Faculty of Resource Science and Technology

Production of Charcoal from *Bambusa vulgaris* and *Dendrocalamus asper*

Muhammad Iz'aan Izzuddin Bin Zaheid

(47795)

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Masters	
PhD	

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47795

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Production of Charcoal from *Bambusa vulgaris* and *Dendrocalamus asper*

Muhammad Iz'aan Izzuddin Bin Zaheid

(47795)

This project report is submitted in partial fulfilment of the requirement for degree of Bachelor of Science with Honours

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APPROVAL SHEET

Name of candidate : Muhammad Iz'aan Izzuddin B. Zaheid

Title of Dissertation : Production of Charcoal From *Bambusa vulgaris* and *Dendrocalamus asper*

……………………………………

(Prof. Dr. Ismail B. Jusoh)

Supervisor

Department of Plant Science and Environmental Ecology

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak (UNIMAS)

Date:

………………………………….

(Dr. Freddy Yeo Kuok San)

Coordinator

Department of Plant Science and Environmental Ecology

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak (UNIMAS)

Date:

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Plant Resource Science and Management Program

Faculty of Resource Science and Management

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Muhammad Iz'aan Izzuddin B. Zaheid

Plant Resource Science & Management
Faculty of Resource Science & Technology
Universiti Malaysia Sarawak

ABSTRACT

Two selected bamboo species namely *Bambusa vulgaris* and *Dendrocalamus asper* were utilized for making charcoal by using steel drum as the kiln. The selected bamboo species had went several preparation steps prior to the carbonization process that turned them into charcoal. The matured culm of each bamboo species aged between 4-5 years old were cut into pieces of 45-65cm length. The pieces were cut according to three major sections of the bamboo, which are the top section, middle section and the bottom section. The pieces were then air-dried for the periods of two weeks before placing them into the kiln for the carbonization process. The kiln was constructed based on the design of Masato Iwasaki's steel drum kiln. The carbonization temperature used was 476±20°C for both selected bamboo species and the temperature were maintained for 5 hours. Proximate analysis were carried out to determine its content of moisture, ash, volatile and fixed carbon (wt %) and its percentage of yield were calculated. The percentage of yield obtained from *B. vulgaris* was 62.1% while *D. asper* was 72.9%. From the proximate analysis, the moisture content, volatile matters, ash and fixed carbon for *B. vulgaris* samples were 3.87%, 18.06%, 4.58% and 73.49%, respectively. Meanwhile, the moisture content, volatile matters, ash and fixed carbon for *D. asper* samples were 4.09%, 13.91%, 5.59% and 76.41%, respectively. These differences were mainly due to the elemental, chemical and physical properties of the bamboo species. The scanning electron microscope (SEM) micrograph of the charcoal produced were taken and it showed that the structure of the charcoal produced from the two species were highly porous. Both bamboo species can be made into charcoal and their charcoal properties showed that they are favorable for many uses.

Keywords: Bamboo, carbonization, charcoal, proximate analysis, scanning electron microscope (SEM)

ABSTRAK

Spesies buluh terpilih iaitu Bambusa vulgaris dan Dendrocalamus asper telah digunakan untuk menghasilkan arang dengan menggunakan dram keluli sebagai tanur. Spesies buluh yang dipilih telah menjalani beberapa langkah persediaan sebelum melalui proses karbonisasi yang menukarkannya menjadi arang. Kulma matang setiap spesies buluh yang berumur antara 4-5 tahun dipotong dengan panjang di antara 45-65cm. Kulma dipotong menjadi kepingan mengikut tiga bahagian utama buluh, bahagian atas, bahagian tengah dan bahagian bawah. Kepingan tersebut kemudiannya dikeringkan bagi tempoh dua minggu sebelum meletakkan ia ke dalam tanur untuk proses karbonisasi itu. Dalam projek ini, tanur telah dibina berdasarkan reka bentuk tanur keluli drum Masato Iwasaki. Suhu karbonisasi yang digunakan adalah 476± 20 ° C untuk kedua-dua spesies buluh yang dipilih dan suhu ini dikekalkan selama 5 jam sepanjang proses karbonisasi. Analisis proksimat telah dilakukan untuk menentukan kandungan lembapan, abu, bahan ruapan dan karbon tetap (% berat) dan peratusan hasil telah dikira. Peratusan hasil yang diperolehi daripada B. vulgaris adalah 62.1% manakala D. asper adalah 72.9%. Daripada analisis proksimat, kandungan lembapan, bahan ruapan, abu dan karbon tetap untuk sampel B. vulgaris adalah 3.87%, 18.06%, 4.58% dan 73,49%, masing-masing. Sementara itu, kandungan kelembapan, bahan ruapan, abu dan karbon tetap untuk sampel D. asper ialah 4.09%, 13.91%, 5.59%, dan 76.41%, masing-masing. Perbezaan ini adalah disebabkan oleh unsur elemental, kimia dan sifat fizikal spesies buluh. Mikrograf mikroskop elektron pengimbas(SEM) arang yang dihasilkan telah diambil dan ia menunjukkan bahawa struktur arang yang dihasilkan oleh kedua-dua spesies ini adalah amat berliang. Kedua-dua species buluh ini boleh dijadikan arang dan sifat arang mereka menunjukkan kesesuaian untuk pelbagai kegunaan.

