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Characterization of Biochar Produced from Different Feed Stocks

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Authors' contributions

This work was carried out in collaboration between both authors. Author DD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author ET managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Imprudently disposed and burning of organic wastes have been causing environmental pollution and greenhouse gas emission. 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 derived from each of Eucalyptus globules (EG), Acacia decarance (AD), farm yard manure (FYM) and rice straw (RS) were collected and biochar was produced by slow pyrolysis at 300^{o}C in the furnace. The determination of pH, carbon, phosphorus, cation exchange capacity, electrical conductivity and exchangeable basic cations of individual biochar was performed and statistical analyses carried out to compare the means values obtained. Higher carbon content was observed in biochar produced from AD (65.00%) compared with that of biochar produced from other feedstock types included in this study. pH value of Bbiochar produced from EG and RS were 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 (4.70 DS m^{-1}) and the low value from EG (0.68 DS m^{-1}),

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respectively. The maximum concentration of exchangeable magnesium (20.95%), potassium (16.40%) and sodium (1.77%), EC and phosphorous (2288.75 ppm) were testimony in biochar produced from FYM is potential to prove phosphorus fertilizer requirement of a crop but calcium (39.50%) was from biochar produced from AD. Higher CEC (129.75 $cmol_c\ kg^{-1}$) was detected in biochar produced from EG followed by biochar produced from RS (127.5 $cmol_c\ kg^{-1}$), AD (117 $cmol_c\ kg^{-1}$) and FYM (87.25 $cmol_c\ kg^{-1}$). Generally, the current finding revealed that biochar from different feedstock's 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.

1. INTRODUCTION

Conversion of agricultural wastes into Biochar does not only save natural resources, but also prevents environmental pollution. Various studies of biochar effects in different soil substrates have been scientifically carried out during the last decade and the majority of those findings proved positive effects on plant growth and soil properties [1]. Biochar has attracted high attention because of its potential use in many aspects like a soil amendment to improve soil quality [2], carbon sequestration [3,4,5] (Reicosky, 2009), inhibited loss of nitrogenous fertilizer, because biochar acts as slow release fertilizer encapsulated [6] and filter potentially hazardous chemicals due to its strong sorption capacity to many contaminants [7].

Biochar can be produced from many sources of feedstock 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 [8]. In addition pyrolysis affects chemical properties of biochar like cation exchange capacity (CEC), pH and carbon content of biochar [9]. Biochar quality and quantity is mainly influenced by its feedstock type as well as pyrolysis condition [10]. Pyrolysis alters the nutrient content in the resulting biochar, which affects nutrient uptake by plants [11].

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 feedstock's [12]. 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 cause 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 is not yet available. Therefore, this work aimed to characterize biochar produced from different feedstock's based on chemical properties.

2. MATERIALS AND METHODS

2.1 Feedstock Collection and Biochar Production

Eucalyptus and Acacia leaves were collected from local charcoal production left over, farm yard 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 a 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 300ºC at a rate of 10ºC/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 passed through a 2 mm 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.

2.2 Experimental Design

The characteristic of biochar experiment was conducted to compare five different feedstock's biochar yields in completely randomized design with four replications. The completely randomized design was appropriate experimental design to exploit the variation of each biochar product and its desired characteristics.

2.3 Analysis of Chemical Properties of Biochar

The pH of a biochar was determined in water at 1:2.5 biochar to water ratio [13]. Electrical conductivity was measured by a conductivity meter on standard biochar paste extracts obtained by Appling suction [14]. Organic carbon of the biochar was determined by following the wet digestion method described by Walkley and Black [15]. The available phosphorus was determined using the standard Olsen extraction method [16]. 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 Rowell [17]. Cation exchange capacity was determined at a soil pH level of 7 after displacement by using normal ammonium acetate with titrimetry by distillation of ammonium that was displaced by sodium [18].

