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PREPARATION OF BIOCHAR FROM DIFFERENT FEEDSTOCKS AND THEIR QUALITY ASSESSMENT

Mahfuja Akhter[1], Md. Shajib Molla[1], Muhammad Maniruzzaman[2*], A.K.M Faruk-E Azam[2], Fatamatul Mohosina[3].

Abstract

Biochar is widely recognized as an efficient tool for carbon sequestration, soil fertility and soil conditioner. It facilitates to retain more nutrients in field conditions. The understanding of its chemical and physical properties, which are strongly related to the type of the initial material used and pyrolysis conditions, is crucial to identify the most suitable application of biochar in soil. Biochar quality depends on feedstocks nature. For better choice of feedstock an experiment was carried out in the Agricultural Chemistry Laboratory, Department of Agricultural Chemistry and Central Laboratory, Patuakhali Science and Technology University, Patuakhali, during August, 2014 to September, 2015. The detailed investigation was carried out to know the nutritional status in feedstocks and its biochar. Four feedstocks namely rice straw, wood (rain tree), cow dung and saw dusts were used. Biochar was pyrolyzed in a biochar stove maintaining temperature <400°C. The highest yield obtained from cow dung feedstocks and lowest from rice straw. The highest organic matter, nitrogen, phosphorus, calcium and magnesium were found in both feedstock and biochar of cow dung and potassium and sulphur percentage were detected from rice straw. The lowest OM, N, P, K, Ca, Mg and S were obtained from saw dust feedstock and biochar, respectively. The status of different nutrients of biochar depends on the nature of feedstocks. The overall performance indicates that biochar prepared from cow dung was the best among the four biochar.

Keywords: biochar, carbon sequestration, pyrolysis.

Introduction

Biochar is the solid product, produced by the process of pyrolysis from the thermo-conversion of biomass under little or no oxygen for use in soils as an amendment (Gaskin *et al*., 2008; Lehmann and Joseph 2009).When pyrolyzed charcoal is added to soils to improve soil functions and reduce emissions from the organic materials that would otherwise naturally degrade to greenhouse gases (GHG), it is termed biochar (Lehmann and Joseph 2009). Pyrolysis is a thermochemical process in which the biomass was burned without oxygen. (Widowati*et al.,* 2010). Carbon (C) sequestration via conversion of biomass into a more durable form has been proposed a strategy to combat global climate change (Lehman *et al.,* 2006; Macious and Cmps, 2010). Due to its predominantly aromatic structure, charcoal can be chemically and biologically stable in soil for hundreds to thousands of years compared with biomass feedstock (Antal and Gronli 2013; McHenry 2009). Biochar production offers a simple, sustainable tool for managing agricultural wastes. This can be

[1] Department of Environmental Science, Patuakhali Science and Technology University
[2] Professor, Department of Agricultural Chemistry, Patuakhali Science and Technology University
[3] Department of Genetics and Plant Breeding, Patuakhali Science and Technology University
* Corresponding author: maniracm@yahoo.com

achieved by converting agricultural waste into a powerful soil enhancer that can preserve cropland diversity and discourage deforestation (Zolue, 2013). Sustainable biochar can be used now to help combat global warming by holding carbon in soil and by displacing fossil fuel use (IBI, 2009). Research has shown that the stability of biochar in soil greatly exceeds that of un-charred organic matter. Biochar retains nitrogen emissions of nitrous oxide hence the potency of the greenhouse gas may be reduced (Wang, 2013). Turning agricultural waste into biochar also reduces methane (another potent greenhouse gas) generated by the natural decomposition of organic matter. To achieve an advanced process for improving product yields from pyrolysis of selected biomass, it is important to undertake proper characterization (Zolue, 2013). As such, the physical and chemical properties of biochar have to be determined so as to fully ascertain the mechanism by which these biochar produced from different feedstocks can improve the productivity of agricultural soils (Laird *et al.,* 2010a). Different feedstocks may have different physio-chemical properties. It is therefore, likely that these different physio-chemical properties will influence the quality of the biochar produced when the feedstocks are carbonized and may in turn govern their suitability for use (Verheijen*et al.,* 2010). Unfortunately, there is no research about biochar production and characterization in Bangladesh from different feedstocks. Therefore, the present research work will be undertaken for preparation of biochar from four feedstocks is a first step and to investigate their chemical characteristics of these biochar.

