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Investigation on Chemical Properties of Some Myanmar Bamboo Species

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1 Introduction

Bamboo is the most versatile forest product and some people praised crude oil as *black gold*, rubber as *white gold*, teak as *yellow gold* and bamboo as *green gold*. In India, bamboo is well-known as *the poor man's timber*, while in China, bamboos is considered as *a friend of the human being* and in Vietnam, it is called *brothers by the Vietnamese people*. Bamboo which belonged to the family Gramineae and now it is placed under Poaceae has a wide range of distribution in Myanmar. It belongs to over a hundred genera, covering over 1000 different species, ranging in size from less than a few feet to well over 100 feet in height. Myanmar has more than 90 bamboo species.

Bamboo-based development can improve the environment by substituting for deforestation and by providing good inexpensive houses, schools and clinics. It also can provide a wide range of employment opportunities at all levels of skill and capital involvement and is particularly suitable for community-based micro-credit financed activities. The use of bamboo should be encouraged in watershed management, soil and water conservation, rehabilitation of degraded land and rural development. Bamboo resources are concentrated in rural areas, and most of the rural people make their living in connection with bamboo cultivation and processing wholly or partially. Therefore the successful exploitation of bamboo resources is one of the useful ways for the economic development of poor rural areas.

Bamboo can often provide innumerable opportunities for environmental improvement by sequestration of carbon and yielding more oxygen than equivalent stand of trees and working as a natural environmental cleaning system. Bamboo shoot are rich in fiber, protein and minerals. The process product developed from bamboo shoot can provide food and nutritional security to rural people. Bamboo bio-mass is a potential alternative source for bio-energy and opportunity to pioneer another industrial usage through gasification to produce electricity. Bamboo a versatile material, has found uses in manufacturing pulp and paper, panel products, construction material, high strength fiber composites and an array of modern new generation bamboo products. The world will probably face a shortage of wood-base fibre in the future. Bamboo can substitute for wood-base fibre in the future.

For the efficient utilization of bamboos, Bamboo Products Processing Section, the ITTO Bamboo Project have to identify promising bamboo species for quality bamboo products by analyzing the chemical properties for 15 main bamboo species, which are commonly used for furniture, handicraft and pulp and paper. Among these 15 species, six bamboo species, Tin (*Cephalostachyum pergarcile*), Kyathaung (*Bambusa polymorpha*), Myin (*Dendrocalamus strictus*), Thaik (*Bambusa tulda*), Kyalo-wa (*Dendrocalamus brandisii*) and Wanet (*Dendrocalamus longispathus*) had already been investigated and presented in last research congress which held on 2006. The remaining 9 bamboo species, Tabindaing wa (*Bambusa longispiculata*), Wagyi (*Dendrocalamus calostachys*), Wabogyi (*Dendrocalamus giganteus*), Wabo myet san gye (*Dendrocalamus hamiltonii*), Wanwe (*Dinochloa macellandii*), Kayin wa (*Melocanna baccifera*), Waya (*Gigantochloa nigrociliata*), Thana wa (*Thyrsostachys oliveri*) and Htiyo wa (*Thyrsostachys siamensis*) are investigated and discussed in this paper.

The chemical composition of bamboo is of special interest and great importance to the pulp and paper industry, bamboo based industry and preservation for quality bamboo products. The interesting chemical composition of bamboo, such as hot water solubility, 1% NaOH solubility, alcohol/benzene solubility, cellulose, ash, silica, and starch contents are investigated.

The objective of this paper is to investigate the test results of chemical properties of nine bamboo species, which are useful for comparison of bamboos, for further processing and for selection of a species for specific purposes.

2 Literature review

The chemical constituents of the bamboo culm tissue provide the nourishment for the attacking organisms. The main components of bamboo are similar to those of wood. Mainly are cellulose as a skeleton (approximately 40 %), hemi-cellulose as a matrix (approximately 25 %) and lignin as an incrusting material (approximately 25 %); these values are comparable with those of wood. Minor components are water-soluble compounds, sugars, starch, tannins, waxes and inorganic salts. The composition varies slightly according to species, age, culm part and growing conditions.

Hemi-cellulose consists of pentosan mostly, the amount of hexosan is very little. More than 90 % of hemi-celluse is xylan, the experiment shows: bamboo xylan is D-glucuranate arabinoxylan, containing 4 oxygen-methyl-D-glucuranate, L-arabinose, and D-xylose. The molecule ratio is 1.0: 1.0-1.3:24-25. The composition of arabinoxylan of bamboo is different from that of needled and broad leaved trees. The polymerized molecules of bamboos are more than that of trees. The pentose content of bamboo is 19-23 %, approaching to that of broad-leaved trees, much higher than that of needled-leaved trees (10-15 %). This means it is acceptable to extract uronic acid in the process of pulping and hydrolysis (Zhang Qisheng et al., 2001).

