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RESEARCH ARTICLE

Characterization of Biochar derived from wood biomass of *Prosopis juliflora*

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ABSTRACT

Prosopis Wood Biochar (PWB) produced through pyrolysis of wood biomass of *Prosopis Juliflora* was characterized for its physicochemical characteristics, energy properties, surface morphology and functional groups. PWB had a pH of 8.70, EC of 1.49 dS m^{-1}, H/C of 0.11 and O/C ratio of 0.13. The zeta potential of the PWB was - 24.2 mV with microporous surface characteristics (pore size of about 1.32 μm to 2.51μm diameter and length was 1.34 μm to 10.14 μm). PWB had aldehyde as predominant functional groups along with alkyl halides, alkenes and aromatic compounds.

Keywords: *Pyrolysis, Prosopis Wood Biochar, FT-IR, SEM*

INTRODUCTION

Biochar is a carbon-rich product obtained by thermal decomposition of organic material under limited supply of oxygen and at relatively low temperatures (Lehmann and Joseph, 2009). The application of biochar and its market is increasing over the years for the search of the carbon-rich product with tailored characteristics. Biochar markets for remediation, fuel cell, wastewater treatment, carbon offsets, as capacitors, as an alternative for charcoal and coal, as packaging materials are in high demand. Biomass and agricultural residues are either dumped or burnt thereby releasing more of greenhouse gases. In contrast, converting the biomass into char reduces the volume of biomass and converting the carbon into a more inert form that slowly undergoes decomposition (Lehmann, 2007).

A number of wood, sludge and agricultural residues were converted into biochars resulting with different characteristics. Lignocellulosic is one of the major components of biomass product that is renewable and reusable, it is an environmentally friendly product (Wang *et al.,* 2015). Agricultural wastes such as tea waste, coffee waste, watermelon seed hulls (Akkaya and Guzel, 2013), lam tree (*Cordia africana*) sawdust, groundnut shell, coir waste (Kavya et al., 2015) castor (*Ricinus communis*) (Maheshwari and Santhi, 2013) and cocoa (Mathew, 2017) biochars were produced and used. Because of its high carbon content, Prosopis Wood Biochar (PWB) is utilized either as biochar (Angaleeswari and Kamaludeen, 2017) or hydrochars (Shalini et al.,2018). In the current study, Prosopis wood was converted into biochar and its characteristics are detailed.

MATERIAL AND METHODS

Raw material

Prosopis wood was collected from different localities such as Telugupalayam and Thondamuthur in Coimbatore district. Samples were air dried at room temperature and stored in the high-density polyethylene bags to carry out the Biochar production.

Biochar production

Biochar of Prosopis was done through pyrolysis at 450˚C for 2-3 hours. The resulting biochar was crushed and sieved through 2mm size. Then the sieved biochar of PWB was kept in an oven at 60˚C for 48 hr to reduce the moisture content. Biochar samples were stored in an airtight container for further analysis.

Characterization techniques

The Prosopis wood biochar was characterized based on standard protocols. The proximate analysis (volatile, fixed carbon, ash content) was carried out according to ASTM (E-892, E-830) (ASTM 1977) and ultimate analysis (C, H, O, N) are calculated. The bulk density (gcm^{-3}) was estimated as Mass/ Volume. The PWB was also analyzed for pH, EC (dSm^{-1}) (M/s. Elico, India), CEC (cmol p^+ kg^{-1}), pore space (%), and water holding capacity (%) using standard techniques (Jackson 1973). The surface morphologies were visualized with SEM (ICON ANALYTICAL, FEI, QUANTA 200). The dried samples were coated with a thin layer of gold to reduce electron altering effects and to obtain clear and high-resolution images at 5000 X at 20 Kv. Surface elemental analysis was also conducted simultaneously with the SEM

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at the same surface locations using EDAX (ICON ANALYTICAL, EDAX, GENESIS XM4). In this FTIR analysis, Prosopis biochar was especially used to determine the functional groups present for each temperature and biomass, especially carbons. FT-IR spectra were recorded with 1.0 mg of biochar sample embedded in potassium bromide 30.0 mg (KBr) and then pressed into pellets separately and observed in an FTIR (Model 8400S of Shimadzu, Japan) using Attenuated Total Reflectance (ATR) technique having wavelength source 400-4000 cm^{-1} (Trakal *et al.,* 2014).