Materials and Methods

Collection of sample

Four types of feedstock were used in current research. Rice straw was collected from Agronomy Research Field of Patuakhali Science and Technology University on 17 August, 2014. Rain tree wood was collected from Dumki, Patuakhali on 29 August, 2014. Cow dung was collected from nearby dairy farm of Patuakhali Science and Technology University on 16 October, 2014. Saw dust from Saw mill of Thana Bridge, Dumki, Patuakhali.

Experimental materials

Four feed stocks namely rice straw, rain tree wood, cow dung and saw dust were used for biochar preparation. Chemical analysis were conducted for both raw and biochar samples.

Biochar stove

Biochar from four feedstocks have been produced in biochar stove developed by Mia *et al.* (2012). The biochar stove had an open cylindrical section for fuel insertion and closed combustion chamber adjacent to it, closed with lid in where dry feedstock was placed.

Production of biochar

Collected feedstocks were naturally sun-dried for 4-7 days on concrete floor with plastic sheet (depending on initial moisture content). Rain tree wood and rice straw were cut into small pieces. As the moisture reached 15% after drying, cow dung was broken by hand to meet size of 4 – 5 cm while it was separated from other materials (i.e. small stones, plastics, grass, branch etc.)

Individually 12 kg of each feedstock, (rice straw, rain tree wood, cow dung and saw dust) was pyrolyzed each time with average 6 kg fuel. The average residence time was (6 hours) and the average temperature was <400 ^{0}C.Then the stove was cooled down and pyrolyzed biochar weighed. After the pyrolysis process, biochar was grounded and sieved to less than 0.5mm in diameter. Then each sample was air dried, tagged and stored in air tight condition.

Processing and preparation of biochar and feedstock extract

Sieved biochar and air dried feedstocks were oven dried at 72°C for 24 hours. Then feed stocks were ground by electronic grinder (Model-A 11 B S 2) and sieved. Exactly 0.5g of finely ground material weighed in electrical balance and taken into a 250 mL conical flask and 10 mL di-acid mixture (HNO_3 : $HClO_4$=2:1) was added. The flask was placed on the electric hot plate for heating at 180-200^{0}C until the solid particles were disappeared and white fumes were evolved from the flask (Jackson, 1973). It was cooled at room temperature, washed with distilled water repeatedly and filtered into 100 mL volumetric flask through Whatman 42 filter paper and the volume was made up to the mark with distilled water. The extracts were preserved separately in plastic bottles for the analysis of different elements.

Results and Discussion

Biochar production (Kg):

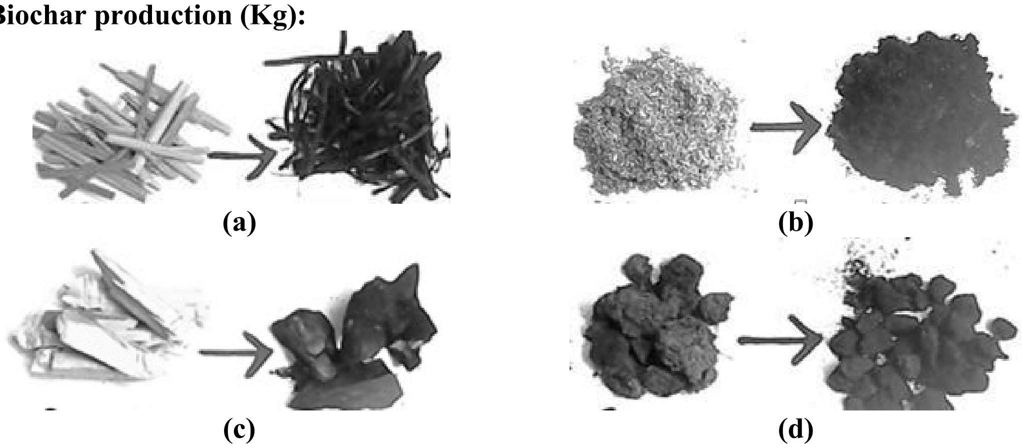

Figure 1. Biochar produced from four different feed stocks namely (a) Rice straw, (b) Saw dust, (c) Wood and (d) Cow dung.

The output of biochar from selected feedstocks used in this experiment was given in Figure 1. In this figure output of biochar from 12 kg feedstocks arranged as cow dung (9.45 kg)> wood (8.24 kg)> saw dust (8.17)> rice straw (3.64 Kg). There was a significant difference among the output value of different biochar produced from different feedstocks. Cow dung biochar shows the highest yield of biochar and rice straw show the lowest yield of biochar. Output of wood and saw dust biochar were statistically similar. The yield of biochar is influential to the characteristics of feedstocks. This result was supported by Edmund (2012) who observed that herbaceous feedstocks yield lower than other type due to high ash content of herbaceous feedstocks.

