STUDY ON PREPARATION AND CHARACTERIZATION OF WHITE BAMBOO CHARCOAL

Zar Che Win[1], Khin Thet Ni[2], Khin Hnin Aye[3]

Abstract

In this research work, the physico-chemical characteristics (moisture, ash, volatile matter, lignin content, etc,.) of two types of bamboo Kyakhatwa *(Bambusa arundinacea)*, Kyathaungwa *(Bambusa Polymorpha)* were determined and they were used to prepare white charcoal by forced air type updraft kiln and by makeshift furnace. The physico-chemical properties of prepared white charcoal samples were compared with those of the commercial white charcoals from Japan and Myanmar. The morphological analysis of prepared charcoals and commercial white charcoals was conducted by SEM (Scanning Electron Microscopy) method. The decolourization property of prepared white charcoals and commercial white charcoals was determined by using 0.01M potassium permanganate solution. According to the results, charcoal made by makeshift furnace from Kyathaungwa *(Bambusa polymorpha*) was found to have the highest fixed carbon content (86.24 %w/w) among the charcoals samples made by different methods and also higher than that of two commercial white charcoals. All white charcoal samples prepared from bamboo had a greater number of pores than commercial white charcoal. Therefore, the absorption capacity for decolourization of the prepared white charcoal was higher than that of both commercial white charcoals.

Keywords: white charcoal, decolourization, makeshift furnace, updraft kiln

Introduction

Charcoal is a light, black, porous material resembling coal, with about 85 per cent carbon. It is produced by heating biomass under a system of controlled supply of air. This can be done by the conventional pit method, in brick or metal kilns, or in drums. Wood, sugarcane waste, rice husk and bamboo are commonly used for making charcoal. Charcoal made from bamboo has good properties, similar to wood and other ligno-cellulosic material in terms of high carbon content and calorific value (Jian, 2004).

Two types of charcoal exist; black charcoal and white charcoal. These charcoals are produced using different burning methods. Although they are produced in a substantially similar way, the quality of the charcoals is totally different depending on how the flame is extinguished (Guan, 2004). Compared to ordinary black charcoal, the technology of making white charcoal is difficult. The technology is mostly used in Japan and parts of China and Korea. White charcoals are now being used in the scientific world for industrial purposes such as electronic components and medical applications. Black charcoal renders the hands black when holding, but white charcoal does not make it because it is hard like cast iron (Jian, 2004).

White charcoal is created by carbonizing the wood at a moderately low temperature, then the kiln temperature is increased to around 1000 ° C near the end of the process to make the wood red hot. It is important to be quite skilled in removing the charcoals, which have turned deep red, from the kiln when making white charcoal and smother it quickly with a powder covering to cool it. The powder is a mixture of sand, ash, and soil. This will give the charcoal

[1] Dr, Assistant Lecturer, Department of Industrial Chemistry, Dagon University
[2] Dr, Professor & Head (Retired), Department of Industrial Chemistry, University of Yangon
[3] Dr, Professor & Head, Department of Industrial Chemistry, Yadanabon University

layer a whitish hue. This is where it originated the name "white charcoal." The rapid temperature rise, followed by rapid cooling, burns the outer layer of the wood, leaving a smooth hard surface. It is also regarded as a "hard charcoal". Mangrove (an evergreen tree from tropical coasts) can be used in the manufacture of charcoal. Bamboo is producing an excellent charcoal. It not only provides a new way of using bamboo, but by reducing pollutant contamination, it also promotes environmental protection. Bamboo charcoal is a material of outstanding absorption properties that is environmentally friendly (Oya, 2002).

High-temperature carbonized bamboo charcoal has such properties as being dense and porous, with a large specific surface area of micro-hole structures; being rich with natural minerals; having good release of far-infrared ray; having good electric conductivity, etc. Bamboo charcoal is a functional resource for the protection of the environment and has developed rapidly in recent years because (1) the wood that can be used as high-grade charcoal decreased rapidly and almost exhausted; (2) the bamboo harvest period is short because it grows very quickly. As a result, producing bamboo charcoal does not harm forest and environment; (3) bamboo charcoals are similar in characteristics to and can substitute high-quality hardwood charcoal; (4) bamboo charcoal is strong in strength and easy to produce into different shapes. Although wood charcoal makes a good fuel, bamboo charcoal is almost three times as porous as wood and bamboo charcoal contains a large amount of minerals, such as iron, manganese and potassium (Guan, 2004).