Lignins are generally classified into three major groups based on their structural monomar units. Gymnosperm lignin is a dehydrogenation polymer of conifer alcohol. Angiosperm lignin is a mixed dehydrogenation polymer of conifery and sinapyl (2) alcohols, and grass lignin is composed of mixed dehydrogenation polymer of coniferyl-, sinapyl- and p-coumaryl (3) alcohols. in grass lignin p-cumaric is esterified to the side chains of the lignin polymer (Takayashi Higuchi, 1987).

The specific features of bamboo lignin lie in the existence of dehydrogenated polymerides and 5-10% of acrylic ester. The lignin content of bamboo of 1 year of age is in the range of 20-25%, approaching to broad-leaved wood and some grass (such as wheat straw), slightly less than needle-leaved. Less lignin content means less consumption of chemicals in pulping process and easier pulping process.

The chemical composition of bamboo is of special interest to the pulp and paper industry and will directly influence the quality of pulp and resultant paper. The following components and percentage are generally cited: holocellulose (61-71%), lignin (20-30%), ash (1-5 (-9)%, solubility in cold water (1.6-4.6), hot water solubility (3.1-7.0), alcohol-benzene and water solubility implies increased consumption of chemicals in pulping. The other nutrient substances such as protein (1.5-6%), glucose (2%), starch (2.2-5.18%), as well as fat and wax (2.8-3.55%) are still included. So they are very susceptible to mould rotting and

moth eating during their transportation and storage, which factors make their span of use much shorter.

It can also provide information for bamboo preservation. The 1% NaOH solubility indicates the amount of low molecular weight carbohydrates consisting mainly of hemicellulose and degraded cellulose; as such , it may indicate the degree of decay, e.g. by fungi, heat and oxidation. Silica is the main constituent in ash and ultimately present problem for the pulp and paper making process. The silica content of bamboo culm is generally higher than that of wood (0.5-4.0%) and mostly deposited in the epidermis. Since bamboo contains more impurities than wood, cooking is more costly and pulp yield is less (Drasfield and Widjaja, 1995).

However, different constituents are preferred by fungi and insects. The starch content is of considerable importance for its vulnerability to insects and staining fungi. The starch granules are accumulated in the parenchyma cells, in culm fibers and subterranean rhizome. The amount of starch varies generally between 2-6%, but can reach up to 10%. It is influenced by age, height and site, whereby the lower part contains less starch than the middle and top portions (Walter et. al., 2003)

The proximate chemical compositions of bamboo culms are generally similar to those of hardwoods, except that alkaline extract, ash and silica contents are higher than in hardwoods. High silica content causes scaling during evaporation of the spent liquor for recovery of the chemicals in pulping.

3. Material and Methods

3.1 Material

The most abundant and well-known 9 bamboo species were selected for testing chemical properties. These species are:

1. Tabindaing wa (*Bambusa longispiculata*),
2. Wagyi (*Dendrocalamus calostachys*),
3. Wabogyi (*Dendrocalamus giganteus*),
4. Wabo myet san gye (*Dendrocalamus hamiltonii*),
5. Wanwe (*Dinochloa maclellandii*),
6. Kayin wa (*Melocanna baccifera*),
7. Waya (*Gigantochloa nigrociliata*),
8. Thana wa (*Thyrsostachys oliveri*),
9. Htiyo wa (*Thyrsostachys siamensis*)

Tabindaing wa, Wabogyi and Waya were collected from Kawhmu township of Yangon Division; Wanwe and Htiyo wa were collected from Pyinmana Township, Nay Pyi Taw; Thana wa was collected from Madaya Township, Mandalay Division; Wabo myet san gye was collected from Thabaitgyin Township of Mandalay Division, Wagyi was collected from Pindaya Township of ShanState and Kayin wa was collected from Ye Kyi Township of Ayeyawadi Division.

3.2 Methods

Bamboo culms were selected from various clumps in the standing condition. Seven to ten clumps per each species were randomly chosen, and six culms were randomly selected from each clump. They were sound and free from any defects, and were representative of average dominant bamboo culms of the locality. They were at least 3 years old.

Before felling, one ring was marked at a height of one meter from the ground with silver paint. The name of the species, the name of locality, the age of the culms and date of felling and transportation were recorded.

3.2.1 Chemical Properties

The approximate chemical analysis of bamboo is based on TAPPI methods using three replicates, which were randomly cut from each portion. For chemical study, each bamboo was divided into three portions, Bottom (B), Middle (M) and Top (T). All samples were ground to 60-80 mesh size.