Organic matter content (%):

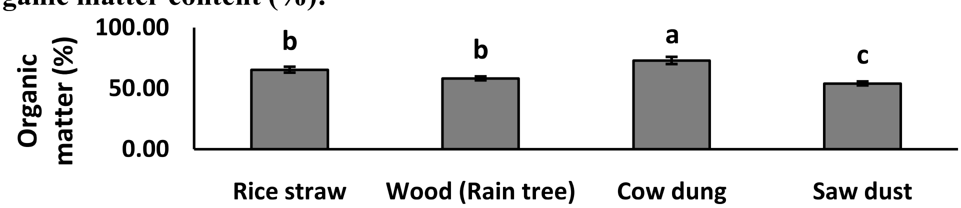

Figure 2. Organic matter content in different biochar

Organic matter content of biochar was presented in figure 2. There was a significant difference among the OM content of different biochar produced from different feedstocks. The highest organic matter was found in cow dung biochar which was significant at 5% level, and lowest organic matter was found in saw dust biochar. There is no statistical difference between rice straw and wood biochar. The results is in consonance with organic carbon contents obtained by Chan and Xu (2009) for a variety of biochar materials. Demimbras (2006) suggestad that feedstocks from animal waste have higher OM content than other sources when pyrolyzed at moderate temperatures. The higher level of organic carbon in cow dung biochar than other biochar types could be as a result of the higher carbonization process occurred in cow dung biochar. It is suggested that the cow dung biochar would convert more atmospheric carbon into a more stable form of carbon than rice straw, wood and saw dust biochar.

Nitrogen content (%):

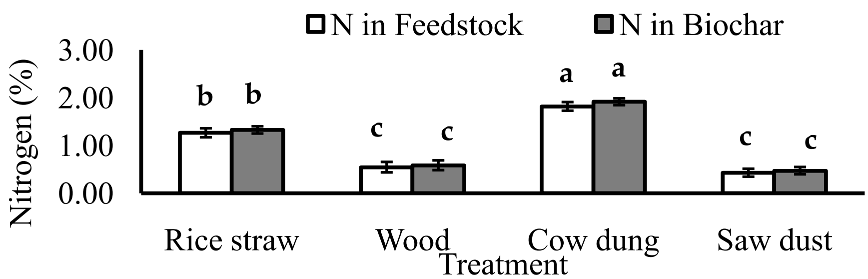

Figure 3. Nitrogen content in different biochar and feedstock

The result of nitrogen percentage influenced by different feedstocks is presented in figure 3.There was a significant difference ($P<0.05$) among the nitrogen concentration in feedstocks and different biochar produced from different feedstocks. The highest nitrogen percentage was found in cow dung feedstock (1.81667) and biochar (1.913), on the other hand the lowest nitrogen percentage was found for both feedstocks (0.42667) and biochar (0.4707) of saw dust. Similar result was observed by Zolue (2013) in case of slow pyrolysis at low temperature <400°C. Wang(2013) found that the total nitrogen rate of cow dung ranged from 0.99 to 2.01%. These results are in agreement with those data obtained by the study. Cao and Harris (2010) noted that N concentration of animal origin biomass greater than plant origin and that was concomitant with this research finding.

Phosphorus content (%):