RESULTS AND DISCUSSION

Composition of PWB

The moisture content of the Prosopis wood biochar (PWB) was less (1.49 %) as it is exposed to a higher temperature during pyrolysis. The pH of the biochar is alkaline (8.7) (Table 1).

Table 1. Physico chemical characteristics of Prosopis Wood Biochar

Parameter	PWB
Moisture content (%)	1.49
pH	8.70
EC (dSm^{-1})	1.49
Pore space (%)	30
Cation exchange capacity (cmol (p^+) kg^{-1})	15.7
Particle size (nm)	277
Zeta potential (mV)	-24.4

Similar alkaline pH of biochars was reported in coir waste (Kavya et al., 2015) and coconut shell (Angaleeswari et al., 2017a). Biochars with alkaline pH was used for the removal of cations during wastewater treatment. Berek (2014) stated that during pyrolysis at high temperature there will be increase in pH of the biochar content.

Table 2. proximate and Ultimate composition (%) of Prosopis wood biochar (PWB)

Proximate analysis (%)		Ultimate analysis (%)	
Fixed carbon	37.92	C	81.54
Ash content	1.59	H	0.75
Volatile matter	79.23	O	15.19
		N	1.10
		S	0.37

Electrical Conductivity of the biochar is responsible for the exchange of ions. EC of PWB was recorded to be 1.49 dS m^{-1} with a bulk density (0.48 g cc^{-1}), and particle density (0.26 g cc^{-1}). Shenbagavalli and Mahimairaja (2012) reported similar results. Cation-exchange Capacity (CEC) of the PWB was 15.7 cmol kg^{-1}. Most of the chars have CEC ranging from 9.76-15.70 and this high CEC facilitates the char to be used for sorption of cations and heavy metals (Yao *et al.,* 2011 and Jiang *et al.,* 2012). CEC varies significantly between terrestrial-derived biomass from different feedstocks, ranging from 4.5 to 40 cmol kg^{-1} (Bird *et al.,* 2011 and Uzoma *et al.,* 2011).

Table 3. Elemental ratios, Density and Energy Properties of Prosopis Wood biochar(PWB)

Biochar yield (%)	40
Bulk density (g/cc)	0.48
Particle density (g/cc)	0.26
H/C	0.11
O/C	0.13
Calorific value (J)	26.11

Elemental composition of Biochar

The elemental composition of the biochar (Fig. 1) revealed that the char contains the carbon (73 percent), nitrogen (2.3 percent), oxygen (12.98 percent).

Table 4. Functional groups of PWB

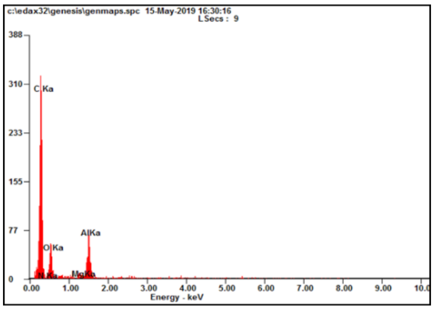
Functional Groups	Frequency (cm^{-1})	Bond	Intensity	Mode
Alkyl Halides	481.15	S-S	Strong	Deformation
Alkenes	988.31	CC	Medium	Bending
Aromatic compounds	1582.31	CC	Medium	Stretching
Aldehyde	2788.56	CH	Broad	Stretching

The fixed carbon content is more (37.92 percent) compared to ash content (1.59 percent) (Table 2), wherein all the material has been converted to carbon, which can be considered as a good adsorbent. The elemental composition of PWB reveals that its rich in carbon (81.54 percent) due to the carbonization process which has added the carbon content to it with a negligible amount of sulphur and hydrogen.

The percentage composition of carbon with 81.54 (higher than other) due to significant temperature rise, with low content of nitrogen and hydrogen due to the loss of moisture during the carbonization process. The C/N ratio of the Prosopis Biochar was 87.6. These values are closely similar to those reported for other carbonized Biochar (Novak *et al.,* 2009; Rondon *et al.,* 2007) moisture and an ash content of PWB (0.47,1.26 percent) but pore space was lower (31.01 percent).