Myanmar is one of the bamboo-rich countries in the world. Millions of bamboo poles are harvested each year, most of which go to paper making industry and used as a major building material in rural area. Only less than 1% of it is used for bamboo charcoal (Takaya, 1999). Therefore, preparation of bamboo white charcoal using white charcoal process would be one useful value added application of bamboo in Myanmar.

In this research, two types of bamboo were carbonized to produce white charcoal using two types of furnaces; forced air type updraft kiln and makeshift furnace.

Materials and Methods

Raw Materials

Two types of bamboo Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa Polymorpha*) were collected from Hlaing Township, Yangon Region and Kan Myint village, Phayargyi Township, Bago Region. They were collected at the age of over 3 years. They were cut into required size and air dried for one day. Forced air type updraft kiln and makeshift furnace were constructed for the preparation of white bamboo charcoal and the schematic diagrams were shown in Figures (1) and (2).

Preparation of White Charcoal

White bamboo charcoal was made by carbonizing the bamboo at a moderately low temperature in forced air type updraft kiln with and without sagger and in makeshift furnace according to the process as shown in Figure (3). As shown, the air dried bamboo were loaded into the furnace and ignition was started. For ignition, firewood and wood charcoal was used for forced air type updraft kiln and electricity was used for makeshift furnace to start heating. For 2 hours, carbonization was conducted in both forms of furnaces at a relatively low temperature

(800-900 °C). Once the end of the cycle was near, to make the bamboo red hot, the kiln temperature was increased to around 1000 °C -1100 °C. The air blower was used to increase the heating temperature of forced air type updraft kiln and temperature controller was used to control the temperature of makeshift furnace. The temperature of the updraft kiln during carbonization could be noted by using pyrometer. Deep red charcoal was extracted from the kiln at the end of the carbonization process and immediately smothered it with a powder coating and cooled it. The powder is a sand, soil and ash mixture. This would then give the surface of the charcoal a whitish hue. The rapid increase in temperature followed by rapid cooling resulted in a smooth hard surface. After cooling for 2 hours, charcoal samples were taken out from the mixture, packed in the plastic bags and stored for further analysis. The steps for the preparation of white charcoal using forced air type updraft kiln and makeshift furnace were shown in Figures (4,5, and 6).