2.4 Statistical Analysis

The values were analyzed using One-way analysis of variance was performed for each the pH, EC, CEC, Ca, Na, Mg, K, and P. mean values were separated using the LSD test. Statistical analyses were performed with the SAS statistical software version 9.2.

3. RESULTS AND DISCUSSION

3.1 Biochar Conversion Efficiency

The current study showed that presence of significant difference in biochar yield t ($p < 0.05$). The yield varied from 9.67% for RS to 25.64% for AD (25.64%) (Mean = 19.25%) (Table 1). The possible reason for the difference in biochar yield could be due to difference in lignin, cellulose and hemicelluloses contents between feedstocks. In fact, rice, a monocotyledonous plant that possesses almost no lignin ranked last. Similar finding was reported by Yongwoon, et al. [19] from their work on the production and characterization of biochar from various biomass materials. One surprising result is the biochar yield of farm yard manure which was comparable to that of Eucalyptus, a lignocellulosic material. In fact, according to Domingues, et al. [20] lignocellulosic based biochar tend to have higher fixed carbon content than manure based biochar.

Table 1. Biochar yield from different feedstocks

Biochar feedstock	Biochar yield (%)
Eucalyptus	21.26^b
Acacia	25.64^a
FYM	21.55^b
Rice straw	9.67^c
Mean	19.52
CV (%)	7.74
Standard Error	± 1.51

Means with the same letter are not significantly different, FYM = farm yard manure

3.2 Biochar Reaction (pH), Electrical Conductivity and Carbon Content

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) (Table 2). Biochar produced from FYM and *Acacia decrance* showed moderately alkaline pH level, but biochar produced from rice straw and *Eucalyptus globules* indicated moderately acidic. Generally, pH value of Biochar produced from different feedstock has significant difference at ($p < 0.05$). Variability of pH value in between biochar produced from different feedstock type, the pyrolysis temperature being the same, the difference in pH was probably due to a difference in ash content of biomass materials. This finding is in agreement with Ronsse, et al. [21] detected an influence of the feedstock type and pyrolysis conditions on the pH of the biochar. Higher pH values's biochars have higher ash contents and their ash fraction contains more elements suitable for plant nutrition [22,23].

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) (mean = 3.3 ds/m). A possible reason for the highest EC value of biochar could be due to an increase of high soluble and exchangeable base cations as outlined by Demirbas [24]. Maximum total carbon was derived from AD (65.50%) followed by rice straw (40.90%), EG (37.25%) and FYM (23.25%). Biochar derived from various feedstocks has 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 biochars are related to the feedstock containing more volatile organic carbon compounds that are lost during the drying and carbonation processes [25].

3.3 Macro and Micronutrients and Cation Exchangeable Capacity

There were significant differences 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 diochar. EG and RS biochars presented the lowest contents of Na, K, Ca and Mg (1.10, 4.38, 15.05 and 13.00%). The higher content of macro and micronutrients in AD and farm yard manure biochar indicated that the relevant chemical components were concentrated in biochar during the pyrolysis of feedstock as explained by Yaun, et al. [26]. High calcium content are 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 [27].

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 reported by Knoepp, et al. (2005). The amount of phosphorus produced from different feedstock explained significant difference at (p<0.05) (Table 3).

The cation exchange capacity of biochar produced from *Eucalyptus* (129.75 $cmol_c\ kg^{-1}$) and rice straw (127.50 $cmol_c\ kg^{-1}$) showed non-significant difference. But low value of CEC was observed from biochar produced from FYM

Table 2. Biochar pH, Electrical Conductivity (EC) and carbon content (carbon) of biochar produced from different feedstock

Biochar feedstock type	Chemical properties		
	pH	EC (ds/m)	Carbon (%)
Eucalyptus	5.94^{c}	0.68^{d}	37.25^{c}
Acacia	8.07^{a}	3.79^{c}	65.50^{a}
FYM	8.17^{a}	4.70^{a}	23.25^{d}
Rice straw	6.40^{b}	4.29^{ab}	40.90^{b}
Mean	7.14	3.37	41.73
CV (%)	0.80	0.15	1.37
Standard Error	±0.06	±0.26	±0.57