Kata kunci: Analisis proksimat, arang, buluh, karbonisasi, mikroskop electron pengimbas (SEM)

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LIST OF ABBREVATIONS

FC	Fixed Carbon
cm	centimeter
mm	millimeter
mg	milligram
g	gram
kg	kilogram
SD	Standard Deviation
SEM	Scanning Electron Microscope
°C	degree Celsius
wt%	mass percentage

CHAPTER ONE

INTRODUCTION

1.1 General Background

Bamboos are considered as one of the forest most versatile product. It can be utilized into various things such as construction material, handicraft and furniture, food sources, medicine and as an alternative domestic fuel resource in a form of charcoal. China, Indonesia and Vietnam were the major producers and exporters of bamboo in Asia. According to Ball and Lobovikov (2007), China exported approximately USD $25 million worth of bamboo, roughly a third of the world total. Followed by Indonesia and Myanmar which exported USD $10.6 million and USD $7.7 million worth of bamboo respectively. One of the most significant usage of bamboo is that it can be made into charcoal. Regular charcoal is commonly used in cooking, generating heat and to the most extend in generating power in steam boilers to drive the motors in electric power stations.

Malaysian charcoal industries are mainly depending on tree woods obtained from the timber and wood processing industries. Some of the highly demanded charcoal were produced from the valuable tree species of *Rhizopora apiculata* or locally known as Bakau Minyak. This tree species originated from the mangrove forest that held significant function in the ecosystem. One of the vital function of mangrove forest is to act as a barrier against the climate change and natural event such as the tsunami. The area of Kuala Sepetang and Gelang Patah which are in the state of Perak and Johore, respectively are the main area of mangrove forest that are being exploited for producing charcoal in Malaysia. If the mangrove forest is continuously exploited without any plans on sustaining it resources, it might pose danger to its natural wildlife and humans.

Countries such as Thailand and Burma had already begun to use bamboo as their new alternative raw material source of charcoal in the effort to reduce forest destruction and to promote economic growth among rural communities. Bamboo have a rapid growth rate and able to grow in abundance compared to the other woody plant species that might take more than five years to reach maturity (Tewari, 1992). It is also known that bamboo produces excellent charcoal (Kumar and Chandrashekar, 2014). By using bamboo as an alternative raw material source in producing charcoal in Malaysia, environmental problems such as over-exploitation of forest resources can be reduced and economic improvement among the rural community can be established as the demand for charcoal in Malaysia increased steadily over the years.

1.2 Objectives

The specific objectives of this project are:

1) To produce charcoal from *B. vulgaris* and *D. asper* by using steel drum kiln.

2) To determine the quality of the *B. vulgaris* and *D. asper* charcoal produced.

CHAPTER TWO

LITERATURE REVIEW

2.1 Distribution of bamboo

Bamboo are plants that are members with the subfamily of Bambusoideae of the grass family Poaceae. There are 1250 species of bamboo ranging from 75 genera that are distributed around the world which most of them are woody and fast growing (Ellis and Soderstrom, 1988). Bamboos mostly nurture at the sea level in tropics and up to 4000 meters in temperate region. They are found naturally in all subtropical and temperate regions except in Europe but most of them are mainly distributed in the tropics region (Tewari, 1992). In Malaysia there are 7 genera that consist of 44 species of bamboos out of which 25 are indigenous (Ng, 1980).

2.2 Significance of bamboo

According to Tewari (1992), bamboos hold its special significance based on the following four reasons. Firstly, bamboo is faster growing amongst the woody plant species, getting harvestable maturity in less than five years. Secondly, the plantation technology for large scale cultivation of bamboo is known. In a meantime, standard practices had been developed with culm cutting and the tissue culture methods are gaining in advancement. Thirdly, mature bamboo ranks potentially higher than juvenile wood as material by having less variability in structure. The fourth reason is despite of the bamboo dynamic and invasive growth habit, it is considered more “environmentally friendly” in comparison to alien plant species in several countries.