Surface morphology of Prosopis wood biochar

A SEM image (Fig-2) of crudely pulverized Prosopis based biochar clearly reflects that the hardwood biomass pattern of higher resolution (5000X). Irregular elongated structures at the micro-scale level and the particles were aggregated in a random manner. Macro and microporous structure were observed on surface scatter manner with a pore size varying from 1.32 μm to 2.51 μm diameter and length was 1.34 μm to 10.14 μm (Fig. 2). Similar to our results, Mathew (2017) reported 1.614 μm pore diameter of Cocoa pod waste biochar. SEM



Element	Wt%	At%
CK	73.70	81.54
NK	02.34	02.22
OK	12.98	10.78
MgK	00.87	00.48
Matrix	Correction	ZAF

Fig. 1 Elemental composition of Prosopis wood biochar

results indicate the surface properties of biochar and also pore dimension based on which they are also used for stripping of pollutants. The macroporous structure of biochar is potentially important to water holding and adsorptive capacity of pollutant in soil and solution systems (Angin, 2013).

The particle size was measured to be in nanometers (277 nm), which relates not only the higher surface area also the improved adsorptive potential with rich active sites for adsorption. The zeta potential of the PWB (- 24.2 mV) due to the presence of negatively rich charged surfaces of the PWB. The pore size measured from SEM was found to be micrometers ranging from 1.390 to 3.590 µm (Fig. 2) its micropore size having a pattern of regular and irregular circular shape and also oval shaped pores can be seen in the micrographs. The presence of such micropores increases the surface area of the biochar and ultimately aids in more adsorption. Biochars having the high surface area and pore volumes have a greater affinity for metals because metallic ions can be physically sorbed onto the char surface and retained within the pores.

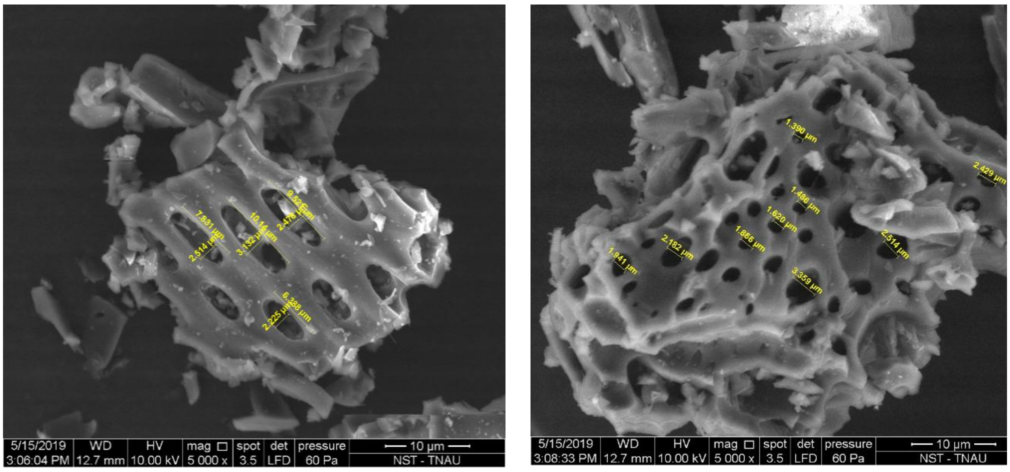


Fig 2. Surface characteristics of Biochar (5000x)

Functional groups of Prosopis wood biochar

The FTIR spectra of the PWB (Fig. 3 and Table 4) showed a strong peak at 481.15 cm^{-1} with an S-S bonding of Alkyl Halides functional group of strong deformation. The reflections at 2788.56 cm^{-1} are caused by C-H Aldehyde vibrations, 1582.31 cm^{-1} produced by C=C aromatic chain vibrations, 988.15 cm^{-1} produced by alicyclic and aliphatic chain vibrations and 481.15 cm^{-1} caused by S-S functional groups of biochar. Similar CH, OH, CC, SS bond were found for studied by Manikandan and Subramanian (2015). Angaleeswari and Kamaludeen (2017b) reported that these functional groups play a major role in the sorption of nickel ions.

