Determinations of Optimum Pyrolysis Conditions for Producing Refuse Tea Biochar

HAHI Amarasinghe*[1], SK Gunathilake[1] and AK Karunarathna[2]
[1]Department of Natural Resources, Faculty of Applied Sciences, P.O. Box 02, Belihuloya Sabaragamuwa University of Sri Lanka
[2]Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

Abstract
It has been estimated that approximately four metric tons of refuse tea is produced daily from the tea processing industries in Sri Lanka. At present refuse tea is considered as a waste product from tea processing and, dumping and composting are the common practices of disposal. Manufacturing of biochar from organic waste is an emerging technology where biochar can be used for soil applications, environmental remediation and carbon sequestration. Hence, this research aimed to determine optimum pyrolysis conditions for producing refuse tea biochar. The pyrolysis experiments were done in a small air-tied steel reactor which was kept in a muffle furnace. Initially, refuse tea was pyrolyzed at temperatures between 300 °C and 500 °C for different residence time ranging from 15 to 60 minutes. The physical and chemical characteristics of biochar such as moisture content, ash content, carbon content, volatile matter content, bulk density, pH and electrical conductivity (EC) were analyzed following the biochar quality standards proposed by International Biochar Initiatives (IBI). Results showed that the yield of biochar varied with the residence time for a given temperature treatment. The proximate analysis of produced biochar showed the fixed carbon content varied from 26%-58%, consequently, the volatile material content was very high for optimum conditions. This research revealed that refuse tea can be effectively converted to biochar between 450 to 500 °C temperatures subjected to residence time of 45 to 60 minutes.
Keywords: Biochar, Refuse tea, Pyrolysis
****Corresponding author:*** hemaliamarasinghe@gmail.com

Introduction
The estimated Ceylon black tea dust production is 120 metric tons per month. The dust grade tea are not merely absolute refuse, and tea dust are usually further processed to extract black tea from the dust. The extraction and further processing of Refuse tea is an axillary industry mainly concentrated in Gampola in the Kandy district. Handling and disposal of absolute refuse tea (ART) are worldwide problems faced by tea industries in the world, therefore significant number of research studies have been conducted to examine the potential resources that can be recovered from absolute refuse tea. Pyrolizing of tea dust for energy recovery and biochar production are emerging technologies. Development of high quality biochar using tea refuse has been proposed as one of the alternative way of resource recovery and safe disposal. Biochar is a carbon rich product obtained from thermal decomposition of organic materials in absence of oxygen (Lehmann *et al.*, 2010).

Researchers have shown that addition of biochar in to soil reverses soil fertility decline, improves crop yields, and improves plant response to fertilizer (Dharmakeerthi, 2011). It has also been suggested that biochar may have the potential to reduce leaching of pollutants from agricultural soils. This property of biochar is explained by the strong adsorption affinity of biochar for soluble nutrients such as ammonium (Lehmann *et al.* 2002), nitrate (Mizuta *et al.*, 2004), and other ionic solutes (Radovic *et al.*, 2001). In addition, pyrolizing of tea dust for energy recovery and biochar production are emerging technologies. The aims of this study were determine the optimum material handling and material mass balance for slow pyrolysis of refuse tea, determine the optimum thermal conditions for slow pyrolysis of refuse tea and to characterize biochar according to the guidelines/test categories of International Biochar Initiative.

Materials and Methods
Quality of the produced biochar and the performances of the reactor were analyzed at Soil and Water Engineering Laboratory, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya.

Three Absolute Refuse Tea (ART) samples were collected randomly from the bulk from a black tea post-processing factory in Gampola area. The heating energy required to achieve higher temperature to produce biochar from refused tea were given by placing the pyrolytic reactor in a Muffle furnace, type 6000 - model F 6018.

Refuse tea was packed tightly in the pyrolytic reactor by compressing, minimizing amount of air entrapped in the reactor. Then, the lid was placed on the top and tightened to avoid air exchange between in and out. Once the muffle furnace reached the set temperature, the reactor was kept inside the furnace. Pyrolysis was carried out by using five combinations of temperature (300, 350, 400, 450, 500 ^{0}C) and four retention times (15 min, 30 min, 45 min and 1 hour).