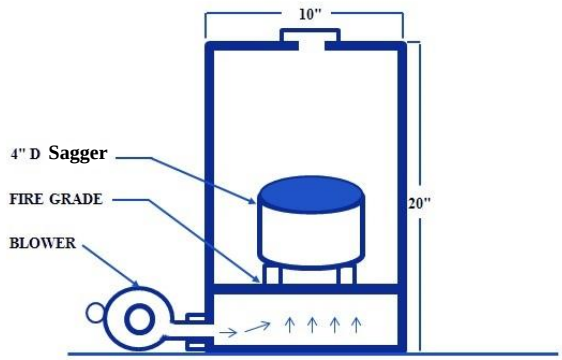

Figure 1 Schematic Diagram of Forced Air Type Updraft Kiln

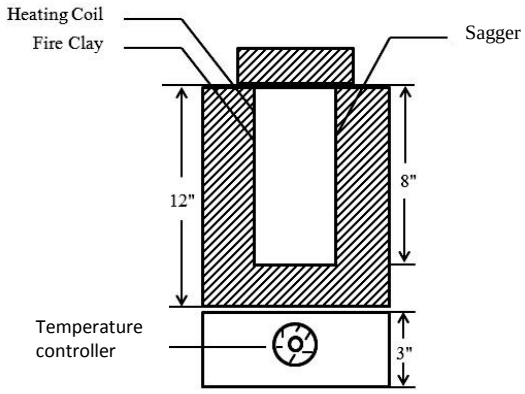

Figure 2 Schematic Diagram of Makeshift Furnace

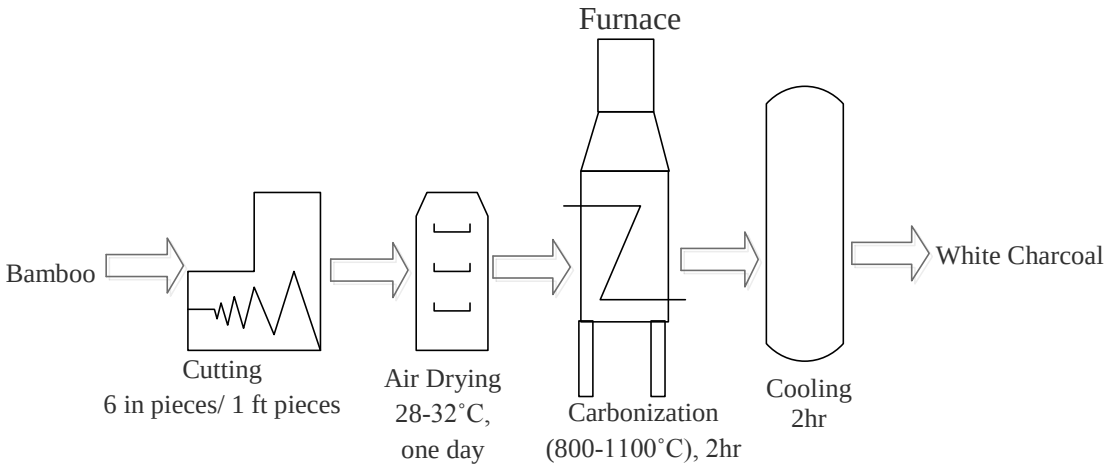

Figure 3 Process Flow Diagram for the Preparation of White Charcoal

Figure 4 Processing of White Charcoal by Forced Air Type Updraft Kiln with Sagger

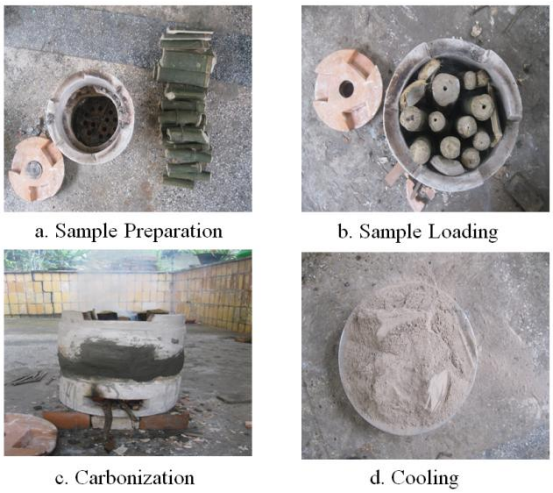

Figure 5 Processing of White Charcoal by Forced Air Type Updraft Kiln without Sagger

Figure 6 Processing of White Charcoal by Makeshift Furnace

Analysis of Samples

For the determination of decolourization property of charcoal, 2 grams of charcoal was soaked in 100 ml of 0.01 M Potassium Permanganate solution for 3 days. Absorbance was determined using Spectrophotometer.

Before carbonization, the analysis of raw bamboo was carried out according to ASTM and TAPPI standard methods. After carbonization, the analysis of charcoal was also carried out using the same procedure. The standard methods used for the analysis are listed as follows:

Determination of Moisture Content (ASTM D 2867-04)

Determination of Volatile Matter Content (ASTM D 5832-98)

Determination of Ash Content (ASTM D 2866-94)

Determination of Fixed Carbon Content (ASTM D 3172)

Determination of Acid Insoluble Lignin (T 222 om-02)

Determination of 1% Sodium Hydroxide Solubility (T 212- om 02)

Determination of Alcohol-benzene Extractives (T 204 cm-97)

Determination of Moisture Content (ASTM D 2867-04)

About (1) g of charcoal sample was weighed in a clean, dry , and weighed watch glass and it was added into a dry and tared porcelain crucible and heated at 105 ºC in an oven for (1) hour. After that, the sample was cooled in a desiccator and recorded the weight. The process was repeated until the constant weight could be obtained. The percentage loss in weight has been calculated as follows:

$$M_{,\%} = B - C/B - A \times 100$$

Where:

A = mass of porcelain crucible (g)

B = mass of porcelain crucible plus sample before drying (g)

C = mass of porcelain crucible plus sample after drying (g)

M = percentage of moisture in the analysis of sample

Determination of Volatile Matter Content (ASTM D 5832-98)