The following chemical properties were tested:

(i)	Hot water solubility	TAPPI T 207 (1978)
(ii)	1% NaOH solubility	TAPPI T 212 (1978)
(iii)	Alcohol/benzene solubility	TAPPI T 204 (1978)
(iv)	Cellulose	TAPPI T 203 (1978)
(v)	Ash	TAPPI T 15 (1978)
(vi)	Silica	
(vii)	Starch	

3.2.1.1 Hot water solubility

Oven-dried ground 60-80 mesh size sample (2±0.1 g) was weighed and placed in a flask and 100 ml of distilled water was added. Then the flask was attached with reflex condenser and placed in the boiling water bath at (100º C). Boiling was continued for three hours. After boiling, the content of the flask was filtered with a previously oven-dried, cooled and weighed 1-G-1 crucible. The residue in the flask was washed with hot water and poured in the same crucible to filter all content in the flask. The crucible with content was kept in an oven at (105±2º C) for eight hours. After eight hours, the crucible was removed from oven and cooled in desiccators and weighed. Oven drying, cooling and weighing were repeated until constant weight of the crucible with content was obtained. Material dissolve in hot water was calculated when the weight of crucible with content obtained. Then, hot water solubility percent was calculated. The same procedure was repeated for each of the remaining samples.

% of Hot water solubility = (B-C)/A x 100

Where, A = OD Wt. of sample in gram

B = OD Wt. of 1-G-1 crucible in gram

C = OD Wt. of crucible with content in gram

3.2.1.2 Alcohol - Benzene Solubility

Alcohol - Benzene Solubility of raw material consists of all components soluble in organic solvent. It principally consists of all components soluble in organic solvent. It principally consists of resins, fatty acid, their esters, waxes and saponifiable substances. Low single organic substance is capable of removing the substances.

5 g of oven-dried sample was weighed and placed in a previously oven-dried, cooled and weighed porous thimble. Then, thimble was placed in a soxhlet apparatus and extracted with (250 - 300 ml) alcohol-benzene mixture (33 parts of ethyl alcohol and 67 parts of benzene) for six hours or until the color of mixture was clear. After extraction, thimble was removed from the soxhlet apparatus and dried in the oven at (105±2ºC) for eight hours. After oven drying, thimble was cooled in desiccators and weighed. Oven drying, cooling and weighing were repeated until constant weight of the thimble with content was obtained. Alcohol-benzene solubility percent was calculated when the constant weight of thimble with content was obtained. The same procedure was repeated for each of the remaining samples.

% of Alcohol-benzene solubility = (B-C)/A x 100

Where, A = OD Wt. of sample in gram
B = OD Wt. of thimble in gram
C = OD Wt. of thimble with content in gram

3.2.1.3 Holocellulose content

Holocellulose is the major component of cell wall material (60-80 %). It is comprised of the total carbohydrate with cellulose, hemicellulose fraction, carbohydrate lignin and cellulosis raw material. However, slight retention of lignin in holocellulose and slight degradation of hollocellulose during the process of each determination can not be ignored. Physical and chemical study of holocelluse gives an idea about quality and quantity of pulp and paper to produce.

Oven-dried extracted free sample (5 g) was weighed and placed in a flask. 60 ml of distilled water, sodium chlorite (1.5 g) and glacia (0.5 ml) were added to the flask. The flask was covered with cap and placed in the water bath at 70-80º C for one hour. After one hour sodium chlorite (1.5 g) and acetic acid (0.5 ml) were again added to the flask. This process was repeated 4-5 times or until the content in the flask became white. Then, the content in the flask was filtered with 1-G-2 crucible. After filtration, the crucible was washed with distilled water and finally with acetone. The crucible was dried in an oven at 105±2 ºC for eight hours. After eight hours, crucible was removed from oven, cooled in desiccators, and weighed. Oven drying, cooling and weighing were repeated until the constant weight of the crucible with content was obtained. Holocellulose content was calculated when the constant weight of crucible with content obtained. The same procedure was repeated for each of the remaining samples.

% of Holocelluse content = (B-C)/A x 100
Where A = OD Wt. of extracted free sample in gram
B = OD Wt. of 1-G-2 crucible in gram
C = OD Wt. of 1-G-2 crucible with content in gram

3.2.1.4 Ash content

The ash content in any raw material can be estimated for the mineral salt like silica, calcium, magnesium, etc. present in the meal.