2.3 Utilization of bamboo

Bamboos are versatile plants which have around 1500 documented uses (Kumar and Chandrashekar, 2014). It is able to produce more biomass per acre than any tree and has a great potential to substitute wood in many ways (Tewari, 1992). Usage of bamboo varies from household products to industrial applications (Naik et al., 2016). Mainly, bamboo is used as paper pulp resources, construction material, handicraft and furniture, food source for humans and animals, medicine and as an alternative of domestic fuel in the form of charcoal for cooking and heating (Kumar and Chandrashekar, 2014). Besides that, there are some other usage of bamboo charcoal that are much in need such as in water purification, food industry, pharmaceutical industry and metallurgical industry (De Freitas et al., 1999). Hu et al., (2009) reported that charcoal from bamboo were highly effective in removing Ciprofloxacin, which are the major substance in pharmaceutical waste. Their research also discovered that bamboo charcoal had higher adsorption capacity, about 613 mg / g much higher than other type of charcoal. Bamboo charcoal also can be further used as a decolorizing sugar agent, organic preparation and alcohol and petroleum solvents (Kumar and Chandrashekar, 2014).

2.4 Charcoal from bamboo

Bamboo charcoal has been traditionally used as a substitute for wood charcoal and mineral coal for ages. Bamboo is turned into charcoal through the process known as pyrolysis. Pyrolysis of bamboo can be divided into four stages namely drying, pre-carbonization, carbonization and calcination (Jiang, 2007). The calcination stage which also known as the refining stage is very important in determining the charcoal quality (Jiang, 2007). Pyrolysis will enter the calcination stage when the temperature is greater than 450°C. Over the advancement of technology, bamboo charcoal can be use as fuel, adsorbent and conductor in this modern day. In addition, activated bamboo charcoal can be used for absorbing excess moisture, cleaning environmental pollutants, producing medicines and health products (Ball and Lobovikov, 2007). Furthermore, Ahn & Choi (2014) reported that bamboo charcoal had significant antibacterial properties on the *S. mutans* bacteria, which are the main contributor to tooth decay problem. At present, China is the world's leader in bamboo charcoal production while Japan, Republic of Korea and Taiwan are the main consumers of bamboo charcoal (Ball and Lobovikov, 2007).

2.5 Factors affecting charcoal making process

According to Kumar et al. (1999) charcoal can be produced from any lignocellulosic raw material but not all of them yield good quality charcoal. Quality of charcoal differ according to physical, chemical and anatomical properties of species (Kumar, 2002). In additions, temperature, heating rate, chemical composition, particle size, moisture content and the preparation steps are the main factors to be consider in the charcoal making process (Sharma et al., 1992). Jiang (2007) suggested that the bamboo used to make charcoal should have the moisture content around 15% to 20%. The kiln temperature during the pyrolysis process must be controlled properly to prevent sudden escalation in temperature, as the bamboo inside the kiln will crack if the temperature of the kiln rise drastically (Jiang, 2007).

2.6 Recent studies on bamboo charcoal

Ahn et al. (1998) had studied about the general properties of charcoals produced from 3 species of bamboo and find out that the charcoals have the average calorific value of 7,800 kcal/kg indicating their good fuel potential (Chandrashekar and Kumar, 2014). Meanwhile, Konwer et al (2007) study involving eight species of bamboo of north east India found out that the charcoal produced have low fixed carbon content ranging from 62.1% -67.5% thus rendering them unsuitable for metallurgical usage and only suitable for domestic usage or as fuel gasifiers. Chandrashekar and Kumar (2014) carried out a study about the yield, chemical composition and calorific value based on four species of bamboo which were consist of *Bambusa bambos, Dendrocalamus brandisii*, *Dendrocalamus stocktii* and *Dendrocalamus strictus.* The charcoal was prepared at a different carbonization temperature ranging from 300°C to 800°C and the change of fuel properties were evaluated. In their study, they concluded that charcoal yield decreased with carbonization temperature, whereas fixed carbon, elemental carbon and ash content increased with the rise in carbonization temperature. From these findings, more study about fuel properties of bamboo charcoal from the other bamboo species are required in order to determine which bamboo species are suitable for making charcoal in a larger scale of production that can generate profits while maintaining natural resources sustainability.

