

Bamboo scraps and hardwood chips biochar derived from a cone-truncated open fire kiln for use as a nutrition medium for agricultural purpose

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Abstract. An experiment on the production of biochar from bamboo scraps and hardwood chips for use as materials to improve soil was done by burning the biomass of the bamboo scraps and hardwood chips in Pyrolysis conditions at a temperature range of 5700-00°C with a cone-truncated open fire kiln which reduces burning time to 45-60 min. Experimental results revealed that the average bamboo-scrap biochar of 2.5 kg resulted from burning 15 kg of the bamboo scraps; likewise, the average hardwood-chip biochar of 2.2 kg resulted from burning 15 kg of the hardwood chips. According to analyses, the bamboo-scrap biochar was composed of 8.6% moisture content, 8.0% volatile substance, 9.0% ash, 83% fixed carbon, 250mg/g iodine and pH 10.3; whereas, the hardwood-chip biochar was composed of 6% moisture content, 8.2% volatile substance, 3% ash, 88.8% fixed carbon, 300 mg/g iodine, and pH 10.1. The result of planting experiments showed that after mixing the biochar for soil nourishment and compost into the planting soil, the morning glory and kale can grow better than those planted in normal soil and soil with compost.

1 Introduction

Thailand is an agricultural country, 7,942,582 registered households own total areas of 95,360,138.5 rais [1]. Most farmers follow single-crop-farming occupations for commercial purposes; thus, they grow rice, sugarcane, cassava, rubber, palm oil, and fruits, etc. They also grow vegetables, fruit trees, field crops and various types of perennials for their uses. Each year, there are many waste materials of biomass having been disposed in vain instead of being changed and put back into the soil as plant nutrients [2]. Therefore, these waste materials of biomass can be used as soil improvement materials by, for example, composting from them and using bio-extracts from vegetables and fruits to help increase soil fertility in agricultural areas. In addition, these waste materials of biomass can be

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processed through slow and fast heat-based decomposition with temperature control and limited oxygen so as to get a solid black product called "biomass charcoal or biochar" to be used as a soil improvement material which can be useful for water storage, a reserving source of plant nutrients, a habitat for microbes, used to adjust the soil condition and as a stimulant for soil to react and help the plant nutrients to exchange cationic charge among one another better. The soil improvement biochar can help plants grow with increased yields and can be so stable that it can store carbon in the soil for many years. Biochar is currently attracting farmers all over the world as it is an innovation that helps solve soil degradation problems [3]. By the production process with temperature control and oxygen limitation in the combustion process, the biochar can help reduce the loss of plant nutrients. Over the past decade, soil and environmental researchers have focused on the potential to improve soil fertility and carbon dioxide capture from the atmosphere in a form that can be maintained for hundreds and thousands of years [4].

The biochar, which is a charcoal-like substance produced from agriculture and forest waste, has 70% of carbon to be used as a soil stimulant, to increase soil fertility, to prevent soil decay and to store carbon in the soil. It can be produced by pyrolysis gasification and hydrothermal carbonization. Small-scale biochar production is possible by using pyrolysis-modified incinerator that requires low cost and relatively simple technology. The important quality of the biochar is its structure which is fine with increased surface area and lots of very small holes, rich in carbon and suitable for reducing carbon dioxide accumulation [5]. Therefore, a chemical process, especially the decomposition with slow pyrolysis resulting in the biochemical properties in an environmentally friendly manner and a sustainable future development has been recently well recognized [6].

In particular, Steiner noted in a book--*Amazonian Dark Earths*-- in 2003 that increasing the biochar efficiency in the soil leads to increased nitrogen absorption among plants up to 400 - 280 % [7] and reduction of climate change. It can also generate income by reducing carbon dioxide emissions for farmers around the world [8]. The physical and chemical properties of biochar depend on the type of raw materials and the temperature in the production of biochar [9]. Production of biochar at 450°C for 2 h makes the biomass from giant Acacia wood to be suitable for the improvement of sandy soils in rain shadow areas to increase the sesame production [8]. From a test of characteristics of the biochar from wood chips before improving soil quality, it has been found that due to its important porous property, the biochar was applied to improve soil ventilation and water holding capacity of soil and to reduce soil hardness. The biochar produced from wood chips can absorb water 4-2 times the original weight [10]. Regarding the development of biochar from bamboo and hardwood for use as soil improvement materials and plant nutrients, when analyzed by XRF machine, it was found that the ashes of the biochar from bamboo and hardwood contained more phosphorus and potassium than those from other materials such as rice husk, palm kernel shell and bamboo [11].