About (1) g of charcoal sample was weighed in a clean, dry , and weighed watch glass and added it into a dry and tared porcelain crucible. The crucible with lid containing the sample was kept inside the muffle furnace and heated to 950℃ for 7 minutes. Then, the sample was cooled in a desiccator for 1 h and weighed. The percentage of volatile matter in the sample has been calculated as follows:

$$\text{Volatile matter, \%} = [(A - B) / A] \times 100$$

Where: A = grams of sample before heating

B = grams of sample after heating at 950℃

Determination of Ash Content (ASTM D 2866-94)

About (1) g of charcoal sample was weighed in a clean, dry , and weighed watch glass and added it into a dry and tared porcelain crucible. The crucible with lid containing the sample was kept inside the muffle furnace and heated to 750℃ for 4 hours. The crucible with lid in place was cooled in a desiccator for 1 hour and weighed. The percentage of ash in the sample could be calculated as follows:

$$\text{Ash, \%} = (D / C) \times 100$$

Where: C = grams of sample before heating

D = grams of residue

Determination of Fixed Carbon Content (ASTM D 3172)

If the moisture content, the ash content and volatile matter content are known, then the content of fixed carbon could be calculated as follow:

$$C, \% = 100 - (M + A + VM)$$

Where: C - Fixed carbon content (%)

M - Moisture content (%)

VM - Volatile matter content (%)

A - Ash content (%)

Determination of Acid Insoluble Lignin (T 222 om-02)

The carbohydrates in wood and pulp are hydrolyzed and solubilized by sulfuric acid; the acid-insoluble lignin is filtered off, dried, and weighed. For each determination, the lignin content in the test specimen was calculated as follows:

$$\text{Lignin \%} = A/W \times 100$$

Where : A= weight of lignin, g

W= oven-dry weight of test specimen, g

Determination of Alcohol-benzene Extractives (T 204 cm-97)

The extractive content was calculated as follows:

$$\text{Extractables, \%} = [(W_e - W_b)/W_p] \times 100$$

where, W_e = oven-dry weight of extract, g

W_p = oven-dry weight of wood or pulp, g

W_b = oven-dry weight of blank residue, g

Determination of 1% Sodium Hydroxide Solubility (T 212- om 02)

Wood or pulp is extracted with hot 1% sodium hydroxide solution for 1 h. The loss in weight is determined and calculated as percent solubility. The percent solubility (*S*) was calculated as follows:

$$S = \frac{A-B}{A} \times 100$$

Where, *A* = oven-dry weight of the test specimen before extraction, g

B = oven-dry weight of the test specimen after extraction, g

Results and Discussion

The quality expressed by moisture, ash, volatile matter and fixed carbon content for bamboo, prepared charcoal samples and commercial samples from Myanmar and Japan are given in Tables (1) and (2). The colour (absorbance) of decolourized Potassium Permanganate solution by prepared charcoal samples are shown in Table (3).

Table 1 Characteristics of Two Bamboo Samples

Sr. No.	**Characteristics**	**Kyakhatwa (*Bambusa arundinacea*)**	**Kyathaungwa *(Bambusa polymorpha)***
1.	Moisture	7.21	
2.	Ash	2.00	4.00
3.	Volatile Matter	82.40	79.21
4.	Fixed Carbon	8.7	8.58
5.	Lignin	25.24	25.60
6.	Alcohol- benzene Extractives	3.2	4.29
7.	1% NaOH Extractives	20.24	24.92

Table 2 Comparison of the Physico-chemical Properties of Prepared Charcoal Samples and Commercial White Charcoals

Sr. No.	**Types of Charcoal**	**Types of Kiln**	**Physico-chemical Properties**			
			Moisture	**Ash**	**Volatile Matter**	**Fixed Carbon**
			(%w/w)			
1.	*White Charcoal	Brick Kiln	9.4	5.28	10.34	74.98
2.	**White Charcoal		9.04	1.19	3.87	85.9
3.	Kyakhatwa	Forced Air Type Updraft Kiln (Using Sagger)	5	9	28	58
4.	Kyathaungwa		**10**	**3**	11	76
5.	Kyakhatwa	Forced Air Type Updraft Kiln (without Sagger)	5	**11**	**29**	**55**
6.	Kyathaungwa		9	**11**	22	58
7.	Kyakhatwa	Makeshift Furnace	**3.33**	5.57	7.79	**83.31**
8.	Kyathaungwa		5.26	4.13	**4.37**	**86.24**

*White charcoal from Myanmar Yoshida Co.Ltd.
**White Charcoal from Japan (http://www.mokutanya.jp)