2.7 Steel drum as kiln in producing charcoal

The prevalent use of cylindrical transportable metal kilns for charcoal production dated back in Europe in the 1930's (FAO Forestry Department, 1983). During the Second World War the technique was further developed by the United Kingdom (U.K.) Forest Products Research Laboratory. Several versions of the original design have been used throughout the United Kingdom. This technology was transferred to developing countries in the late 1960's, notably by activities in the Uganda Forestry Department (Burnette, 2013). Charcoal can be produced in kilns constructed from standard 45-gallon steel drums. This method has been operated successfully using fast burning raw materials such as coconut palm timber, coconut shells and scrub wood (FAO Forestry Department, 1983). Meanwhile, the usage of steel drum kiln in producing bamboo charcoal are practiced in the country such as Thailand and Myanmar within its rural community due to the kiln easy construction and efficiency (Burnette, 2013).

2.8 *B. vulgaris* and *D. asper* current uses

B. vulgaris species are from the genus *Bambusa* of the clumping bamboo tribe of Bambuseae (Tewari, 1992). *B. vulgaris* are mainly distributed in tropical and subtropical regions in Asia. This species also can be found along the wet tropics area (Wong, 1995). According to Tewari (1992) *B. vulgaris* had many uses. The leaves can be used for animal fodder, the stem can be used for construction material, the whole plant for ornamental purpose and the young shoot can be consumed as food for human. Meanwhile, *D. asper* bamboo is a large , densely-clumping tropical species native to the Southeast Asian region (Wong, 1995). This species is traditionally used for building material due to its straight culm, timber-like physical and large culm diameter (Tewari, 1992). The young shoots of *D. asper* are used as a source of food in Asia.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Preparation of raw bamboo material

Samples of *Bambusa vulgaris* and *Dendrocalamus asper* were collected from the area of Kg. Pinang, Kota Samarahan and Sabal, Simunjan, Sarawak, respectively. Total of four culm of the selected bamboo species were harvested for this project, counting two for each species. The age of the selected bamboo species were 4 years up to 5 years old. The internode parts of the bamboo were included for the carbonization and were cut into sections using chainsaw with the length between 45±0.5cm to 65±0.5cm each (Figure 1). The wall thickness of the bamboo were around 5±0.5 mm to 30±0.5 mm. Later, the cut sections of the bamboo were split into three pieces per sections by using axe and machete. The split bamboo pieces were labeled and arranged according to their respective sections namely the top section, middle section and the bottom section. Then, they were air dried for 5 days to three weeks to remove any excessive water(Figure 1). After the samples were dried, the dry weight for each samples were weighed and recorded.

Figure1: Bamboo samples being prepared and cut into pieces for air-drying.

3.2 Construction of the kiln

In this project, the kiln was based on Masato Iwasaki's designed steel drum kiln (Iwasaki, 2004a) with slight modification. This design was selected because it is simple to be constructed, cost effective and can be mobilize in a short time. The kiln was constructed with two steel drums. Basically, the kiln consists of two sections namely the carbonization furnace and the firewood chamber. The first steel drum was used to construct the carbonization furnace and the second steel drum for the firewood chamber (Figure 2).

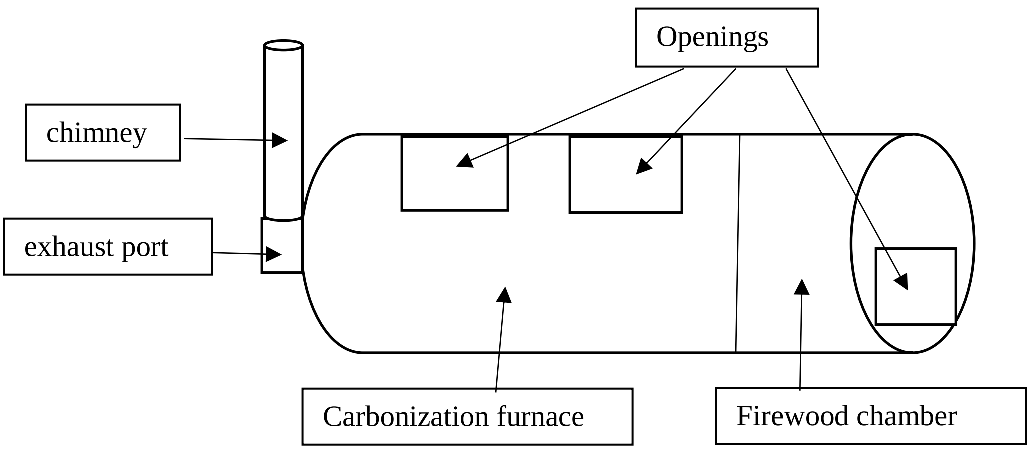

Figure 2: Iwasaki kiln main parts.