The biochar produced from different raw materials and under different conditions may cause the physical and chemical properties of the soil to be different as well. Therefore, the production of biochar designed to improve the physical and chemical properties of the soil depends on the conditions in the pyrolysis process and the raw material used [6].

Therefore, the main objective of this study is to compare the properties of bamboo and hardwood biochar burned by a cone-truncated open fire kiln that is effective in the reduction of waste and burning cost and time. Moreover, the properties of both biochars and the results of both biochar in growing plants are to be investigated.

2 Materials and methods

2.1 Materials and equipments

Bamboo scraps and hardwood chips discarded (Figure 1.) were collected, exposed to the sun for 48 h to dry and reduce humidity and then burned in a cone-truncated open fire kiln (Figure 2.). The temperature was measured by Infrared Thermometer (DT8011H). The pH and moisture level were measured by Soil pH and moisture tester (Takemura DM-15). Pyrolysis conditions occurred at the absence of oxygen 500-700°C for 45 min to 1 h, then the burning output was taken to study the chemical properties and used as nutrition medium for planting.



a) bamboo scraps.



b) hardwood chips.

Fig.1. Material for biochar burning a) bamboo scraps b) hardwood chips.



a) starting burning.



b) during burning.

Fig.2.A cone-truncated open fire kiln a) starting burning and b) during burning.

2.2 Properties testing method

The volatile matters, fixed carbon, and ashes content of the biochar produced were characterized following standard methods of ASTM D3174-[12], ASTM D3175-[13] and ASTM D3172-[14]. The iodine absorption technique was from ASTM D4607-[15].

2.3 Biochar-mixed soil on the Morning glory and Kale planted in the demonstration Plot

The soil texture for this study is loam which has field capacity 18-26% and permanent wilting point 8-12%. In order to compare the growing result with and without compost and biochar so we prepare demonstration plot for planting the Morning glory and Kale in three different plot a) soil mixed with compost and biochar b) soil mixed with compost and c) ordinary soil.

3 Results and discussions

3.1 Burning temperature results

Burning Temperature results are shown in Figure 3. The temperature from hardwood chips and bamboo scraps are 676.4 and 536.5°C. The burning temperature of hardwood is higher than bamboo.



a) hardwood chips.

b) bamboo scraps.

Fig. 3. Burning temperature result of hardwood and bamboo biochar.

3.2 Volatile matters, fixed carbon and ashes content of biochar

The volatile matters, fixed carbon, and ashes contents of the chosen biochar are presented in Table 1. The volatile matter content superseded the amount of tars and releasable gasses in biochar. The fixed carbon content specified the soil fuel and carbon content left after the volatile matter was dispelled. The ashes content informed the amount of mineral matter and incombustible matter in biochar [16]. Therefore, the biochar from bamboo which had 9% of ashes content should have a higher amount of inorganic mineral content than biochar made from hardwood chips.

Table 1. The chemical content analysis of bamboo scraps and hardwood chips biochar.

Content	unit	Type of Biochar	
		Bamboo	Hardwood
Volatile Matters	%	8.0	8.2
Fixed Carbon	%	83.0	88.8
Ashes	%	9.0	3.0

3.3 Iodine absorption analysis

The iodine absorption analysis was tested to define the surface porosity of biochar. The higher iodine number meant the higher porous on the surface which defined by iodine absorption. The obtained iodine numbers clearly ascertained that hardwood biochar has a higher surface porosity of bamboo biochar in this study (Table 2). This result showed the hardwood biochar a candidate for the nutrient enrichment medium used for soil because the hardwood biochar would improve the soil moisture by retaining water in biochar high porous structure.

