (73.63%) and lignin (27.37%) content of *Dendrocalamus asper* higher than *Schizostachyium brachycladum* (71.96%; 26.18%) and *Schizostachyium lima* (72.77%; 26.05%). Cell wall thickness of *Dendrocalamus asper* (0.90 micron) higher than *Schizostachyium brachycladum* (0.80 micron) and *Schizostachyium lima* (0.77 micron), although fiber proportion of *Dendrocalamus asper*

(32.64%) was lower than *Schizostachyium lima* (33,30%). It can be said that chemical component of cell wall not only depend on fiber proportion but also thickness of the cell wall. Chemical component of cell wall might be higher because of proportion of fiber is higher than the other species, although its thickness is lower.

Pore proportion of *Schizostachyium brachycladum* (14.96%) was higher than *Dendrocalamus asper* (12.58%) and *Schizostachyium lima* (13.23%) (Figure 5) indicate that *Schizostachyium brachycladum* easily attack by powder post beetle because sugar and starch are main substance of pore cell. Soluble alcohol benzene extractives (3.43%) of *Schizostachyium brachycladum* was lower than *Dendrocalamus asper* (4.10%) and *Schizostachyium lima* (3.49%) that it easily attack by termite. Traditionally, local people prefer *Schizostachyium brachycladum* to make fences, rafting, and fish traps, although its extractives content lower than other species. This contradiction have to clarify by a study to determine sugar and starch content of *Schizostachyium brachycladum*. It is important to determine soluble NaOH extractives content of *Schizostachyium brachycladum* that resist fungus attack, and soluble alcohol benzene extractives against termite.

Lack of information about chemical component of bamboo have to resolve with study of mayor and minor species of bamboo that important to develop bamboo for local people and industry. Study about location in relation with thickness of bamboo to clarify presumption of local people that bamboo grown at wet condition generate thicker bamboo.

Chemical component and anatomical features according to portion of bamboo cane.

There is significant effect of cane's portion to the soluble hot water extractives, soluble alcohol benzene extractives, fiber length, fiber diameter and lumen, proportion of parenchyma and fiber. Alpha cellulose (46,04%) and lignin (26,67%) was higher at the bottom part than middle portion 44,98%; 26,57%) and top portion (43,89%; 26,36%) of the cane (Figure 6).

Alpha cellulose content at the bottom of the cane was higher than middle and top portion, This findings indicate that bottom portion could be transform into higher pulp than other part of the cane. Result of study by Ulfah (1999) on three species of bamboo indicated that bottom portion of the cane contain higher alpha cellulose (45,38%) than middle (44,48%) and top portion (43,68%), but lignin content (25,64%) at the bottom was lower than middle (25,99%) and top portion (26,22%).

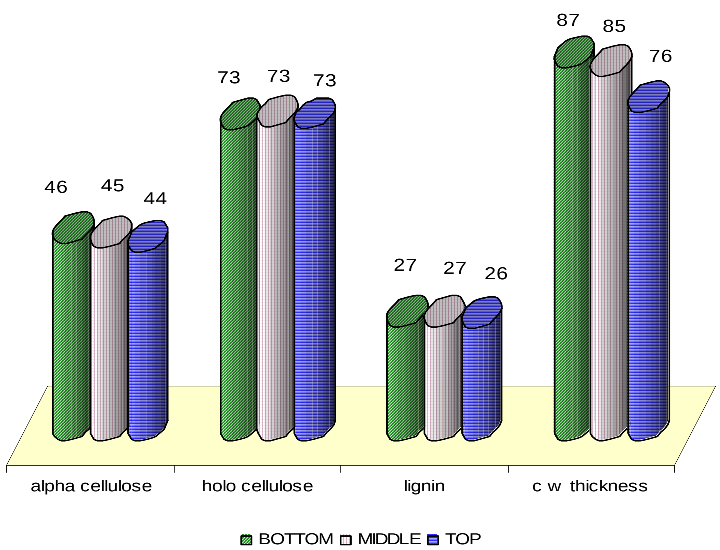

Figure 6. Comparison of bamboo based on portion of the cane in term of alpha cellulose (%), holo cellulose (%), lignin (%) and cell wall thickness (micron).
Notes: cell wall thickness multiply by 0.01

Cell wall thickness of bottom portion (0,91 micron) was higher than middle (0,80 micron) and top portion (0,77 micron), that makes alpha cellulose content of bottom portion was higher than middle and top portion. Holo cellulose content (72.54%) of bottom portion was lower than middle (73.14%) and top portion

(72.67%). Main component of cell wall is cellulose and lignin which is to bind cell that makes bamboo and wood became rigid. Lignin is thermo plastics substance that makes bamboo ease to shape by heat treatment. Heat treatment have been carried out by people to make furniture and handicraft from bamboo and rattan.

