# Investigationon the Preparation of Bamboo Charcoal Using White Charcoal Process by Different Kilns

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**Abstract**

White charcoal is a kind of charcoal that is very popular in Japan and Asia and it is better in quality than any other types of charcoal. In this research work, Kyakhatwa*(Bambusaarundinacea)* and Kyathaungwa*(Bambusapolymorpha)* were carbonized in a makeshift furnace, an earth kiln and a drum kiln using white charcoal process. The physico-chemical properties of charcoal such as moisture, ash, volatile matter and fixed carbon content were determined, and compared with the value of commercial white charcoal from Japan, Thailand and Myanmar. According to the results, the bamboo (Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa polymorpha))* charcoals prepared by using makeshift furnace have higher fixed carbon content than other charcoal samples made by using earth kiln and drum kiln. The fixed carbon content of these two charcoals were 67 % (w/w) and 65 % (w/w) respectively whereas all commercial white charcoals were >80% (w/w). Activated charcoal was also prepared using these two types of bamboo by chemical activation process and compared the physico-chemical properties of these activated charcoals with that of the charcoals prepared by makeshift furnace. As a result, the bamboo charcoals prepared by using makeshift furnace have lower fixed carbon content than that of activated charcoal because the fixed carbon content of activated charcoals were 75 % (w/w) and 73 % (w/w) respectively. Therefore, preparation of white charcoal using brick kiln might be consideredbecause almost all of the commercial white charcoals were prepared by using brick kiln.

***Key words***: white charcoal, makeshift furnace, earth kiln, drum kiln

## Introduction

Myanmar is rich in bamboo resources and the species is greatly used by the rural people.In Myanmar, bamboo is useful material for construction, industry, transportation, food and agriculture(Pan, 2013).Bamboo charcoal and active carbon is an item of new products developed in Myanmar in recent years.Being of special microstructure, bamboo material possessed extreme absorbing and other special capacities after carbonization.Their uses in the areas of high and newtechnology are of important.There are many valuable species of bamboo in Myanmar and they are abundant along the border area with China and Thailand(Lwin, 2010).

Charcoal is made through the control burning of bamboo in brick or metal kilns, earth kiln or in drums in Myanmar.Bamboo charcoal is referred as a green biofuel because it produces less smoke and air pollution than natural charcoal. Bamboo-based charcoal production can fight deforestation and mitigate climate change(Mingjie 2004).Its high heating value also makes it an efficient fuel.It can also be used for the replacement of chemical fertilizers and agricultural chemicals(Shenxue 2004).Bamboo wastes from other industries such as basket, chopsticks and construction work can also be used for the production of charcoal.

Currently, there are two kinds of charcoal include the ordinary "black charcoal" and "white charcoal". These charcoals are made by different technical method of carbonization. Although, they are produced in a basically similar manner, the quality of the charcoal differs totally depending on how the fire is extinguished.

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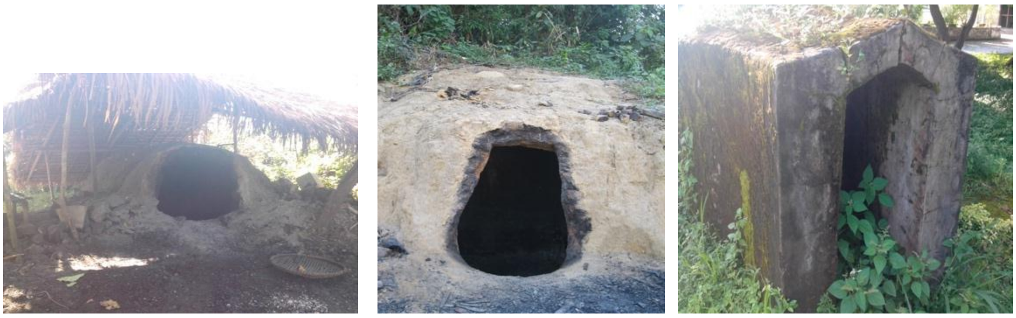
The method for producing white charcoal is difficult compared to ordinary black charcoal (Pijarn et al. 2017).White charcoal production technique is roughly divided into six stages, starting with placing the wood into a specially shaped bincho kiln, drying the wood, carbonizing it, refining the carbonized product, removing it from the kiln, and finally extinguishing it on sand outside the kiln.It is synthesized by pyrolyzing hard woods, such as oak at relatively low temperature (200-400°C) for a period, typically of a few days and then raising the kiln temperature to 1000°C towards the end of the pyrolysis process. The white hot charcoal is then withdrawn and smothered with a moistened mixture of earth, ash and sand. The term white charcoal arises from the use of ash to quench the material, which gives a pale grey hue to the charcoal surface. (Chia et al. 2014)