After the sample was heated for a given residence time at each temperature, the reactor was taken out. Then, the reactor was quenched by immersing in a water bath to avoid further oxidation of produced biochar. The quenching time varied depending on both pyrolyzing temperature and retention time. Thereafter, the biochar was collected from the reactor, weighed, and packed in plastic bags for subsequent analysis. The properties of biochar were analyzed using proximate analysis, mentioned in Table 1.

Table 1: Analytical parameters and methods

Analytical parameter	**Method/Instrument and Condition**
Moisture Content	ASTM Method D3173
Ash	ASTM Method D3174
Carbon content	Experimental method
Bulk Density	Laboratory Method
pH	pH meter
Electrical Conductivity	Thermo orient Model 145A

Biochar characterization and quality estimation were done based on Standardized Product Definition and Product Testing Guidelines for Biochar standards, by International Biochar Initiative (IBI, 2012).

Results and Discussion

The amount of biochar obtained by pyrolyzing at 300^{0}C for 15 minutes was comparatively low and the color of biochar was pale brown which was different from the quality biochar color (shiny black) and some amount of raw material was remained. The partial pyrolysis was due to comparatively low temperature with short residence times; a combination that was not sufficient to breakdown organic compounds like Lignin, Cellulose and Hemi-cellulose material of the raw material.

The equilibrium moisture content of produced biochar was very low, except some retention times, as high pyrolysis temperature, water was vaporized. It was less than moisture content in paddy husk char (5%) and saw dust char (7%) recorded by Ryu *et al.* (2005).

Average ash content of refuse tea biochar was greater than typical value (0-5 %) of ash content in wood, paddy husk and saw dust chars (Ryu *et al.*, 2005). Ash increases the soil pH, thereby increasing available phosphorous. And also, it improves the aeration in the crop root zone, increases the water holding capacity and level of exchangeable Potassium and Magnesium.

Figure 1 shows the mass recovery after pyrolysis at different residence times. According to the figure 1 temperature between 450 ^{0}C and 500 ^{0}C showed the lowest mass recovery. Since, refuse tea is a biomass which composed of hemicellulose, cellulose and lignin, all these materials might have decomposed at lower temperatures and lower residence times, compared to woody and lignified materials. Thus, it is evident that lower residence times are adequate at a range of temperatures between 350 ^{0}C and 500 ^{0}C.

The chemical, physical and morphological properties of biochar are largely influenced by the residence time for a given temperature treatment. At the temperatures between 400 ^{0}C and 500 ^{0}C and residence time of 30 to 60 minutes, refuse tea cannot be effectively converted into biochar due to higher mass losses.

The mass loss for each trial of material mass balance is defined as the difference between the amount of refuse tea input and the amount of biochar output. Mass loss increased with the increasing pyrolysis temperature as well as the retention time due to complete conversion of biomass into gaseous products. At the temperatures between 300^{0}C and 350^{0}C, amount of mass loss was minimum compared to higher temperatures. Material mass balance revealed that between 450 ^{0}C and 500 ^{0}C and the residence time of 45 and 60 minutes, refuse tea can be effectively converted into biochar.