As a raw material, Prosopis wood is made up of polymers of lignocellulose (mainly hemicelluloses, cellulose, and lignin), after biochar having surface active groups (hydroxyl, carboxyl, and amine, etc.,) in their structures that are capable to bind heavy metals. The results obtained that the spectra of biochar (Fig.3) agreed well with the spectra of reference to carbon and surface functionality. The functional groups of aldehyde, alcohol, amines, aromatic compounds and alkenes are being indicated corresponding to the peaks observed in FTIR analysis with a medium to strong intensity of bond strength. The richness in functional groups on it represents its more adsorption rate due to the affinity of those compounds towards heavy metals. Angaleeswari and

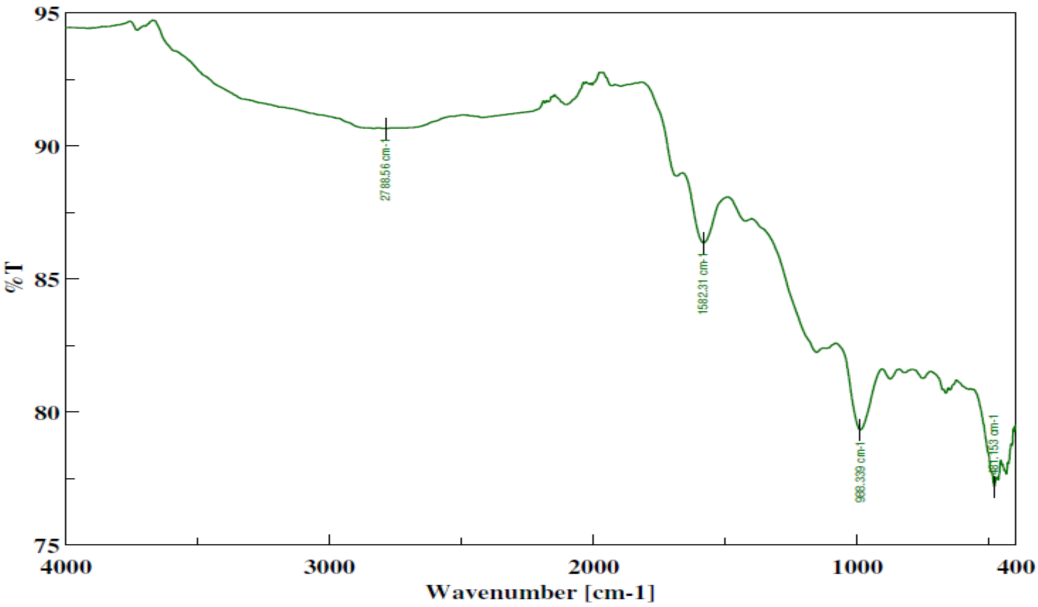


Fig 3. FTIR spectra of PWB

Kamaludeen (2017b) reported that these functional groups play a major role in the sorption of nickel ions.

CONCLUSION

Biochar production is a viable waste management option Prosopis wood, due to abundance could be used as a potential feedstock for biochar production. The current investigation revealed that PWB could be used as an adsorbent for pollutants owing to its charge and functional group characteristics. Modification of biochar to design for more adsorption can be another mode to utilize it for other applications.

REFERENCES

Akkaya, G. and Güzel, F., 2013. Bioremoval and recovery of Cu (II) and Pb (II) from aqueous solution by a novel biosorbent watermelon (*Citrullus lanatus*) seed hulls: kinetic study, equilibrium isotherm, SEM and FTIR analysis. *Desalination and Water Treatment,* 51(37-39), pp.7311-7322.

ASTM 1977 – 04 (2017), Standard Test Method for Determining Initial, Fractional, Filtration Efficiency of a Vacuum Cleaner System

Angalaeeswari, K and Kamaludeen Sara Parwin Banu. 2017a. Production and characterization of coconut shell and mesquite wood biochar. *International Journal of Chemical Studies,* 5(4): 442-446.

Angalaeeswari, K and Kamaludeen Sara Parwin Banu. 2017b. Utilisation of mesquite (Prosopis juliflora) wood biochar for adsorption of nickel ions in aqueous solution *International Journal of Chemical Studies*, 5(4): 687-690.

Angın, D., 2013. Effect of pyrolysis temperature and heating rate on biochar obtained from pyrolysis of safflower seed press cake. *Bioresource technology*, *128*, pp.593-597.

Bird, M. I., Wurster, C. M., Silva, P., Bass, A. M. and De Nys, R. 2011. Algal biochar production and properties. *Bioresource Technol.*, 102 (2): 1886-1891.