White charcoal is a traditional charcoal of Japan and a type of lump charcoal or hardwood charcoal.It is made at a very high temperature and has an alkaline effect.It does not release smoke or other unpleasant odors.White charcoal is harder than black charcoal and when it is striking, a metallic sound is ringing.It can absorb chemical substances because it has numerous small pores.It has found uses other than as a fuel. It is used as water purifiers, agents to keep vegetables and other foods fresh, soil enhancers, humidity regulators for the walls and floors of homes, and deodorants.(Mingjie 2004)White charcoal has the ability to warm the body and help improve blood circulation, skin, and hair when added to the bath.It also helps reduce blood pressure and cholesterol.It supplies negative ions, and purifies and balances the moisture content in the air.Burning at high temperature makes the white charcoalto be good for absorption of electromagnetic waves from electrical appliances like computer monitors and mobile phones.(Shenxue 2004)



(a) (b) (c)

**Fig.1**(a) Earth Kiln (Local name -Yaite Pho)**,** (b)Earth Kiln (Local name-Galaing Pho), (c) Brick Kiln

## Materials and Methods

### Raw Materials

In this research work, the main raw materials weretwo species of bamboo Kyakhatwa (*Bambusaarundinacea*) and Kyathaungwa (*Bambusapolymorpha)*). Kyakhatwa *(Bambusaarundinacea)* was collected from Hlaing Township, Yangon Region. Kyathaungwa*(Bambusapolymorpha)* was collected from KanMyint village, Bago Region. Three types of kiln were used for the preparation of charcoal. They were drum kiln, earth kiln and makeshift furnace.

After harvesting, bamboo were air dried (about 30°C) for one day to reduce the moisture content. Then they were cut into the desired length, 1ft for drum kiln and earth kiln and 4 in for makeshift furnace.

## Charcoal Making

The dried bamboo were first loaded into the earth kiln and drum kiln. Then, they were carbonized at about 400-1000°C for 2 days in the earth kiln and for 4 hours in the drum kiln. After carbonization, the inlet of the drum kiln was closed for a while to extinguish the fire. And then, the carbonized bamboo was cooled by covering it with the mixture of soil, ash and sand for 1 hour. However, the cooling of carbonized bamboo in the mixture of sand, ash and soilwas carried out as soon as the inlet of the earth kiln was opened. After cooling, the charcoal was taken out from the kiln and packed in the plastic bag for analysis. The high heating and sudden cooling of charcoal made the surface of it hard and whitish hue.

For the preparation of charcoal in the makeshift furnace, the bamboo was first placed into the sagger and then it was sealed with clay. The sagger was put into the furnace and heating was started.


**Fig.2** Stages of White Charcoal Processing Using a Drum Kiln

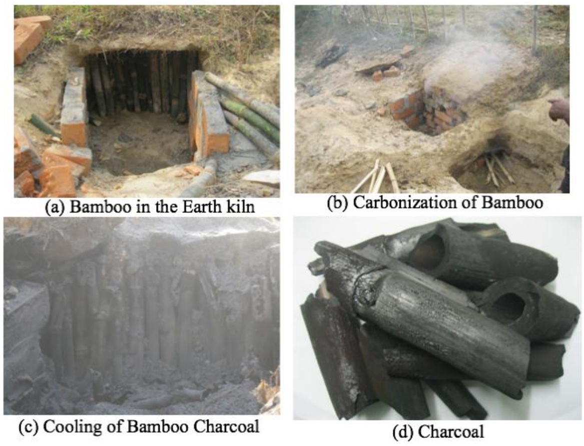



**Fig.3** Stages of White Charcoal Processing Using an Earth Kiln

Carbonization was carried out at 600°C for 3 hours and 1000°C for 1 hour. After carbonization, the sagger was taken out from the furnace and opened it. The charcoal was cooled in the mixture of ash, sand and soil for 1 hour. After that, the sample was kept for analysis. The temperature in the furnace was noted using pyrometer.

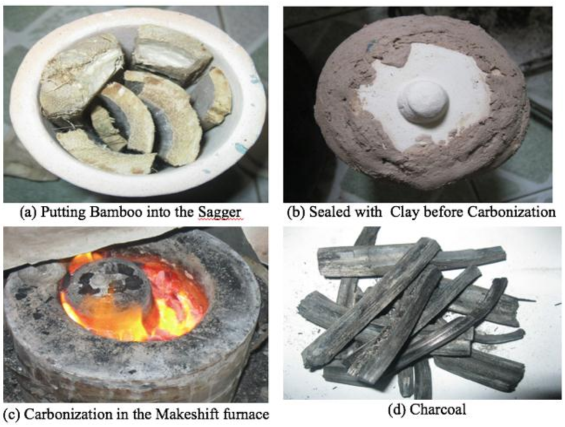



**Fig.4** Stages of White Charcoal Processing Using a Makeshift Furnace

## Activated Carbon Preparation

Moreover, activated carbons were prepared from both types of bamboo by chemical activation process. For the preparation of activated carbon, two types of bamboo (Kyakhatwa *(Bambusa arundinacea)* and Kyathaungwa *(Bambusa polymorpha)*) were carbonized at the temperature of 800˚C for 1 hrin a muffle furnace. Then, the charcoal was grinded into powder for activation process and it was carried out by soaking the charcoal in 10% Sulphuric acid solution for 24 hours. After soaking, the activated carbon was washed with water and dried at 105°C for 1 hr in the hot air oven.