Table 3 Colour (Absorbance) Values of Decolourized Potassium Permanganate Solution by Prepared Charcoal Samples

Sr. No.	Types of Charcoal (Decolourizing Agents)	Types of Kiln	Colour (Absorbance Values)	
			Potassium Permanganate Solution	Decolourized Potassium Permanganate Solution
1.	*White Charcoal	Brick Kiln	1.832	0.139
2.	**White Charcoal			1.289
3.	Kyakhatwa	Force Air Type Updraft Kiln (Using Sagger)		**0.027**
4.	Kyathaungwa			0.103
5.	Kyakhatwa	Force Air Type Updraft Kiln (without Sagger)		**0.021**
6.	Kyathaungwa			**0.027**
7.	Kyakhatwa	Makeshift Furnace		**0.023**
8.	Kyathaungwa			0.141

Colour was determined using Spectrophotometer (TRSP-722).

*White charcoal from Myanmar Yoshida Co.Ltd.
**White Charcoal from Japan (http://www.mokutanya.jp)

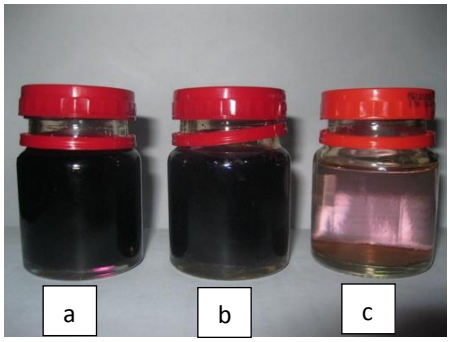

Figure 7 (a) $KMnO_4$ before Decolourization Decolourized $KMnO_4$ by Using Commercial White Charcoals from: (b) Japan (c) Myanmar

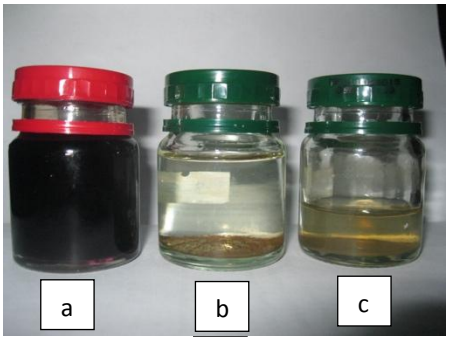

Figure 8 (a) $KMnO_4$ before Decolourization Decolourized $KMnO_4$ Solution by Using White Charcoals from: (b) Kyakhatwa (c) Kyathaungwa Prepared by Forced Air Type Updraft Kiln with Sagger

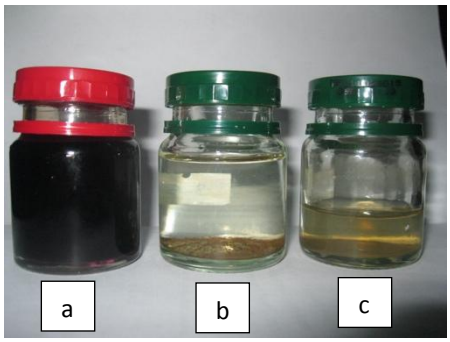

Figure 9 (a) $KMnO_4$ before Decolourization Decolourized $KMnO_4$ Solution by Using White Charcoals from: (b) Kyakhatwa (c) Kyathaungwa Prepared by Forced Air Type Updraft Kiln without Sagger

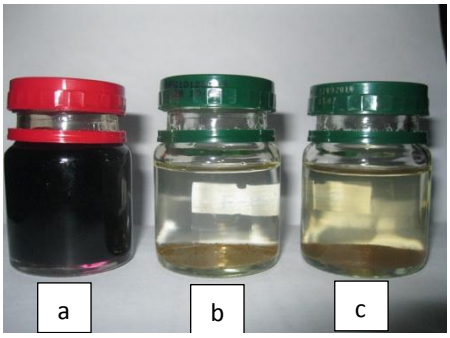

Figure 10 (a) $KMnO_4$ Solution before Decolourization Decolourized Potassium Permanganate Solution by Using White Charcoals from: (b) Kyakhatwa (c) Kyathaungwa Prepared by Makeshift Furnace

