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Characterization of Biochar Produced from Different Feed Stocks for Waste Management

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Abstract

The objective of this study was to characterize the biochar produced from different agricultural wastes to explore its potential use as organic soil amendments. The feedstock of *Eucalyptus globules* (EG), *Acacia decarance* (AD), farmyard manure (FYM) and rice straw (RS) were collected and biochar was produced by slow pyrolysis at 300°C in the furnace. The biochar chemical composition was determined using standard laboratory procedure. Characterization of biochar mainly focused on chemical properties (pH, carbon, phosphorus, cation exchange capacity, electrical conductivity, exchangeable basic cations). Higher carbon content was observed in biochar produced from AD (65.00%) compared with that of biochar produced from other feedstock type included in this study. pH value of Biochar produced from EG and RS showed moderately acidic (pH 5.94) and neutral (pH 6.6), respectively, whereas biochar produced from AD (pH 8.07 and FYM (pH 8.17) revealed moderately alkaline pH level. High and low EC values were recorded in biochar produced from FYM (4.70DS m^{-1}) and EG (0.68DS m^{-1}), respectively. The maximum concentration of exchangeable magnesium (20.95%), potassium (16.40%) and sodium (1.77%), EC and phosphorous (2288.75ppm) were testimony in biochar produced from FYM but calcium (39.50%) was from biochar produced from AD. Higher CEC(129.75cmolckg-1) was detected in biochar produced from EG followed by biochar produced from RS (127.5cmolc kg^{-1}), AD (117cmolc kg^{-1}), FYM (87.25cmolc kg^{-1}). Generally, the current finding revealed that biochar from different feedstocks had different chemical properties, so this difference could contribute for soil fertility improvement as the result agricultural wastes is managed without pollution. But the current work was limited to the characterization of biochar. So, more detailed investigation on the rate and reclaiming the power of the biochar and other issues should be investigated.

Keywords: Biochar; Chemical characterization; Feedstock type; Agricultural waste management

Introduction

Conversion of agricultural wastes into Biochar is not only save natural resources, but also protects environmental pollution. Varies study of biochar effects in different soil substrates have been scientifically examined during the last decade and most of those findings proved positive effects on plant growth and soil properties [1]. Biochar has gotten high attention because of its potential use in many aspects like a soil amendment to improve soil quality [2], sequester carbon [3-6], inhibited loss of nitrogenous fertilizer, because biochar act as slow release fertilizer encapsulated [7] and filter potentially hazardous chemicals due to its strong sorption capacity to many contaminants [8].

Biochar from many sources of feedstock can be produced through the pyrolysis process in the absence of oxygen. Pyrolysis undergoes a variety of physical, chemical and molecular changes. volatilization during pyrolysis causes a significant loss in mass and therefore volume reduction and shrinking without causing much change in the original structure of the feedstock [9]. In addition, pyrolysis affects chemical properties of biochar like cation exchange capacity (CEC), pH and carbon content of biochar [10]. Biochar quality and quantity is mainly influenced by its feedstock type as well as pyrolysis condition [11]. Pyrolysis alters the nutrient content in the resulting biochar, which affects nutrient uptake by plants [12].

Several studies have been carried out to investigate the impacts of pyrolysis temperature on structural characteristics of biochar, sorption affinities to metals and physicochemical properties of different feedstocks [13]. However, the information concerning chemical properties of biochar produced from *Eucalyptus globules, Acacia decarance,* farmyard manure, and rice straw are limited. In other hand burning of crop residues in the field is a common practice during land preparation and disposal of waste like *Eucalyptus globules* and *Acacia decrance* trees have been used in the study area for charcoal production. During this production processes leaves, and branches of the trees were imprudently disposed and burned. These practices have been causing for environmental pollution and contribute to greenhouse gas emission to the atmosphere. Conversion of crop residue, eucalyptus and acacia tree byproduct biomass to biochar can be an alternative and sustainable way of waste management. However, information on the characteristics of biochar from this feedstock type was not studied. Therefore, the objective of this work was aimed to characterize biochar produced from different feedstocks based on chemical properties.