Gaskin, J.W., Steiner, C., Harris, K., Das, K.C. and Bibens, B., 2008. Effect of low-temperature pyrolysis conditions on biochar for agricultural use. *Transactions of the ASABE*, *51*(6), pp.2061-2069.

Jackson, M.L. 1973. Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd., New Delhi, p. 38-56.

Jiang, J., Xu, R. K., Jiang, T. Y. and Li, Z. 2012. Immobilization of Cu(II), Pb(II) and Cd(II) by the addition of rice straw derived biochar to a simulated polluted ultisol. *J Hazard Mater,* 229: 145-150.

Joseph, S., Peacocke, C., Lehmann, J. and Munroe, P., 2009. Developing a biochar classification and test methods. *Biochar for environmental management: science and technology*, *1*, pp.107-126.

Kavya, P., K. Angalaeeswari, V. Bhagyasree, P. Subramanian and Kamaludeen Sara Parwin Banu. 2015. Sorption of nickel by groundnut shell and coir waste biochars. In: Proceedings of International Conference on Agricultural, Veterinary and Environmental Sciences. Vijayawada, Andhra Pradesh, India, pp.67

Lehmann, J., 2007. A handful of carbon.Nature, 447(7141), p.143..Makeswari, M. and Santhi, T., 2013. Removal of malachite green dye from aqueous solutions onto microwave assisted zinc chloride chemical activated epicarp of Ricinuscommunis. *Journal of Water Resource and Protection,* 5(2), p.222.

Mathew, S. 2017. Studies on the bioconversion of cocoa waste for value added products. M.Sc. Thesis, TNAU, Coimbatore.

Rondon, M.A., Lehmann, J., Ramírez, J. and Hurtado, M., 2007. Biological nitrogen fixation by common beans (Phaseolus vulgaris L.) increases with biochar additions. *Biology and fertility of soils*, *43*(6), pp.699-708.

Shalini Ramesh, Pugalendhi Sundararaju, Kamaludeen Sara Parwin Banu, Subburamu Karthikeyan, Uma Doraiswamy and Kamaraj. 2018. Hydrothermal carbonization of arecanut husk biomass: fuel properties and sorption of metals. *Environmental Science and Pollution Research* 26

Shenbagavalli, S. and Mahimairaja, S., 2012. Characterization and effect of biochar on nitrogen and carbon dynamics in soil. *International journal of advanced biological research*, *2*(2), pp.249-255.S

Singha, B. and Das, S.K., 2013. Adsorptive removal of Cu (II) from aqueous solution and industrial effluent using natural/agricultural wastes. Colloids and Surfaces B: Biointerfaces, 107, pp.97-106.

Manikandan, Subramanian, K.S., A., Thirunavukkarasu, M. and Rahale, C.S., 2015. Nano-fertilizers for balanced crop nutrition. In *Nanotechnologies in food and agriculture* (pp. 69-80).

Novak, J.M., Busscher, W.J., Laird, D.L., Ahmedna, M., Watts, D.W. and Niandou, M.A., 2009. Impact of biochar amendment on fertility of a southeastern coastal plain soil. *Soil science*, 174(2), pp.105-112.

Trakal, L., Bingöl, D., Poho el , M., Hru ka, M. and Komárek, M., 2014. Geochemical and spectroscopic investigations of Cd and Pb sorption mechanisms on contrasting biochars: engineering implications. *Bioresource technology*, *171*, pp.442-451.

Uzoma, K. C., Inoue, M., Andry, H., Fujimaki, H., Zahoor, A., and Nishihara, E. (2011). Effect of cow manure biochar on maize productivity under sandy soil condition. Soil Use Manage., 27 (2): 205-212.

Wang, C., Xue, N. and Pradhan, S., 2015. Boosting transition-based AMR parsing with refined actions and auxiliary analyzers. In Proceedings of the 53rd Annual Meeting of the Association for Computational Linguistics and the 7th International Joint Conference on Natural Language Processing (Volume 2: Short Papers) (Vol. 2, pp. 857-862).

Yao, Y., Gao, B., Inyang, M., Zimmerman, A.R., Cao, X., Pullammanappallil, P. and Yang, L., 2011. Biochar derived from anaerobically digested sugar beet tailings: characterization and phosphate removal potential. *Bioresource technology*, *102*(10), pp.6273-6278.