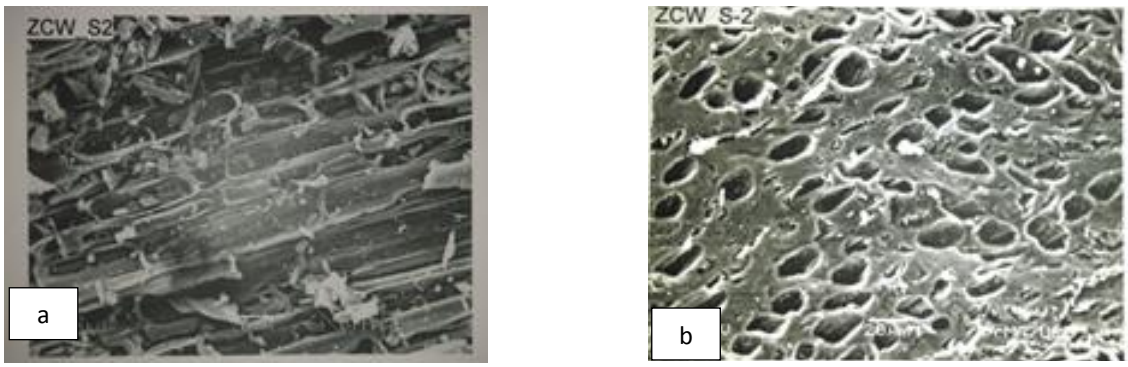

Figure 11 SEM Micrograph of (a) White Charcoal Produced by Myanmar Yoshida Company Ltd. (b) White Charcoal from Japan

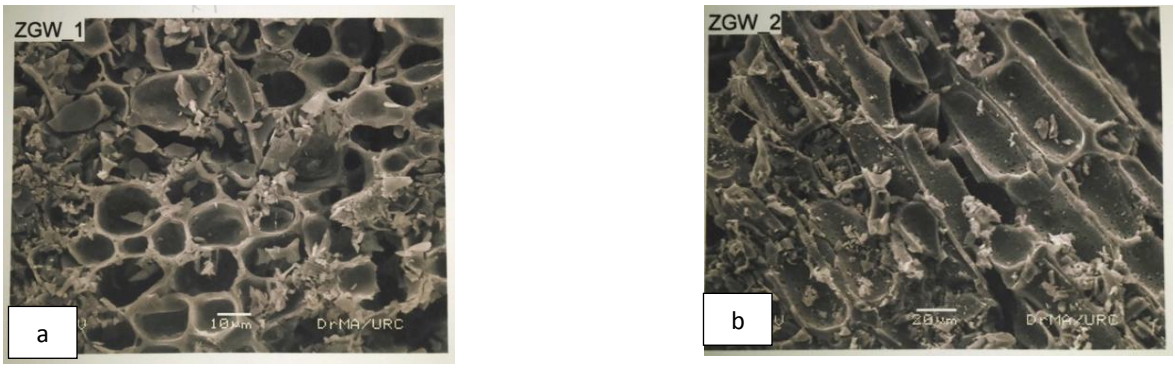

Figure 12 SEM Micrograph of White Charcoal from: (a) Kyathaungwa (b) Kyakhatwa prepared by Forced Air type Updraft kiln Using Sagger

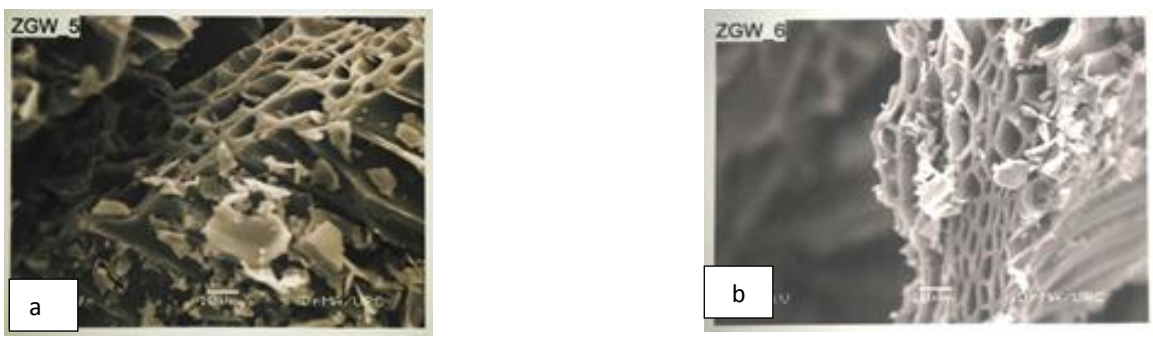

Figure 13 SEM Micrograph of White Charcoals from: (a) Kyathaungwa (b) Kyakhatwa Prepared by Forced Air Type Updraft Kiln Without Using Sagger