Materials and Methods

Feedstock collection and biochar production

The Eucalyptus and Acacia leave were collected from local charcoal production left over, farmyard manure from Debre Tabor University Tana-Guna Integrated Field Research Center and Rice straw from Fogera National rice research center. The feedstocks were kept in laboratory for air drying and the dried feedstocks were chopped with the help of clean knife. The prepared feedstock was placed in a ceramic crucible with a lid and then pyrolyzed in a furnace with the temperature rising to 300°C at a rate of 10°C/m and maintained at the highest temperature for 2 hours and then followed by cooling to room temperature inside the furnace. Afterward, the Biochar sample was grounded and passes through a 2mm mesh sieve and then transported to Bihar Dar Regional soil fertility improvement laboratory. Composite biochar samples from each biochar produced from different feedstock were prepared and analyzed for selected chemical properties.

Analysis of chemical properties of biochar

The pH of a biochar was determined in water at 1:2.5 biochar to water ratio [14]. Electrical conductivity was measured by a conductivity meter on standard biochar paste extracts obtained by Appling suction [15]. Organic carbon of the biochar was determined by following the wet digestion method as described by [16]. The available phosphorus was determined using the standard Olsen extraction method [17]. The exchangeable bases (Calcium, Magnesium, Potassium and Sodium) in the biochar were determined from the leachate of 1 molar ammonium acetate (NH_4OAc) solution at pH 7. Exchangeable Ca and Mg were measured by atomic absorption spectrophotometer and, K and Na was read using flame photometer as outlined by [18]. Cation exchange capacity was determined at a soil pH level of 7 after displacement by using normal ammonium acetate with titrimetrically by distillation of ammonium that was displaced by sodium [19].

Statistical analysis

Statistical analyses were performed with the SAS statistical software version 9.2 software. The pH, EC, CEC, Ca, Na, Mg, K and P values were analyzed using one-way analysis of variance ($p<0.05$) and non-significant ($p>0.05$), were determined using the LSD test.

Results and Discussion

Biochar conversion efficiency

The current study showed that presence of significant difference in biochar yield production potential at ($p<0.05$). Those different feedstock types have different biochar yield production potential. The Higher biochar yield potential was recorded in AD (25.64%) followed by FYM (21.55%), EG (21.26%) and RS (9.67) (Table 1). The possible reason for the difference in biochar yield production potential could be due to difference in lignin, cellulose and hemicelluloses content difference in feedstock. Similar finding is reported by [20]. In the other hand, lignocellulosic based biochar tends to have higher fixed carbon content than manure-based biochar [21].

Table 1: Biochar yield of biochar produced from different feedstock at 300°C.

Biochar Feedstock	Biochar Yield (%)
Eucalyptus	21.26b
Acacia	25.64a
FYM	21.55b
Rice Straw	9.67c
Means	19.52
CV (%)	7.74
Standard Error	±1.51

Means with the same letter are not significantly different.

Biochar reaction (pH)

The highest pH was recorded in the biochar produced from FYM (8.17) followed by AD (8.07), rice straw (6.40) and EG (5.94). Biochar produced from FYM and *Acacia decrance* showed moderately alkaline pH level, but biochar produced from rice straw and *Eucalyptus globules* indicated moderately acidic pH level. Generally, pH value of Biochar produced from different feedstock has significant difference at ($p<0.05$) (Table 2). Variability of pH value in between biochar produced from different feedstock type, but the pyrolysis temperature was same for all feedstock type, so that the biochar reaction difference is due to ash content difference in resulting biochar. This finding agrees with that of *Ronsse* et al. [22]. Higher pH values contain higher ash contents and their ash fraction contains more elements suitable for plant nutrients [23,24].

Electrical conductivity (EC)

Biochar produced from different feedstock have significantly influenced by different ($p<0.05$) in its electrical conductivity (Table 2). The highest electrical conductivity value was obtained from FYM biochar (4.70) and the lowest one was biochar produced from *Eucalyptus globules* (0.68). A possible reason for

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the highest EC value of biochar could be due to an increase of high soluble and exchangeable base cations as outlined by [25].

Carbon (C)

Maximum total carbon was produced from AD (65.50%) followed by rice straw (40.90), EG (37.25) and FYM (23.25%). Biochar produced from different feedstock have significant influence at ($p<0.05$) within its total carbon (Table 2). Biochar produced from manure feedstocks tend to have lower C content than lignocellulosic based feedstocks, because manure-based biochar's are related to the feedstock containing more volatile organic carbon compounds that are lost during the dry and carbonation processes [26].