Soluble hot water (6,52%) and soluble alcohol benzene (3,89%) extractives of bottom portion was higher than middle (5,44%; 3,82%) and top portion 5,43%; 3,37%). This is correlate with pore proportion (14,60%), lumen's fiber diameter (3,23 micron), and cell wall thickness 0,91 micron) of bottom portion was higher than middle (13,43%; 3,02 micron; 0,80 micron) and top portion (13,13%; 0,27 micron; 0,77 micron) (Figure 7).

Amount of extractives content of bamboo depend on pore proportion, pore diameter, lumen's fiber diameter and cell wall thickness that it is hold in lumen and cell wall. Although extractives content of bottom portion was higher but it can protect the portion from termite and fungus. The most important is toxicity of the extractives. According to Ulfah (1999), soluble hot water extractives (6,58%) of bottom portion was higher than middle (6,36%) and top portion (5,64%). Soluble alcohol benzene extractives (3,70%) of bottom portion was lower than middle (3,74%) but it was higher than top portion (3,16%).

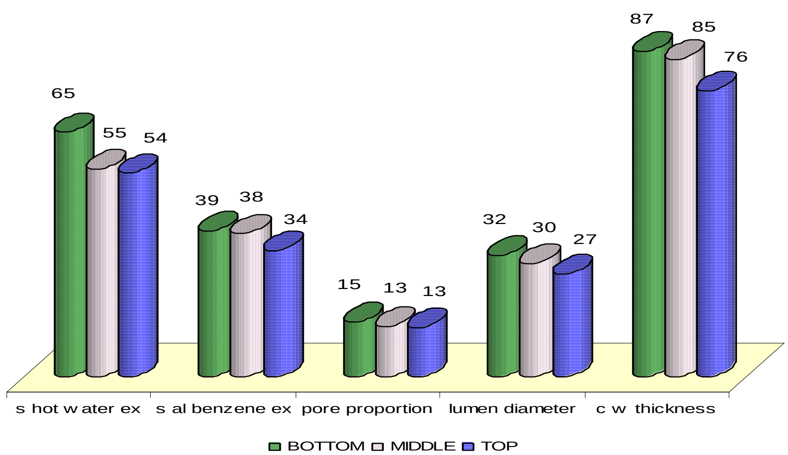

Figure 7. Comparison of bamboo based on portion of the cane in term of soluble hot water extractives (%), soluble alcohol benzene extractives (%), pore proportion (%) lumen's fiber diameter (micron) and cell wall thickness (micron).
Notes: soluble hot water and alcohol benzene extractives, and lumen's fiber diameter multiply by 0.1; cell wall thickness multiply by 0.01

Conclusion and Suggestion.

Conclusion

1. There was significant effect of location to the chemical component and anatomical features of bamboo such as lignin content, diameter of fiber, diameter of lumen fiber and proportion of parenchyma cell.
2. There was significant effect of species to the anatomical features of bamboo such as length and diameter of fiber.
3. There was significant effect of portion of the cane to the chemical component and anatomical features of bamboo such as soluble hot water extractives, soluble alcohol benzene extractives, fiber length and diameter, and lumen's fiber diameter.
4. Chemical component and anatomical features of three species of bamboo such as *Dendrocalamus asper*, *Schizostachyium brachycladum*, *Schyzostachyium lima* from three locations such as Buria, Morekao and Tala, and three portion of the cane was soluble cold water (3.10%-3,79%) ; soluble hot water (5,43%-6,23%) , soluble alcohol benzene (3,37%-4,10%), alpha cellulose (3,37%-4,10%); holo cellulose (71,97%-75,57%); lignin (26,00%-27,37%); fiber length (3,40mm-3,96mm); fiber diameter (4,34micron-4,91micron); lumen's fiber diameter (2,74micron-3,23micron); cell wall thickness (0,76micron-0,91micron); parenchyma proportion (51,95%-56,85%); fiber proportion (27,81%-62,66%,); pore proportion (12,39%-14,60%).

Suggestions.

1. Following study have to be make is chemical component of bamboo such as starch and sugar content, soluble NaOH extractives of commercial and less known bamboo species, anatomical features such as pore diameter and vascular bundle which is not accomplish in this study.
2. There is correlation between starch and sugar content with powder post beetle attraction to the bamboo. It is important to determine what the best time to cut bamboo that may reduce powder post beetle attraction.
3. Traditionally, local people submerge bamboo in water (river) to reduce powder post beetle attraction. It is important to know how long submerge affect chemical component, physic and mechanical properties of bamboo.

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