Carefully weighed oven dried sample (2 g) was placed in a previously oven dried, cooled and weighed crucible. The crucible was ignited in a Muffle furnace at 575±25 ºC for four hours. After ignition, crucible was cooled in desiccators and weighed. Heating, cooling and weighing were repeated until constant weight of the crucible with ash was obtained. Ash content was calculated when the constant weight of the crucible with ash content was obtained. The same procedure was repeated for each of the remaining samples.

% of Ash content = (B-C)/A x 100
Where A = OD Wt. of sample in gram
B = OD Wt. of crucible in gram
C = OD Wt. of crucible with ash content in gram

3.2.1.5 Silica content

Oven-dried sample 5 g was placed in a beaker and 15 ml of concentrated nitric acid was added. Then 5 ml of 75% perchloric acid was slowly added. The beaker was heated on a hot plate until the mixture became white. After heating, 15 ml of dilute hydrochloric acid was added. The content in the beaker was filled with Whitman No. 4. The residue was washed with distilled water (at least 500 ml) to free chlorine-ion. The residue and filter paper were placed in a previously oven-dried, cooled and weighed crucible when the filter paper dried. The crucible was ignited in an electric furnace at (600-700º C) for 15 minutes. Then the crucible was cooled in desiccators and weighed. Ignition, cooling and weighing were repeated until the constant weight of the crucible with silica content was obtained.

% of Silica content = (B-C)/A x 100
Where A = OD Wt. of sample in gram
B = OD Wt. of crucible in gram
C = OD Wt. of crucible with silica content in gram

3.2.1.6 Starch content

Starch is normal constituent in sapwood of the hard- and softwood species, where it is frequently found in the parenchymatous tissues. Starch is readily recognized from the blue color formed upon staining with diluted solution of iodine by using colorimeter spectronic 20.

The specimens were chipped, dried at 50 ºC in oven and ground before being passed sulphuric acid and used for starch analysis with methods suggested by Browning (1978) and Humphreys and Kelly (1961).

4 Results and Discussions

Table 1 shows the ash content in different portions of culm of nine bamboo species.

Table 1: Ash contents of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	2.147	1.894	2.064	2.484
Wagyi	5.440	4.981	5.118	6.220
Wabogyi	1.835	1.681	1.844	1.981
Wabo myet san gye	5.343	6.517	3.817	5.696
Wanwe	5.138	4.463	5.054	5.897
Kayin wa	3.717	3.389	3.789	3.974
Waya	4.323	4.715	4.163	4.092
Thana wa	3.654	3.430	3.594	3.397
Htiyo wa	11.844	10.405	11.780	13.346

It was found that Htiyo wa was high in ash content. The ash content of the nine bamboo species ranged from 1.8 % to 11.8%. Bamboo culm with ash content of (0.8-9.75 %) can be used for machine made products such as skewer and chopsticks (Semana et. al., 1967).

Table 2: Silica content of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	0.646	0.452	0.593	0.895
Wagyi	3.716	2.615	3.610	4.922
Wabogyi	0.956	0.698	0.961	1.209
Wabo myet san gye	4.111	4.594	3.011	4.729
Wanwe	3.747	2.852	3.677	4.711
Kayin wa	1.818	1.430	1.878	2.146
Waya	2.785	3.064	2.644	2.646
Thana wa	2.339	2.077	2.327	2.612
Htiyo wa	5.051	3.422	5.414	6.317

Table(2) showed that Htiowa was also high in silica content (5%). High silica content causes scaling during evaporation of the spent liquor for recovery of the chemicals in pulping.

Table 3: Hot water solubility of the tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	8.696	8.087	8.685	9.317
Wagyi	11.055	11.555	11.580	10.029
Wabogyi	7.765	7.852	7.672	7.772
Wabo myet san gye	9.386	9.722	9.140	9.296
Wanwe	20.638	21.910	20.914	19.091
Kayin wa	9.494	9.881	9.446	9.154
Waya	12.671	12.670	12.139	13.203
Thana wa	17.335	17.276	17.401	17.329
Htiyo wa	12.949	14.509	12.227	12.949

The extractive contents, particularly the cold and hot water solubles are important in the predetermination of water soluble extractives such as tannin, starch, sugar, pectin, and phenolic compounds within the woody materials (Janis, 1969). The results in table 3 showed that Wagyi, Wanwe, Waya, Thana wa and Htiowa contained high concentration of hot water soluble (11-20%), which may influence the susceptibility to insect and fungal attacks (Plank, 1950). The general range of hot water solubility is (3.1-7.0%). (Dransfield and Widjaja, 1995). Therefore, all tested species were higher than the general amount.