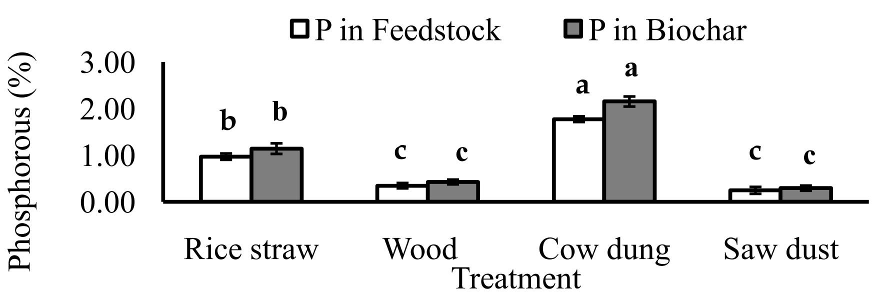

Figure 4. Phosphorus content in different biochar and feedstock

Similarly (%) P in feedstocks and biochar varied significantly ($P<0.05$). Here the highest P percentage was found both in cow dung feedstock (1.774) and cow dung biochar (2.15330). The lowest P observed both in saw dust feedstock (0.24667) and saw dust biochar (0.2937). From figure 4, it is clearly observed that increase in biochar nutrient is correlated with feedstock nutrient concentration. However, P was fully recovered from all types of feedstock. Phosphorus starts to become volatile in high temperature around 700°C, during pyrolysis phospho-carbonaceous structures are created at low temperatures and these structures decompose due to bond scission at high temperatures to form phosphate (Shenbagavalli*et al.,* 2011). Streubel (2011) found that PO_4^{-3} content of cow dung biochar was three times higher than that of rice straw biochar.

Potassium content (%):

There was a significant difference among the K value of different biochar produced from different feedstocks. The highest K (%) was observed in rice straw feedstock (1.54667) and biochar (2.139) and the lowest K (%) was found in saw dust feedstock (0.51667) and biochar (0.641). All feedstock and biochar significantly varied from each other, while no statistically difference observed between wood and saw dust feedstock (Fig.5).

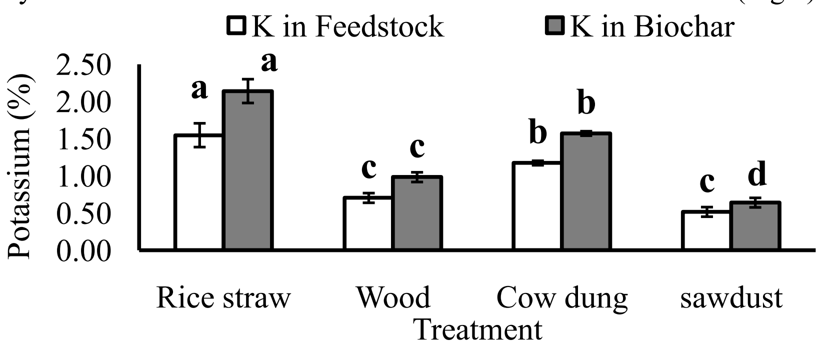

Figure 5. Potassium content in different biochar and feedstock

Uptake of potassic fertilizer from rice field may be the possible reason for retaining high content of K in rice straw. Reasons behind increase in biochar K content may be controlled combustion. This statement was supported by Wu *et al.* (2012) who compared rice straw biochar with feedstock nutrient where % K still preserved and increased in biochar at <400°C.

Calcium content (%):

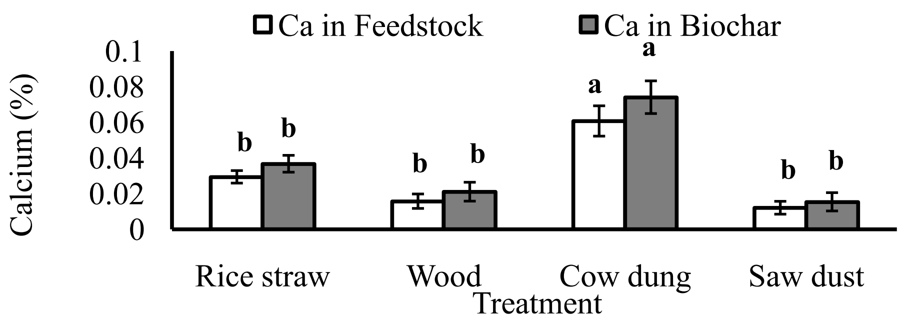

Figure 6. Calcium content in different biochar and feedstock

In biochar production recover of calcium content were statistically significant ($P<0.05$), while all biochar show increase in calcium content comparing their feedstocks (Figure 6). The highest amount of calcium was present in cow dung feedstock (0.0607%) and biochar (0.074%). The lowest amount of calcium was found in saw dust feedstock (0.012%) and biochar (0.01553%) which was statistically similar with rice straw and saw dust biochar. The development of the higher amount of adsorbent such as calcium carbonate, calcium, kaolinite, red mud, activated alumina, activated carbon (Chiang *et al.,* 2002) in cow dung biochar and low amount in saw dust might be the reason of fluctuation in Ca content.