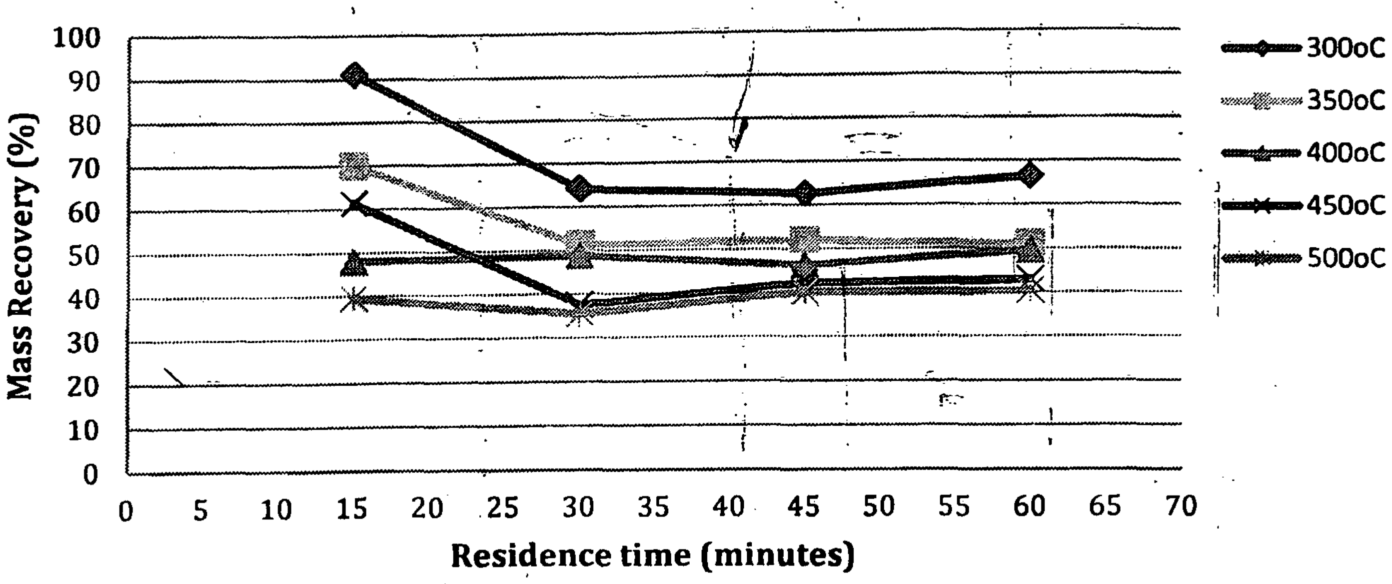

Figure 1: Mass recovery with the increase of residence time

The proximate analysis of produced biochar showed the fixed carbon content varied from 26% - 58%. The experiments showed that refuse tea biochar can be effectively manufactured by pyrolysing at 350 °C for 30 minutes which requires less thermal energy than conventional feedstock like wood or crop residue. This could be due to small particle sizes of refuse tea and leafy nature. Furthermore fast volatilization of organic mass at lower temperatures can be positively used in up scaling the pyrolysis reactor where the excess energy in pyrolyzed gas can be combusted for heat recovery.

The preliminary data obtained from this study can be used for designing and fabrication of large scale pyrolytic reactors which can be used for pyrolysis of refuse tea. This can be started with appropriate that shall develop to efficient pyrolytic reactors with additional testing.

Acknowledgement

Guidance of Dr. A.K. Karunarathne, Senior Lecturer, Department of Agricultural Engineering, University of Peradeniya, Dr. S. K. Gunathilake, Senior Lecturer, Department of Natural Resources, Sabaragamuwa University and the support of Miss. Renuka Aryawansha, University of Peradeniya are greatly acknowledged

References

Dharmakeerthi RS 2011. Soil, A precious natural resource: Agricultural ecosystems, Environmental health and climate change, Soil Science Society of Sri Lanka.

Lehmann J 2010. A future for biochar, Sheraton and UVM conference center, Berlington.

Lehmann J, da Silva Jr JP, Rondon M, Cravo Ms, Greenwood J, Nehls T, Steriner C and Glasser B 2002. Slash -and-char-afeasible alternative for soil fertility management in the Central Amazon. Proceedings of the 17th world congress of soil science,(pp1-12) Bangkok, Thailand.

Mizuta K, Matsumuto T, Hatate Y, Nishihara K and Nakanishi T 2004. Removal of nitrate-nitrogen from drinking water using bamboo powder charcoal, Bioresource Technology.95:255-257.

Radovic LR, Moreno-Castilla C and Rivera - Utrilla J 2001. Carbon materials as adsorbents in aqueous solutions, in LR Radovic (ed)Chemistr and Physics of Carbon, New York, Marcel Dekker.(pp227-405).

Ryu C, Sharifi VN and Swithenbank j 2005. Waste pyrolysis and generation of storable fuel. Sheffield university waste incineration centre(SUWIC), Department of chemical and process Engineering, pp5-18.

Interntional Biochar Institute 2012(online)available at http://biochar-international.org/conferences