## Analysis of Samples

The physico-chemical properties such as moisture content, ash content, volatile matter content and fixed carbon content of raw bamboo and bamboo charcoal were carried out using standard procedures of ASTM and TAPPI. The physico-chemical properties of the prepared activated carbon were also determined and the properties of suitable activated carbon were comparatively studied with those of the processed white charcoals.The standard methods used for the analysis are stated as follows:

### Determination of Moisture Content (ASTM D 2867-04)

The percentage loss in weight as moisture was calculated as follows:

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

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)

The percentage of volatile matter in the sample was 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)

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)

For each determination, the lignin content in the test specimen was calculated as follows:

Lignin % = A/W × 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:

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)**

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

**Determination of Pentosan (T 223 cm – 01)**

The pentosan content in the test specimen could be calculated as follow:

$$\text{Pentosan,\%} = \frac{A}{10W}$$

Where, A = xylan in test specimen, mg

W = oven-dry weight of test specimen, g

## Results & Discussion

Some of the characteristics of two bamboo species in term of fixed carbon, moisture, ash, volatile matter content, lignin, pentosan, etc., were presented in Table 1. When the characteristics of two bamboos were studied comparatively, most of the values were nearly similar except ash content. The ash content of Kyathaungwa was higher two times than that of Kyakhatwa. The ash is an inorganic constituent. The moisture content of raw bamboo was important for carbonization. The moisture content of bamboo legitimately impacts the pyrolysis time and the utilization of fuel. The drying time of bamboo pyrolysis will draw out if the moisture content is excessively high, and therefore, the carbonizing procedure will reach out with more fuel utilization. Then again, the bamboo culms are anything but difficult to cause breaks as a result of not being warmed consistently in the pyrolyzing kiln while drying quickly, and this corrupts bamboo charcoal.The lower moisture content of bamboo accelerates the bamboo pyrolysis process. Be that as it may, the yield of bamboo charcoal will be diminished and its mechanical quality decreased by the energetic exothermic response if the moisture content of bamboo is excessively low. So reasonable moisture content of bamboo is significant for pyrolysis, and the 15%~20% moisture is great for carbonization in an external pyrolyzing equipment(Shenxue 2004).The moisture content of two bamboo species was lower than the literature value of 15-20%.

Normally, charcoal consists of moisture, volatile matter that is volatilized by heat, inorganic matter (ash) that remains after combustion, and fixed carbon that is not reduced by heat itself. Table 2 shows the results of the proximate analysis oftwo types of bamboo charcoal prepared by three different kiln using white charcoal process. Among the charcoal made by three different kilns, the bamboo charcoal prepared by makeshift furnace had the higher fixed carbon content than that of any other charcoals prepared by earth kiln and drum kiln. They were 67.2% and 65.4% respectively.

However, the carbon values of Kyakhat charcoal (61.7%) prepared by earth kiln and Kyathaung charcoal (64%) prepared by drum kiln were similar to that of charcoals prepared by makeshift furnace. Although the final carbonization temperature in the kiln (1000°C) was same, the analysis results were different. According to the analysis of the white charcoal produced by makeshift furnace, the moisture content was less than 10%, the ash content was more than 10%, the volatile content was more than 10%, and the fixed carbon was less than 80%, which means the prepared charcoal has just an ordinary bamboo charcoal quality.The low volatiles content of white charcoal indicates that it is difficult to ignite due to the lack of readily combustible low molecular weight compounds and that it burns very cleanly.