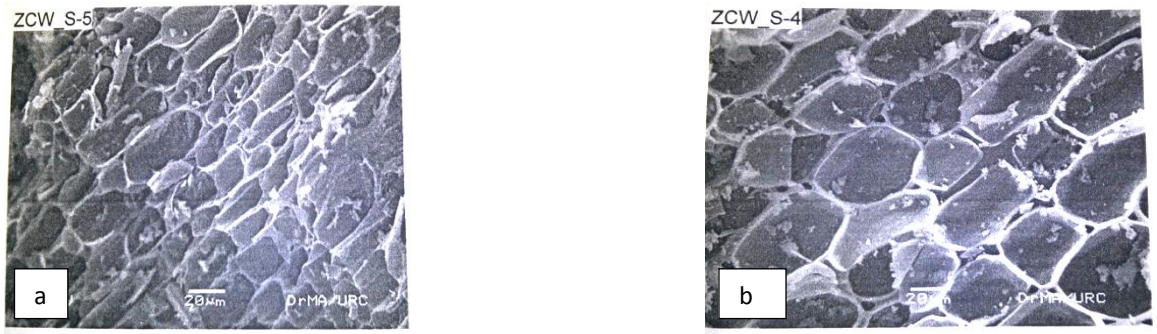

Figure 14 SEM Micrograph of White Charcoals from: (a) Kyathaungwa (b) Kyakhatwa Prepared by Makeshift Furnace

As shown in Table (1), the moisture contents of two types of bamboo (Kyakhatwa (*Bambusa arundinacea*) and Kyathaungwa *(Bambusa polymorpha)*) were 7.21%w/w and 8.21%w/w respectively. The moisture content of bamboo directly affects the time of carbonization and fuel consumption. If the moisture content is too high, the drying time of bamboo pyrolysis will take longer and the carbonizing cycle will continue with higher fuel consumption. The lower moisture content of bamboo makes the bamboo pyrolysis process faster. However, the strength of charcoal is reduced if the moisture content of bamboo is too low (Jian,2004). The ash contents of two types of bamboo were 2 %w/w and 4 %w/w respectively. The volatile matter contents of both types of bamboo was nearly the same as that of wood and other biomass (approximately 80 %w/w). These values were 82.40 %w/w and 79.21 %w/w respectively. The fixed carbon contents of raw bamboos were 8.7 %w/w and 8.58 %w/w respectively.

The acid soluble lignin in both types of bamboo were carried out to determine the hardness of bamboo that was associated with the lignin content. Wood contains about 20-30% lignin. The raw bamboo contains the lignin content of 25.24 %w/w and 25.60 %w/w respectively. Therefore, it might be proved that both types of bamboo are as hard as wood and suitable for charcoal production. Solvent extractives was used to know the amount of solvent-soluble, nonvolatile materials in raw bamboo. The alcohol-benzene extractives values of bamboo were 3.2%w/w and 4.29 %w/w respectively. The amount of solvent extractable matter is markedly influenced by seasoning or drying of bamboo (Jian,2004). 1% NaOH extractives was done to determine the 1%NaOH solubility of bamboo. 1% NaOH extractives values of bamboo were 20.24 %w/w and 24.92 %w/w respectively. The solubility has been related to the strength of bamboo (Jian,2004). Appropriate bamboo moisture content is therefore essential for pyrolysis, and Jian, 2004, reported that 15 percent ~20 percent bamboo moisture content is favorable for carbonization in an external heating pyrolyzing kettle.

Based on the results from Table (1), the strength, hardness and other physico-chemical properties of two types of bamboo were not different significantly. Therefore, both types of bamboo were suitable for the preparation of charcoal. Charcoal made by makeshift furnace from Kyathaungwa *(Bambusa polymorpha*) was found to have the highest fixed carbon content (86.24 %w/w) among the charcoals samples made by different methods and also higher than that of two commercial white charcoals. The fixed carbon content of white charcoal samples from Myanmar and Japan were 74.98 %w/w and 85.9 %w/w respectively. Due to the difference in heating methods and types of furnaces, bamboo white charcoals contained fixed carbon from 55 %w/w to 86.24 %.w/w. With the increasing carbonizing temperature, the corresponding

percentage of fixed carbon in bamboo white charcoal might increase. The charcoal prepared from Kyakhatwa using makeshift furnace had the lowest moisture content of 3.33 %w/w. The highest moisture content was found for the charcoal prepared from Kyathaungwa using forced air type updraft kiln with sagger. The moisture of charcoal determines the quality of the product.