Table 4: 1% NaOH solubility of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	25.948	25.278	26.160	26.407
Wagyi	26.381	25.215	26.498	27.431
Wabogyi	19.500	19.020	19.126	20.354
Wabo myet san gye	23.298	22.810	21.237	25.846
Wanwe	33.523	32.973	33.49	34.107
Kayin wa	25.544	25.415	25.530	25.686
Waya	26.325	26.142	25.826	27.008
Thana wa	30.072	28.678	30.360	31.177
Htiyo wa	32.86	31.874	33.965	32.860

The 1% NaOH solubility varied (19-33%). The highest values for all three parts are observed in Wanwe (33.5%) and Htio wa (32.8%). Wabogyi is low in hot water solubility and 1% NaOH solubility content due to the low content of sugar groups. But compared to the general range of 1% NaOH solubility(15-39%) , all tested species contained suitable amount.

Table 5: Alcohol-Benzene solubility of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	8.752	8.407	8.910	8.939
Wagyi	9.577	8.372	10.013	10.347
Wabogyi	8.235	8.043	8.084	8.579
Wabo myet san gye	7.011	5.930	7.688	7.415
Wanwe	9.148	9.395	10.179	7.871
Kayin wa	7.267	6.620	7.194	7.988
Waya	9.373	8.650	9.467	10.003
Thana wa	8.321	8.500	8.705	8.759
Htiyo wa	8.091	8.169	8.193	7.911

Regarding the alcohol-benzene solubility of tested bamboo species, it was found that Wagyi possessed the highest average value (9.5%) while Wabo myet san gye wa was the lowest (7.0%) (Table5). Normally, the alcohol-benzene solubility should be range between (0.3 – 7.8%) . All tested species are higher than these range.

Table 6: Starch content of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	0.111	0.109	0.109	0.115
Wagyi	0.395	0.348	0.432	0.412
Wabogyi	0.204	0.209	0.209	0.194
Wabo myet san gye	0.303	0.236	0.311	0.361
Wanwe	0.184	0.189	0.178	0.186
Kayin wa	0.241	0.360	0.225	0.137
Waya	0.128	0.124	0.117	0.144
Thana wa	0.553	0.545	0.560	0.554
Htiyo wa	0.318	0.299	0.318	0.338

The starch content of the selected bamboo species were determined using colourimetric measurement of the color formed in the reaction of amylose in bamboo starch with iodine. The starch content of all tested species is lower than 1%. Bamboo species with less than 1% starch content is considered as good quality for construction purposes (Sulthoni, 1985).

Table 7: Cellulose content of tested bamboo species (%)

Species	Average	Bottom	Middle	Top
Tabindaing wa	48.809	47.356	49.532	49.538
Wagyi	41.927	42.627	41.853	41.301
Wabogyi	55.400	55.189	55.574	55.438
Wabo myet san gye	46.023	46.459	43.829	47.781
Wanwe	47.477	48.429	48.296	45.705
Kayin wa	45.631	45.467	46.299	45.128
Waya	58.029	56.074	58.035	59.979
Thana wa	49.957	49.156	50.492	50.222
Htiyo wa	44.922	46.647	45.853	42.266

Table 7 showed that all tested bamboo species contained (41-55%). It is higher than the required amount of cellulose contents (40-48%). The cellulose content of a plant material is important to industries like pulp, paper and wood hydrolysis because it is a key factor affecting the quality of these products.

According to the data of all tables, it showed that ash and silica contents are high in top part of the culm and alcohol/ benzene solubility and 1% NaOH solubility constituents are also high in top part of the culm. It meant that silica and some other extractives such as tannin, starch, sugar, pectin and phenolic compound are present at the top of the culm.

5 Conclusions and recommendations

All tested bamboo species can be considered as construction purpose. According to the chemical composition, all tested bamboo species except Htiyo wa can be used for machine made products such as skewer, chopstick, parquet and mat board. However, all tested species were contained suitable amount of 1% NaOH solubility. It will be low susceptible to insect and fungal attacks. Therefore, it would be low necessary to treat with appropriate preservatives before putting into uses.

All tested species contain high amount of alcohol-benzene solubility and hot water solubility. It mean that, there will be increased consumption of chemical during the pulping process. Cellulose content of tested bamboo species are favorable for pulp and paper making, but they also have a high silica content, which disturbs the chemical recovery systems in chemical pulping. Because of the silica and mineral contents, it will be difficult to recover black liquor in the pulping process.

The season also determines the amount of starch considerably. It is higher in the dry season than in the rainy season because starch has been utilized for new shoots in the rainy season. Seasonal changes of starch content should be considered when planning for harvest. The culm should preferably be cut when the amount of starch is the lowest. The period depends much on the geographical region as well.

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