Means with the same letter are not significantly different, FYM = farm yard manure

Table 3. Macro and micronutrients and Cation Exchange Capacity (CEC) of biochar produced from different feedstocks

Feedstock type	Biochar chemical properties					
	Sodium (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Phosphorus (ppm)	CEC ($cmol_c\ kg^{-1}$)
Eucalyptus	1.10^{d}	4.83^{d}	28.75^{c}	19.50^{b}	339.90^{d}	129.75^{a}
Acacia	1.37^{c}	12.63^{c}	39.50^{a}	19.35^{b}	381.00^{c}	117.00^{b}
FYM	1.77^{a}	16.40^{a}	35.30^{b}	20.95^{a}	2288.75^{a}	87.25^{c}
Rice straw	1.46^{b}	13.12^{b}	15.50^{d}	13.00^{c}	1761.50^{b}	127.50^{a}
Mean	1.42	11.74	29.76	18.20	1192.79	115.38
CV (%)	1.23	1.58	0.62	1.47	1.70	1.10
Standard Error	±0.018	±0.19	±0.18	±0.27	±20.26	±1.27

Means with the same letter are not significantly different

(87.25 $cmol_c$ kg^{-1}). The result on the analysis of biochar revealed that the one produced from eucalyptus had high nutrient retention and water adsorption capacity followed that derived from rice straw, Acacia and FYM in addition to the direct supply of nutrients as indicated by CEC values. Relatively high CEC value in biochar produced from Eucalyptus and rice straw could be due to high oxygen-containing functional group.

4. CONCLUSION

The criteria used to select biochars for a field study are dependent on the soil being amended and the goals of applying the biochar. Characterization of biochar from different feedstock's was made by using their chemical properties. Biochars produced from the pyrolysis of four feedstock samples at 300ºC 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 farm yard manure and *Acacia decrance* may have potential to acid soil reclamation. However, the environmental pollution and ecological disturbance caused by residue disposal and burring can be addressed by means of their conversion to biochar. In fact, continuous disposable and burning agricultural wastes cause environmental pollution and contribute for green house gas emission. The current study was limited to characterization. So, the rate determination and reclaiming powers of the biochar produced from different feedstock should be further studied.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Glaser B, Lehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal. A review Bio. Fertil soil; 2002.
2. Silber A, Levkovitch I, Graber E. pH-dependent mineral release and surface properties of corn straw biochar: Agronomic implications. Environ. Sci. Technol. 2010;44:9318-9323.
3. El-Naggar A, Awad YM, Tang XY, Liu C, Niazi NK, Jien SH, Tsang DC, Song H, Ok YS, Lee SS. Biochar influences soil carbon pools and facilitates interactions with soil: A field investigation. Land Degrad. Dev. 2018;29(7):2162-2171.
4. Matovic D. Biochar as a viable carbon sequestration option: Global and Canadian Perspective. Energy. 2011;36:2011-2016.
5. Kuzyakov Y, Subbotina I, Chen H, Bogomolova I, Xu X. Black carbon decomposition and incorporation into soil microbial biomass estimated by ^{14}C labeling. Soil Biol. Biochem. 2009;41:210-219.
6. Songling C, Ming Y, Chuang B, Susu Y, Yifei J, Hongtao Z, Yulong Z. Preparation and characterization of slow-release fertilizer encapsulated by biochar-based waterborne copolymers. Science of the Total Environment. 2017 ;615:431-437.
7. Borchard N, Prost K, Kautz T, Moeller A, Siemens J. Sorption of copper and sulphate to different biochar before and after composting with farmyard manure. Eur. J. Soil Sci. 2012;63:399-409.
8. Laine J, Simoni S, Calles R. Preparation of activated carbon from coconut shell in a small scale concurrent flow rotary kiln. Chem. Eng. Commun. 1991;99:15-23.
9. Wu W, Yang M, Feng Q, Mcgrouther K, Wang H, Lu H, Chen Y. Chemical characterization of rice straw-derived biochar for soil amendment. Biomass Bioenergy. 2012;47:268-276.
10. Haiqing Y, Kuichuan S. Characterization of Biochar Properties Affected by Different Pyrolylsi Temperature Using Visible-Near-Infrared Spectroscopy; 2012.
11. Kuhlbusch T, Lobert J, Crutzen J, Warneck P. Molecular nitrogen emissions from denitrification during burning. Nature. 1991;351:135-137.
12. Uchimiya M, Wartelle L, Klasson K, Fortier C, Lima I. Influence of pyrolysis temperature on biochar property and function as a heavy metal sorbent in soil. J. Agri. Food Chem. 2011;59:2501-2510.
13. Van Reeuwiik L. Procedures for soil analysis 4th edition. Technical paper 9 ISRIC, Wagningen, the Netherlands; 1993.