The bamboo charcoal releases gaseous offspring such as CO, CO_2, H_2, CH_2 and other hydrocarbons labeled as volatile matter when the bamboo is carbonized under high temperature. The lowest volatile matter content (4.37 %w/w) was found for the charcoal made from Kyathaungwa using makeshift furnace. The charcoals produced from Kyakhatwa *(Bambusa arundinacea)* by forced air type updraft kiln using sagger and without sagger contain the high volatile matter contents (28 %w/w and 29 %w/w). The ash of bamboo charcoal is its inorganic constituent, which is a white or shallow red substance after bamboo charcoal has been burned completely at high temperature. Bamboo charcoal ash elements are complex, all inorganic components in bamboo, mostly Si, K, Mg, Na, Mn, etc. remain in ash. The ash content of white charcoal samples from Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa polymorpha*) produced by force air type updraft kiln without sagger were found to have the same value (11 %w/w). This high value of ash content showed that both samples contain a large amount of silicon. From these results, it is possible to predict that the carbonization was not completed. The lowest ash content (3%w/w) was found for the charcoal sample prepared from Kyakhaungwa using forced air type updraft kiln with sagger. The lower contents of moisture, volatile matter and ash, and the higher content of fixed carbon revealed that the prepared charcoal samples are of good quality. In comparison of the physico-chemical properties especially fixed carbon content of prepared charcoal with commercial white charcoal from Japan and Myanmar, the fixed carbon contents of charcoal prepared from both types of bamboo were higher than that of commercial white charcoal. These values were 83.31 %w/w and 86.24 %w/w respectively.

The decolourization property of prepared charcoal and commercial charcoals were determined using potassium permanganate solution. The results were shown in Table (3) and Figures (7 to 10). According to the results, the colour absorbance value of potassium permanganate solution before decolourization was 1.832. After decolourization with prepared charcoal, the absorbance value of solution was reduced noticeably. Among them, the absorbance values of solution that was decolourized using Kyakhatwa prepared by both makeshift furnace and forced air type updraft kiln with and without using sagger were lowered than that of prepared charcoal (Kyathaungwa) and commercial charcoals. These values were 0.027,0.023 and 0.021 respectively. However, the white charcoal (Kyathaungwa) prepared by using forced air type updraft kiln without using sagger also showed lower absorbance values (0.027) than that of commercial charcoals. It means that both types of white bamboo charcoal prepared by forced air type updraft kiln without using sagger has higher decolourization property than that of commercial white charcoal.

Adsorption capability is one of bamboo charcoal's important characteristics. Since bamboo charcoal forms a lot of pores after pyrolyzing at high temperatures, similar to wood charcoal, it has a broad specific surface adsorption ability (Jian, 2004). The pore structures of the prepared white charcoal samples and commercial white charcoal samples were examined by SEM. Figures (11 to 14) showed SEM micrographs of Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa polymorpha*) charcoal prepared by makeshift furnace and forced air type updraft kiln, and of commercial white charcoal samples. It was obvious that all white

charcoal samples prepared from bamboo had a greater number of pores than commercial white charcoals. Furthermore, charcoal samples prepared from Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa polymorpha)* by makeshift furnace contained the high number of pores which indicated relatively large surface areas for absorption (Figure 14).

Conclusion

According to the results, the physico-chemical properties (i.e in terms of fixed carbon content) of white charcoal made from Kyathaungwa *(Bambusa polymorpha*) by using Makeshift furnace were higher than that of commercial white charcoal. It can be concluded that Kyathaungwa *(Bambusa polymorpha*) could be able to use for white charcoal preparation and Makeshift furnace is a suitable furnace for carbonization of bamboo to produce white charcoal. It is predictable that white charcoal made from bamboo would give the higher absorption capacity for decolourization than the white charcoal made from other (like oak, mangrove, etc.,) because of its abundant porous structure detected by SEM.

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