Table 2: Biochar (pH), electrical conductivity (EC) and carbon content of biochar produced from different feedstock at 300°C.

Biochar Feedstock Type	Chemical Properties		
	pH Water (1:2.5)	EC (ds/m)	Carbon (%)
Eucalyptus	5.94c	0.68d	37.25c
Acacia	8.07a	3.79c	65.50a
FYM	8.17a	4.70a	23.25d
Rice Straw	6.40b	4.29ab	40.90b
Means	7.14	3.37	41.73
CV (%)	0.8	0.15	1.37
Standard Error	±0.06	±0.26	±0.57

Means with the same letter are not significantly different.

Exchangeable basic cations (Ca, K, Mg and Na)

As presented in Table 3, there were significant difference at ($p<0.05$) between feedstocks on exchangeable basic cations. FYM biochar contained the highest Na, K and Mg content (1.77, 16.40 and 20.95%, respectively), while the highest Ca (39.50) was found in AD Biochar. Nevertheless, EG and RS biochar presented the lowest contents of Na, K, Ca and Mg (1.10, 4.38, 15.05 and 13.00%). The higher content of exchangeable basic cations in AD and farmyard manure biochar indicated that the relevant chemical components were concentrated in biochar during the pyrolysis of feedstock as explained by [27]. High calcium content is likely connected with the bioconversion of organic matter into Biochar causing an expected release of compounds as Ca that reacts with carbonate or phosphate and precipitates [28].

Phosphorus (P)

Maximum concentration of P was observed at biochar produced from farmyard manure (2288.75ppm) followed by rice straw (1761.50), *Acacia decrance* (381ppm) and Eucalyptus (339.9ppm) (Table 2). High content of P in the biochar could be due to the charring of organic materials that can highly enhance P availability from plant tissue by disproportionately volatilizing C and by cleaving organic P bonds, resulting in a residue with high soluble P salts associated with the charred material as outlined (Knoepp et al. 2005). The amount of phosphorus produced from different feedstock explained significant difference at ($p<0.05$) (Table 3).

Cation Exchange Capacity (CEC)

As presented in Table 3, the cation exchange capacity of a biochar produced from eucalyptus (129.75cmolc kg-^{1}) and rice straw (127.50cmolc kg-^{1}) showed statistically non-significant difference. But lower value and statistically significance difference in biochar produced from FYM (87.25cmolc kg-^{1}) was observed. The analysis result of biochar revealed that biochar produced from eucalyptus had high nutrient retention and water adsorption capacity followed by rice straw, Acacia and FYM in addition to the direct supply of nutrients as CEC values indicated. Relatively high CEC value in biochar produced from eucalyptus and rice straw could be due to high oxygen-containing functional group [29].

Table 3: Inorganic element composition and cation exchange capacity of biochar produced from different feed stock sat 300°C.

Feedstock Type	Biochar Chemical Properties					
	Sodium (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Phosphorus (ppm)	CECcmolc kg-1
Eucalyptus	1.10d	4.83d	28.75c	19.50b	339.90d	129.75a
Acacia	1.37c	12.63c	39.50a	19.35b	381.00c	117.00b
FYM	1.77a	16.40a	35.30b	20.95a	2288.75a	87.25c
Rice Straw	1.46b	13.12b	15.50d	13.00c	1761.50b	127.50a
Means	1.42	11.74	29.76	18.2	1192.79	115.38
CV (%)	1.23	1.58	0.62	1.47	1.7	1.1
Standard Error	±0.018	±0.19	±0.18	±0.27	±20.26	±1.27

Means with the same letter are not significantly different.

Conclusion

The characterizations of biochar from different feedstock were explored by using the chemical properties of the biochar. Biochar produced from the pyrolysis of four feedstock sample at 300°C had a different biochar yield and chemical properties. The chemical variability of a biochar could have a positive contribution on soil conditioning, specifically biochar produced from farmyard manure and *Acacia decrance* may have potential to acid soil reclamation. However, the environmental pollution and ecological disturbance caused by residue disposal and burring cannot be ignored, because continuous disposable and burning agricultural wastes cause environmental pollution and contribute for greenhouse gas emission. The current study was limited to characterization. So, the rate determination

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and reclaiming powers of the biochar produced from different feedstock should be further studied.

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