Table 2. The iodine number of bamboo and hardwood biochar.

Type of Biochar	Iodine Number (mg/g)
Bamboo	250
Hardwood	300

3.4 Effect of biochar-mixed soil on the Morning glory and Kale planted in the demonstration plot

Table 3 shows the pH and moisture of each demonstration plot comparing before and after planting Morning glory and Kale.

Table 3. The pH and moisture value of bamboo and hardwood biochar.

Type	pH		Moisture level*	
	Before	After	Before	After
ordinary soil	6.8	6.5	1.5	1.5
soil mixed with compost	6.1	5.8	1.0	6.0
soil mixed with compost and biochar	5.5	> 8	7.5	7.8

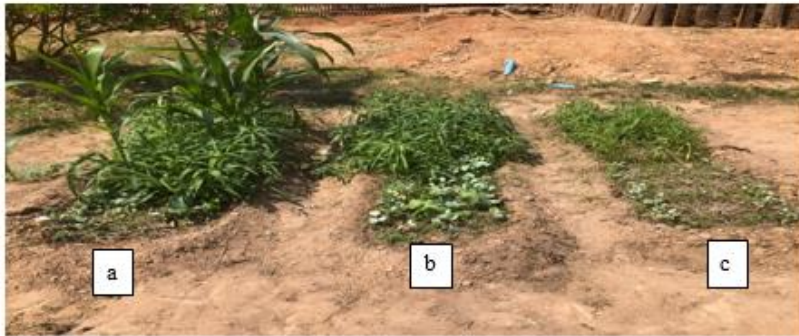
*Moisture level is 1-8. 1 is low moisture and 8 is high moisture.

The biochar for soil nourishment obtained from hardwood chips was taken to be mixed with the planting soil for experimental planting seedlings in the plot to find out planting results from ordinary soil, soil mixed with compost and soil mixed with compost and soil-nourishing biochar. As shown in Figure. 4-5., the soil mixed with biochar from hardwood chips can help to nourish the soil for plants to grow better than the ordinary soil and the soil mixed with compost since the pH of the mixture is more than 7 and higher moisture. The experimental results are in accordance with previous research.



a) soil mixed with compost and biochar b) soil mixed with compost c) ordinary soil

Fig. 4. 5-week planting results of Morning glory and Kale.



a) soil mixed with compost and biochar b) soil mixed with compost c) ordinary soil.

Fig. 5. 6-week planting results of Morning glory and Kale.

3.5 Comparing results of biochar production from other Research

Table 4. shows a comparison of the type of charcoal kiln, input materials, temperature range, % of volatile matter, % of fixed carbon, % of ashes, iodine number and production from other research with this research. The experimental results gave better than previous research.

Table 4. Comparing result of biochar production from other research.

Type [Reference]	Input material	Temperature (°C)	Volatile (%)	Fixed carbon (%)	Ashes (%)	Iodine (mg/g)	Product (out/in) (kg/kg)
Horizontal 200-liter OilDrum [11]	durians hell	400-500	28	57	15	202.32	3-4/100
	bamboo	400-500	26	64	10	177.66	N.A.
	palmshell	400-500	28	65	7	162.81	N.A.
A cone-truncated open firekiln [This research]	bamboo	500-600	8	83	9	250	2.5/15
	hardwood	600-700	8.2	88.8	3	300	2.2/15

4 Conclusions

From the experiments in this study, they have been revealed that the biochar from the bamboo scraps and hardwood chips burned with a cone-truncated open fire kiln effective in the reduction of waste, burning cost and time are interestingly useful to add plant nutrients in soil. The result of growing of biochar from hardwood chips is better than from bamboo scraps. Despite its simple and not complicated characteristics, the cone-truncated open fire kiln can make the temperature of pyrolysis up to 500-700°C. According to results of the analyses, the iodine absorption of biochar is relatively high so they can well store moisture in the soil. The soil mixed with biochar from hardwood chips can help to nourish the soil for plants to grow better than the ordinary soil and the soil mixed with compost; however,

further investigating of important nutrients in the soil from biochar and planting in real plots should be tested to see the exact results.

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