According to the experimental results of activated charcoal, the suitable carbonization temperature was 800˚C and the suitable time was 1 hr (60 min). At these time and temperature, the fixed carbon content of activated carbon fromKyakhatwa *(Bambusaarundinacea)* and Kyathaungwa *(Bambusapolymorpha*) were found to be 75% w/w and 73%w/w respectively. These values were compared with that of charcoal prepared by make shift furnace as shown in Table 3. The fixed carbon content of the charcoals prepared from Kyakhat and Kyathaung by makeshift furnace was lower than that of activated charcoal. They were 67.2% and 65.4% respectively. When these values were also compared with that of commercial white charcoal, the fixed carbon content was lower than that of all commercial white charcoal because the fixed carbon content of commercial white charcoals was > 80%.When the bamboo was heated under high temperature(850±20℃), the bamboo charcoal releases gaseous offspring such as CO, $CO_2$ $H_2$, $CH_2$ and other hydrocarbon which are called as volatile matter (Shenxue 2004). The volatile matter content of charcoal prepared by makeshift furnace was much higher than that of commercial charcoal although they were carbonized at higher temperature (600°C for 3hr and 1000°C for 1 hr).This probably meant that carbonization was not fully completed when the experiment was carried out. The ash content also higher than commercial white charcoals and activated charcoal.The ash of bamboo charcoal is the inorganic constituent and it is a white or shallow red substance after bamboo charcoal has been burned completely at high temperature. The ash elements in bamboo charcoal are complex, all the inorganic components in bamboo will remained in ash, among which Si, K, Mg, Na, Mn, etc., are relatively more. The terminal carbonization temperature of bamboo has great influence on the output and composition of bamboo pyrolysis products(Shenxue 2004). The types of kiln and furnaces for the preparation of charcoal has significant effect on the properties of charcoals whereas all commercial white charcoals were prepared in the brick kiln and their quality was better than prepared charcoal.

**Table 1**. Characteristics of Two Bamboo Species

| Sr.No | Characteristics | Kyakhat (*Bambusaarundinacea*) | Kyathaung *(Bambusapolymorpha)* |
|---|---|---|---|
| | | %w/w | |
| 1. | Moisture | 7.2 | 8.2 |
| 2. | Ash | 2.0 | 4.0 |
| 3. | Volatile Matter | 82.4 | 79.2 |
| 4. | Fixed Carbon | 8.7 | 8.5 |
| 5. | Pentosan | 26.2 | 24.3 |
| 6. | Lignin | 25.2 | 25.6 |
| 7. | Alcohol- benzene Extractive | 3.2 | 4.2 |
| 8. | 1% Caustic Extractive | 20.2 | 24.9 |

**Table 2.**Physico-chemical Properties of Bamboo Charcoals Prepared by Earth Kiln,Drum Kiln and Makeshift Furnace Using Whit Charcoal Process

| No. | Types of Bamboo | Types of Kiln | Physico-chemical Properties | | | |
|---|---|---|---|---|---|---|
| | | | Moisture | Ash | Volatile Matter | Fixed Carbon |
| | | | % w/w | | | |
| 1. | Kyakhat | Earth Kiln | 2.1 | 10.9 | 25.1 | 61.7 |
| 2. | Kyathaung | | 1.3 | 7.8 | 38.1 | **52.6** |
| 3. | Kyakhat | Drum Kiln | 10.8 | 7.9 | 22.1 | 59.1 |
| 4. | Kyathaung | | 4 | 9 | 23 | 64 |
| 5. | Kyakhat | Makeshift Furnace | 2.3 | 11.3 | 18.9 | **67.2** |
| 6. | Kyathaung | | 3.8 | 17.6 | 13.0 | **65.4** |

**Table 3.** Comparison of the Physico-chemical Properties of Activated Charcoal,Charcoal Prepared by Makeshift Furnace and Commercial White Charcoals

| No. | Types of Charcoal | Types of Bamboo | Physico-chemical Properties | | | |
|---|---|---|---|---|---|---|
| | | | Moisture | Ash | Volatile Matter | Fixed Carbon |
| | | | % w/w | | | |
| 1. | Activated Charcoal (Muffle Furnace) | Kyakhat | 8 | 4 | 13 | 75 |
| | | Kyathaung | 10 | 8 | 9 | 73 |
| 2. | Charcoal (Makeshift Furnace) | Kyakhat | 2.3 | 11.3 | 18.9 | 67.2 |
| | | Kyathaung | 3.8 | 17.6 | 13.0 | 65.4 |
| 3. | White Charcoal from Thailand | - | 3.0 | 3.7 | 2.5 | 90.8 |
| 4. | White Charcoal from Myanmar | - | 9.4 | 4.2 | 4.3 | 81.9 |
| 5. | White Charcoal from Japan | - | 9.0 | 1.1 | 3.8 | 85.9 |

## Conclusion

According to the results, the physico-chemical properties (i.e in terms of fixed carbon content) of white charcoals made from Kyathaungwa*(Bambusapolymorpha*) and Kyakahtwa(*Bambusaarundinacea*) by using makeshift furnace were higher than that of charcoals prepared by earth kiln and drum kiln. However, the fixed carbon content of charcoal prepared by makeshift furnace was still lower than that of activated carbon and commercial white charcoals. It can be concluded that both types of bamboo could be able to use for white charcoal preparation and Makeshift furnace is a suitable furnace for carbonization of bamboo to produce white charcoal although some modification of the furnace design is needed.Since the activation process (i.e chemical activation, steam activation) have to be used in the preparation of activated charcoal, it would be more economical to produce white charcoal compared to activated carbon.

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