Magnesium content (%):

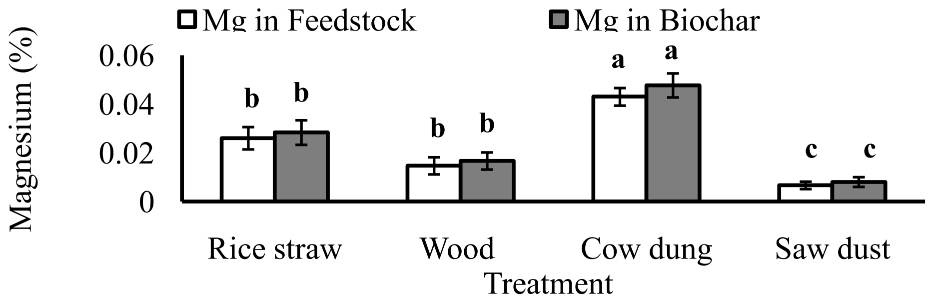

Figure 7. Magnesium content in different biochar and feedstock

There was asignificant difference ($P<0.05$) in magnesium content among the feedstocks and biochar (figure 7). The highest amount of magnesium was present in both cow dung feedstock (0.043%) and biochar (0.04767). The lowest amount of Mg present in saw dust feedstock (0.0067%) and biochar (0.00803%) which was statistically similar with rice straw and wood biochar.

Lu *et al*. (2009*)* found that biochar can remove relatively low concentration phosphates and increased amount of magnesium content in surface of biochar. The use of cow dung biochar might be considered more beneficial for its potential to remove phosphate compounds from its surface of wood biochar, rice straw biochar and saw dust biochar. Lu *et al.* (2009) also suggested that the addition of appropriate metal ions to the structure of the biomass could aid in creating additional basic sites on the char surface which become positively charged (Mg^{2+}) in solution and attract anions to the surface. The result is similar to our experimental results.

Sulphur content (%):

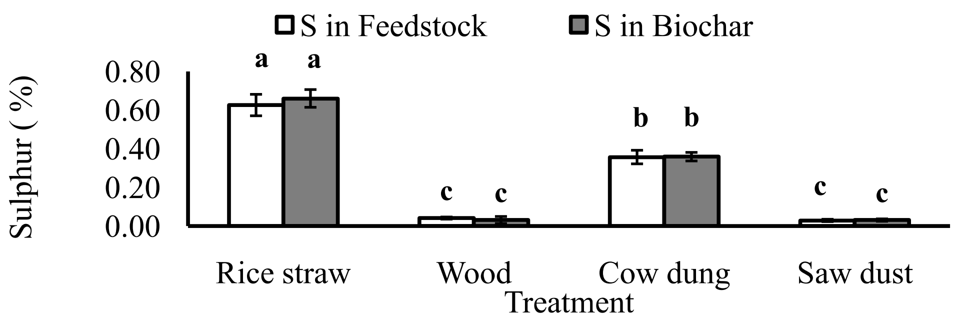

Figure 8. Sulphur content in different biochar and feedstock

Figure 8 showed that there was a significant difference among the sulphur value of different biochar produced from different feedstock. From graphical view of cow dung, slight increase in sulphur content was visible in contrast with feedstock. The highest amount of sulphur present in rice straw feedstock (0.62567%) and biochar (0.66%) and lowest amount was in saw dust feedstock (0.02867%) and wood biochar (0.041%). There was a considerable variation in the content of sulphur due to the feedstock characteristics. Biochar produced from rice straw feedstock were typically high in sulphur content which could contain greater than 45% elemental sulphur (Lima and Marshall, 2005), whereas the cow dung biochar showed minimum results.

Amonette and Joseph (2009) found that much of the sulphur content of the feedstock remain in the resulting biochar, where it is concentrated during pyrolysis. During pyrolysis, the rice straw biochar produced more common S functional groups like sulfonates and sulfates than other biochar types. As a result, rice straw showed highest concentration of sulphur.

Conclusions

Biochar was pyrolyzed in a biochar stove maintaining pyrolysis temperature <400°C. Cow dung feedstock gave the highest amount of biochar (9.45 kg). Rice straw feedstock gave lower amount biochar due to herbaceous nature. The biochar and feedstock were processed for lab analyses. In case of N and P status in both feedstock and biochar of cow dung was higher respectively. Cow dung biochar also showed the highest OM, Ca and Mg percentage along with feedstocks in respect of other type. Similarly, K and S content were higher in both feedstock and biochar of rice straw, respectively. It may be concluded that, in yield of biochar and nutritional aspect cow dung was the best.

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