14. OkaleboJ, Gathua K, Womer P. Laboratory methods of soil and plant analysis: a working manual, 2nd edition. TSBF-CIAT and SACRED Africa, Nairobi, Kenya; 2002.
15. Walkley A, Black C. An examination of different methods for determining soil organic matter and the proposed modifications by the chronic acid titration method. Soil Sci. 1934;37: 29-38.
16. Olsen S, Cole C, Wanatabe F, Dean L. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 1954;939:1-19.
17. RowellD. Soil science: method and applications. Addison Wesley longman limited, England; 1994.
18. Chapman H. Cation exchange capacity. In: Black, C.A. (Ed), methods of soil analysis. American society of Agronomy, Wisconsin USA. 1965;891-901.
19. Yongwoon L, Jinje P, Ki Seop G, Changkook R, Won Y, Jin-Ho J, Seunghun H. Production and characterization of biochar from various biomass materials by slow pyrolysis. School of mechanical engineering, South Korea; 2014.
20. Domingues RR, Trugilho PF, Silva CA, De Melo IC, Melo LCA, Magriotis ZM. Properties of biochar driven from wood and high nutrient biomass with the aim of agronomic and environmental benegits. PLos. One. 2017;12(5).
21. Ronsse F, Sven Van H, Dane D, Wolter P. Production and characterization of slow pyrolysis biochar: Influence of feedstock type and pyrolysis conditions. Biosystems Engineering, Ghent Nniversity, Belgium; 2013.
22. Cantrell KB, Hunt PG, Uchimiya M, Novak JM, Ro KS. Impact of pyrolysis tempertature and manure source on physicochemical characteristics of biochar. Biores. Technol. 2012;107:419-428.
23. Ippolito JA, Spokas KA, Novak JM, Lentz RD, Cantrell KB. Biochar elemental composition and factors influencing nutrient retention in: Lehmann J, Joseph S, 2nd (eds), Biochar for environmental management science, technology and implementation 2nd Ed, earthscan, Routledge Pupl., London, UK. 2015;139-164.
24. Demirbas A. The influence of temperature on the yields of compounds existing in bio-oils obtained from biomass samples via pyrolysis. Fuel Process. Technol; 2007.
25. Novak JM., Johnson MJ. Elemental and spectroscopic characterization of low temperature (350^{o}) Lignocellulosic and Manure Based Designer Biohars and Their Use as Soil Amendments; 2019.
26. Yuan J, Xu R, Zhang H. The forms of alkalis in the biochar produced from crop residues at different temperatures. Bio. Resource Technol. 2011;102:3488-3497.
27. Carchesio M, Tatano F, Lancellotti I, Taurino R, Colombo E, Barbieri L. Comparison of biomethane production and digestate characterization for selected agricultural substrates in Italy. Environ. Technol. 2014;35:2212-2226.

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